Making Sense of *Ryôshiron* (Quantum Theory):

Introduction of Quantum Mechanics into Japan, 1920-1940

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Abstract

This work studies what "quantum mechanics" meant in Japan from the 1920s to the early 1940s, when quantum mechanics was introduced there. By studying various scientific cultures during this period, this work shows how Japanese scientists replicated the scientific practices of quantum mechanics within their scientific cultures. This work shows what the transmission of scientific knowledge involves, analogizing it to "resonance." Similar (but not the same) scientific practices in different places occur when certain cultural and other conditions meet, and when certain partial intermediaries (human or non-human) that tie the two places trigger a resonance of scientific practices. This does not necessarily require personal contact, the implant of "scientific spirits," or the transporting of a totality of practices.

I distinguish three phases of the introduction of quantum mechanics into Japan. The first phase is the period before the introduction of quantum mechanics, the next is the late 1920s, when young scientists began learning quantum mechanics, and the third is the period after Nishina's return to Japan when quantum mechanical research was conducted there. After methodological discussions in Chapter1, Chapter 2 focuses on the first phase and shows that a scientific culture that emphasized advanced mathematics and meticulous calculation dominated theoretical physics. Chapter 3 examines the second phase and reveals how young physicists' efforts to learn quantum mechanics were tied to the rebellious youth culture of the 1920s. Chapters 4 through 7 illuminate various aspects of the third phase. Chapter 4 explores the educational background of Nishina Yoshio, who

played a pivotal role in the third phase, comparing his electrical engineering training and theoretical work in quantum mechanics. Chapter 5 compares practices in Niels Bohr's group in Copenhagen and Nishina's group in Japan, discussing how scientific practices were replicated. Chapter 6 explores Nishina's family background and ties the familial and local cultures of the Nishina clan to Nishina's research style in science. Chapter 7 widens the scope and discusses how philosophical issues of quantum mechanics, in particular Bohr's complementarity, were discussed among Japanese intellectuals, illustrating how differently intellectuals from different cultural backgrounds interpreted these problems.

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Conventions

Romanization in this dissertation follows the modified Hepburn system in Kenkyusha's Japanese-English Dictionary. Romanization of some other proper names follow customary forms (for example, Tokyo rather than Tôkyo). A circumflex is used for a long vowel instead of a macron for the typographical reason.

Most personal names are romanized in this way, except a few when I am aware of the preference of the person in question. Here are names that I confirmed their unconventional spellings:

Hirosige Tetu (rather than "Hiroshige Tetsu")

Husimi Kôdi (rather than "Fushimi Kôji")

Ito Kenji (rather than "Itô Kenji")

Sano Shizuwo (rather than "Sano Shizuo")

Taketani Mituo (rather than "Taketani Mitsuo")[1]

Terazawa Kwan-iti (rather than "Terazawa Kan'ichi")

Tomonaga Sin-itiro (rather than "Tomonaga Shin'ichirô")

Umeda Kwai (rather than "Umeda Kai")

In most cases, however, I simply romanized according to the rules, without confirming how historical figures romanized their names.

Figures and tables are always at the end of each chapter.

Japanese names are written in the traditional order (the family name first, the given name second), except when they appear as author names of an European language publication.

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1. Taketani used both "Mituo" and "Mitsuo," but more often the former.

The University of Tokyo has a very complex history, and its name changed over time. To avoid confusion, I usually call it Tokyo University, regardless of its official English name. Similarly, I omit the pompous "imperial" when I mention other imperial universities, except when that pompousness is relevant, and when I refer to the category of "imperial university" in distinction to other higher education institutions. As the university itself, Tokyo University's constituent schools ("Gakubu") adapted different English names over time, which I use "College" rather than "Faculty." Most academic departments in this book belonged to Tokyo University, and I omit "Tokyo University" when it is not confusing to do so.

As written in the text, "Riken" refers to the Institute of Physical and Chemical Research.

I use the Japanese era system only when I point to a period vaguely. For the readers unfamiliar with Japanese history, the Meiji Era is from 1968 to 1912, the Taisho Era, 1912 to 1926, Showa Era, 1926 to 1989 (a new era starts when an emperor dies and a new emperor is enthroned; hence the first year of a new era always overlaps with the last of the previous era). In this work, "prewar" usually means "before World War II," not "before World War I" because this is the way the Japanese equivalent to "prewar" (senzen) means in Japan and because I want to avoid writing "pre-World War II.".

Chapter 1
Introduction:
How Does Science "Travel"?

Nishina Yoshio landed in Yokohama on December 21, 1928, off a steamship that had cruised from San Francisco across the gloomy winter sea to Japan. After almost a decade stay abroad, he had finally come back home, tasting the tense and chilly air of late December, when all of Japanese society was rushing to prepare for the New Year's celebration. With his homecoming, Nishina was one of only a few Japanese physicists whose works were recognized internationally. His paper with Oskar Klein on the quantum-relativistic electron, hailed by the scientific community, surpassed any previous work in theoretical physics conducted in Japan. In 1928, no other Japanese physicist had as much understanding of the new physics of quantum mechanics, in both its theoretical and experimental aspects, as Nishina. No other Japanese physicist possessed a vision as clear as his about the future course of physics. No other Japanese physicist had as wide a circle of acquaintances among foreign physicists as he had. Finally, no other Japanese physicist had comparable training and experience under the acknowledged leader of the field, Niels Bohr.

Nishina did not know it, but his return to Japan would later be seen as a historic moment in the introduction of modern physics into Japan. After his return, Japan's theoretical physics began to flourish. Young theorists flocked around the new quantum mechanics and began contributing to its developments. Yukawa Hideki became one of the founding fathers of particle physics, not only in Japan but throughout the world, when he published his meson theory in 1935.[1]

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1. Hideki Yukawa, "On the Interaction of Elementary Particles," *Proceedings of*

Tomonaga Sin-itiro, Sakata Shôichi, Tamaki Hidehiko, Kobayashi Minoru, and others were producing theoretical works in competition with European and American physicists.

This apparently sudden rise of theoretical physics in Japan in the 1930s and the "scientifically" important works by Japanese physicists during and after this period have received some attention from both Japanese and non-Japanese historians of science. In particular, historians, such as Laurie Brown, Morris Low, Olivier Darrigol, S. S. Schweber, and others have closely studied Yukawa Hideki's meson theory, Sakata Shôichi's works that followed it, and Tomonaga Sin-itiro's work on QED during and after the war. Dong-Won Kim has also reaised the question of the "emergence of theoretical physics."[2]

The goal of this work is, however, not to record major scientific breakthroughs in Japan, nor is it to explain or give historical backgrounds to the scientific version of the "Japanese miracle." Rather, it is to use this case to study how knowledge travels between different cultures, taking advantage of the richness of scientific activities and historical accounts of this period of physics in Japan. As some scholars suggest, in all appearances, Nishina seemed to have

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the Physico-Mathematical Society of Japan, Series III 17 (1935): 48; Yukawa first published his theory in 1934 in Japanese. refs.

2. Dong-Won Kim, "Emergence of Theoretical Physics in Japan," *Annals of Science* 52 (1995): 383-402; Silvan S. Schweber, *QED and the Men Who Made It: Dyson, Schwinger, Feynman, and Tomonaga* (Princeton: Princeton University Press, 1994); Laurie M. Brown, "Hideki Yukawa and the Meson Theory," *Physics Today* 39, no. 12 (1986): 55-62; Olivier Darrigol, "The Quantum Electrodynamical Analogy in Early Nuclear Theory or the Roots of Yukawa's Theory," *Revue d'Histoire Des Sciences* 41 (1988): 225-97; Olivier Darrigol, "Yukawa et Tomonaga: L'essor de la physique théorique japonaise," *Recherche* 23 (1992): 42-50; Olivier Darrigol, "Elements of Scientific Biography of Tomonaga Sinitiro," *Historia Scientiarum* 35 (1989): 1-29.

"brought back home quantum mechanics."[3] It was as if, through Nishina, underdeveloped physics in Japan had finally received an infusion of knowledge from advanced countries.[4] Yet, the matter was not so simple. Even before Nishina's return to Japan, there was burgeoning interest in quantum mechanics. Nishina's students had been trained at universities before receiving his personal tutelage. None of Nishina's colleagues with whom he worked side by side in Copenhagen were nearly as successful as Nishina. Introducing quantum mechanics involved much more than bringing back Royal Copenhagen's porcelain.

What, then, happened before and during the apparently sudden emergence of theoretical physics after Nishina's return? The goal of this work is to understand the process of the introduction of quantum mechanics into Japan.[5] Put in more general terms, it is an attempt to clarify how a certain set of scientific knowledge (and various inevitable attachments to the knowledge) is "transferred" from one cultural sphere to another. Using the example of the introduction of quantum mechanics into Japan, this work examines this issue of the transmission of scientific knowledge. "Transfer of knowledge" is not as simple as it might appear. This work aims to analyze this issue in light of cultural, historical, institutional, and technical factors. In particular, I stress how scientific knowledge, practices, and cultures are entangled in the phenomen of knowledge transfer.

The title of this work has two meanings: How historical actors' "make sense," and how we do. On the one hand, this work studies how Japanese

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3. Sugiyama Shigeo, *Nihon no kindai kagakushi* (Tokyo: Asakura Shoten, 1994), 80.

4. Kim, "Emergence of Theoretical Physics in Japan."

5. Whereas my main focus is theoretical physics, since the activities of the main character, Nishina, ranged from theoreticla physics to experimental physics, I do

physicists and other intellectuals tried to understand "quantum theory," or what they called "ryôshiron." On the other, this work aims to understand "ryôshiron," the version of quantum mechanics that Japanese physicists introduced and practiced in Japan.

Before starting a historical narrative, it is necessary to clarify some notions in analyzing the issue of "transfer of knowledge." In this chapter, I am going to outline this problem-complex regarding knowledge, meaning, practice, and culture, as well as their transmission.

Meanings and Practices

I start with the notion of meaning, which will turn out to be linked with "practices." Let us take an obvious example: What is "quantum mechanics"? When I ask about the "meanings" of quantum mechanics, I refer to not only the denotation but also the connotations of quantum mechanics. To account for science as a human activity, it is essential to take the feelings and nuances of scientific notions into account. Describing the bare bones of science does not give the whole story. Moreover, what makes the bare bones of a scientific theory or how to make the distinction between denotation and connotation is not obvious. I claim that these depend on historical contexts.

In the film "The Gods Must Be Crazy" (1980), Bushmen in the Kalahari Desert encounter an unfamiliar technological object, a coke bottle. The Bushmen perceive totally different meanings in the coke bottle than the one familiar to us. They use it as a tool, a musical instrument, and even as a weapon. In this instance, the coke bottle stops functioning as a "coke bottle" as we know it. Even if the

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not strictly confine the topics of this work to theoretical physics. In particular, Chapter 6 deals more with experimental than theoretical physics.

material substance remains the same, the function and values of an object can change completely.

Similar things can happen in science. In the early eighteenth century, Japanese "mathematicians" obtained some mathematical results, that had counterparts in European mathematics. For example, the Japanese mathematician Takebe Takahiro (Kenkô) calculated the value of π up to forty decimal places in 1722.[6] About the same time in Europe, people like Abraham Sharp and Thomas Fantet de Lagny were calculating π up to more than 100 places. Besides the number π, European and Japanese mathematics shared a few other mathematical subjects and techniques, such as the integration of the circle, ellipse, and sphere, and the theory of determinants. In the case of the calculation of π, their methods were different: Whereas the eighteenth century European mathematician were able to use the method of calculating through an infinite series of arctangents, the Japanese "mathematician" had to make an ingenious use of polygons to calculate π. Not only the methods, but also the cultural meanings of their practices differed. For European mathematicians, the calculation of π was, although fairly marginal to the mainstream, a part of an established scientific discipline of mathematics, whose practitioners belonged to scientific or academic institutions sponsored by the state. Sharp was the Astronomer Royal, and Fantet was a member of the Académie des Sciences. On the other hand, in Japan, calculating π could hardly be considered a scientific or academic practice. Mathematics was outside the mainstream academic

6. Takebe Kenkô, *Tetsujutsu Sankei* (1722). The text is available on line from http://www.tcp-ip.or.jp/~hom/historyofmath/document/tetsujutsu/hmframe.html; David Eugene Smith and Yoshio Mikami, *A History of Japanese Mathematics* (Chicago: Open Court, 1914), 144. For a recent study in English on Takebe's earlier works with Seki Takakazu, see: Ken'ichi Sato, "On the Theory of Regular Polygons in Traditional Japanese Mathematics: Reconstruction of the Process for the Calculation of the Degree of Kaihoshiki Appearing in the Taisei Sankei by Seki and Takebe Brothers," *Historia Scientiarum, Series 2* 2, no. 71-85 (1998).

world that was dominated by Confucianism. Solving a mathematical problem was a competition of mathematical skills (not a result of scientific curiosity) among practitioners of "mathematics," who supported themselves by teaching abacus, worked as a calendar maker, or served feudal lords as masters of (the game of) mathematics. Yet, the meaning of mathematics was not same in Japan. Japanese "mathematicians" took their work as a kind of art, similar to chess, poetry, or a tea ceremony.[7] Even if these two theories were mathematically almost equivalent, they had totally different cultural meanings.

In these examples, the coke bottle and mathematics had different meanings in different cultural contexts. Both of them kept their identities, even when they had different meanings. In the case of the coke bottle, it was a material identity. We see something with the same form and substance, and therefore identify it as a coke bottle. Yet, it is us who identity it as a coke bottle, not the Kalahari bushmen.

And there is no reason why identity should be based on theobject's material constitution. Take a round tray, as an example. It can easily change its identity into a Frisbee. In that case, the identity is based on function. In the case of Japanese mathematics, the identity can been seen as mathematical equivalence, and this was established later by Japanese mathematicians and historians who learned Western mathematics. But there is no reason why we have to regard Japanese mathematics as mathematics at all. People usually do not regard a chess master as a specialist of game theory. It is contingent that contemporary observers with some modern (namely Euro-American) mathematical education regard "Japanese mathematics" as a form of mathematics.

In these cases, identities are contingent, but not arbitrary. For us, even when used as a weapon, a coke bottle is still a coke bottle because we do not have any name for a coke-bottle-used-as-a-weapon. If a round tray becomes a Frisbee, that is when we want to use it as a Frisbee. It is because of us. Japanese mathematics is mathematics because Japanese mathematicians and historians of mathematics after the Meiji Restoration, who knew Western mathematics, perceived Japanese mathematics as mathematics. It is because of an act of interpretation by someone that things keep or lose their identities. In either case, it is not that there are certain essential meanings of a coke bottle or mathematics that go through different cultures.

Here, Davidsonian semantics seems to provide insight into the relation between practice and meaning.[8] As Joseph Rouse suggested, Davidsonian considerations of the notions of science are quite relevant to the program of cultural studies of science.[9] According to Davidsonians, a word is not a representation; its meaning appears only in relation to its use in the actual world. Samuel Wheeler writes:

> Without a magic language whose terms carry meanings by their very nature, the determination of what sentences mean and what is true, that is, what the facts are, rests on a single kind of data, what people say when. Thus, there is no separating learning a language from learning about the world.[10]

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7. Mikami Yoshio, *Bunkashijô yori mitaru Nihon no sûgaku* (Tokyo: Iwanami Shoten, 1999), 25-136.

8. Here I mean by "Davidsonian semantics," an interpretation of Donald Davidson's philosophy of language by his followers, such as Samuel Wheeler, Bjorn Ramberg, and others.

9. Joseph Rouse, "Against Representation: Davidsonian Semantics and Cultural Studies of Science," in *Engaging Science: How to Understand Its Practices Philosophically* (Ithaca: Cornell University Press, 1996), 205-36.

10. Samuel Wheeler, "True Figures: Metaphor, Social Relations, and the Sorties," in *The Interpretive Turn*, edited by David Hiley, James Bohman, and Richard Shusterman (Ithaca: Cornell University Press, 1991), 201.

Along with Davidsonians, I claim that these notions or terms that are used diachronically or transculturally cannot have well-defined meaning without being situated in a context, and here a context consists of practices, including, among others, utterance of the term and various activities attached to it.

An essentialist definition of quantum mechanics might be the following: "quantum mechanics is a physical theory, which describes systems by state vectors in a Hilbert space, stipulating an equation of motion for the state vectors, commutation relations for canonical variables, and a procedure for converting state vectors to observable probabilities."

From my viewpoint the definition of quantum mechanics as it was understood in Europe during the late 1920s requires at least a paragraph, that should begin with: "'Quantum mechanics' is a term coined by Max Born in 1924 to designate a theory for atomic phenomena, in contrast to classical mechanics which deals with macroscopic phenomena.[11] The content of the theory itself was non-existent when this term was coined.Werner Heisenberg's 1925 paper filled this gap,[12] and Pascual Jordan and Max Born further developed Heisenberg's theory,[13] which constitutes what one now calls matrix mechanics, although Heisenberg continued calling it 'quantum mechanics'. Soon, Erwin Schrödinger proposed a new theory that could be applied to the same kind of problems as matrix

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11. Max Born and Pascual Jordan, "Zur Quantenmechanik," *Zeitschrift für Physik* 34 (1925): 858-88.

12. Werner Heisenberg, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," *Zeitschrift für Physik* 33 (1925): 879-93.

13. Born and Jordan, "Zur Quantenmechanik"; Max Born, Werner Heisenberg, and Pascual Jordan, "Zur Quantenmechanik II," *Zeitschrift für Physik* 35 (1925): 557-615.

mechanics.[14] This theory is what we now call wave mechanics. Schrödinger himself and Paul A. M. Dirac showed that these two theories gave the same results for the same problems;[15] physicists then began to regard these as different formulations of one theory, 'quantum mechanics'."[16]

An essentialist definition cannot help but be a historical fiction. The more clearly one formulates quantum mechanics, the more distant it becomes from the way people actually understood it. The fact that Heisenberg continued calling his matrix mechanics "quantum mechanics" pinpoints another difficulty. One would hesitate to claim that Heisenberg's use of the term was incorrect, but this is an unavoidable accusation if one adopts an essentialist stance. From my viewpoint, the totality of activities in which the utterance of the term "quantum mechanics" occurred shaped its multiple meanings.

From the practices of historical actors we can interpret how they understood and gave meanings to quantum mechanics. On one hand, we cannot talk solely about meanings, because the meanings of quantum mechanics were dependent on the practices of its practitioners. On the other, a study solely concerned with practices would lead to a behaviorist account, which does not help

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14. Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Erste Mitteilung," *Annalen der Physik* 79 (1926): 361-76; Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Zweite Mitteilung," *Annalen der Physik* 79 (1926): 489-527.

15. Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Virte Mitteilung," *Annalen der Physik* 81 (1926): 109-39; P. A. M. Dirac, "The Physical Interpretation of the Quantum Dynamics," *Proceedings of the Royal Society of London, Series A* 113 (1926): 621-41; also Pauli, whose work was not published.

16. There is also a problem of translation. These German physicists talked about *Quantenmechanik* rather than quantum mechanics. Between German and English, the correspondence is relatively non-problematic. In Japanese *Ryôshi rikigaku* is now the word for quantum mechanics, but in the period under the consideration, people usually used *Ryôshi-ron,* literally "quantum theory" for "quantum mechanics."

us to understand practices. Studies on practices and meanings are complementary,[17] and Davidsonian semantics suggests a way to unite them.

I have already tacitly introduced the notion of culture into some of the discussions above. Parallel to the relation between meaning and practice, culture can be seen in two ways. Culture can be the matrix that generates practices. For example, one can see culture as something like Pierre Bourdieu's "habitus," a "system of organic and mental dispositions and of unconscious schemes of thought, perception and action," which "allows the generation . . . of all thoughts, all perceptions and actions in conformity with objective regularities."[18] "Culture" can also mean a set of interpretive frameworks, through which we attach meanings to things. For example one may use "culture" in a Geertzian way: A culture is a historically transmitted pattern of meanings, or a system of inherited conceptions expressed in symbolic formwith which people communicate and develop their knowledge about and attitudes toward life.[19]

Cultural Meaning and Transmission of Knowledge

The consideration in the previous section is in accordance with the view that the transmission of knowledge is an appropriation.[20] Traditionally, a study of

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17. I owe this insight to David Kaiser.

18. Pierre Bourdieu, "Structuralism and Theory of Sociological Knowledge," *Social Research* 35 (1968): 705-06; also see: Pierre Bourdieu, *Outline of a Theory of Practice*, translated by Richard Nice (Cambridge: Cambridge University Press, 1977). Although Bourdieu sees culture as a special form of the habitus (the habitus for arts for example), we do not need to make such a *distinction* here. See p. 200, n. 26. I discuss habitus more closely in Chapter 6.

19. Clifford Geertz, *The Interpretation of Cultures: Selected Essays* (New York: Basic Book, 1973), 89.

the transmission of knowledge is often regarded as a question of "reception." When a scientific idea is transmitted, however, it is not necessarily simply "received"; it can be actively transformed, distorted, or appropriated. Even when a historian uses the term "reception," it does not necessarily mean the simple relocation of knowledge. For example, Loren Graham, in a paper entitled "The reception of Einstein's ideas" describes how Vladimir Fock and Arthur Eddington gave different meanings to relativity theory, and how their understandings were embedded in the political or religious cultures (dialectical materialism and Quakerism) in which they lived. On the one hand, Eddington saw in Einstein's definition of physical quantities in relativity theory a clear delineation of the boundary of natural sciences. He considered this delineation to belong to the realm of measurable things, and took it as pointing to the realm of spirituality, which was supposed to lie beyond the world of things that could be measured. On the other, Fock emphasized constant quantities in relativity theory and claimed that this theory signified the objective reality of nature, which fit into dialectical materialism, rather than philosophical relativism.[21] A more appropriate term than "reception" is "appropriation," as used by Andrew Warwick in relation to the introduction of relativity theory into Britain. He shows how the meaning of relativity changed when British scientists incorporated it into their own practice, by

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20. The aspect of appropriation in the introduction of scientific knowledge was emphasized by A. I. Sabra. See: A. I. Sabra, "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement," *History of Science* 25 (1987): 223-43.

21. Loren Graham, "The Reception of Einstein's Ideas: Two Examples from Contrasting Political Cultures," in *Albert Einstein: Historical and Cultural Perspectives*, edited by Gerald Holton and Yehuda Elkana (Princeton: Princeton University Press, 1982), 107-36.

reinterpreting it.[22] These studies suggest a way to understand "reception" in terms of historical actors' cultures and practices. Therefore, it is a question of what "relativity theory" meant to those who had specific sets of practices.

The problem of knowledge thus can be seen through this meaning-practice-culture entanglement. Again, the phenomenon of transmission illuminates how scientific knowledge works. The transmission of quantum mechanics across cultures involved more than importing writings on quantum mechanics. Japanese physicists had to interpret the formal theory using available interpretative resources, which differed from those available to the European physicists who codified the theory of quantum mechanics. In order to start working on quantum mechanics, they had to recreate the practices of quantum theory, which were not easily transferred. The question is how practice can be transferred, when knowledge can be conceived as practice.

Thus, transmission of knowledge involves the transmission of practices. This is not a novel point. Simon Schaffer, for example, would claim that the multiplication of contexts enables the transfer of knowledge, and for Schaffer the multiplication of contexts is nothing other than a transfer of practices.[23] Similarly, when Bruno Latour stresses "the dependency of facts and machines on networks

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22. Andrew Warwick, "Cambridge Mathematics and Cavendish Physics: Cunningham, Campbell, and Einstein's Relativity, 1905-1911. Part I: The Uses of Theory," *Studies in History and Philosophy of Science* 23 (1992): 625-56; Andrew Warwick, "Cambridge Mathematics and Cavendish Physics: Cunningham, Campbell, and Einstein's Relativity, 1905-1911. Part II: Comparing Traditions in Cambridge Physics," *Studies in History and Philosophy of Science* 24 (1993): 1-25.

23. Simon Schaffer, "A Manufactory of Ohms," in *Invisible Connections: Instruments, Institutions, and Science*, edited by Robert Bud and Susan E. Cozzens (Bellingham: SPIE Optical Engineering Press, 1991), 23-56.

to travel back from the centers to the periphery," he seems to have essentially the same model in mind.[24]

Although I agree that practices constitute the contexts within which knowledge is transmitted, these models are not completely satisfactory in two respects. First, if one applies Schaffer's idea of "multiplication of contexts," the original contexts where quantum theory was practiced should be imposed on the physicists in Japan, in the case of the transmission of quantum mechanics, for example. Such a view would, however, underrate the differences of the context that persist. Since in reality it is impossible to replicate all of the relevant contexts, the multiplication of contexts is always partial and often selective. Second, Schaffer's and Latour's models are predicated on the transfer of practices, which is not accounted for. As I already stated above, the question is how practices transfer, and this is not an easy question.

Peter Galison's idea of the "trading zone" gives us an alternative viewpoint. He stresses the two aspects of the knowledge transfer that Schaffer and Latour failed to address, namely, the activity of interpretation that takes place upon "taking up" and the locality of the shared elements.[25]

Galison's view fits in perfectly with the ideas I have developed here so far. The activity of interpretation is absolutely essential in my conception of the transmission of knowledge, as illustrated by the question of what quantum mechanics meant in Japan. The issue of locality is implied in my discussion of

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24. Bruno Latour, *Science in Action* (Cambridge: Harvard University Press, 1987).

25. Peter L. Galison, "Material Culture, Theoretical Culture and Delocalization," in *Science in the Twentieth Century*, edited by John Krige and Dominique Pester (Amsterdam: Harwood Academic Publishers, 1997), 669-82. See also: Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: The University of Chicago Press, 1997).

identity. Things can keep their identities, even in different cultural contexts. Then, parts of these things are shared, other parts not.

Adapting Galison's ideas, I describe the case in Japan in a slightly different form. Instead of talking about "transfer" (as do Shaffer and Latour), I regard what happened as a "resonance" that occurred through various kinds of mediation. Introducing the practice of quantum physics needed human mediation, for example. This model implies three things. First, it incorporates a mediator. In the case I study here, where the geographical and cultural distance is vast, it seems more reasonable to set up a mediator between two parts. Second, the process of translation across cultures transformed the practice, incorporating the new into the old. Practice (and therefore knowledge) is not a stable entity that one can carry around. Rather, it is a process, and the transmission of quantum mechanics from Europe to Japan was a resonance of two events, mediated on multiple levels, including formal mathematical theories, cultural values, skills, techniques, and meanings. Third, in accordance with Galison's ideas, mediation does not have to take place on all the levels, and it does not imply a global or total relocation of contexts. Tuning forks do not need to be identical for them to resonate.

In the case of (identical) tuning forks, the resonated sounds are identical, but resonance does not necessarily imply replication of the same phenomenon. In 1928, Arnold Sommerfeld visited Japan and gave several lectures for scientists. One of the lectures was about resonance in classical mechanics. He used the system consisting of a solid body suspended by a spring. When the frequency of the perpendicular oscillation equals that of the circular oscillation, there is a resonance between them. If the system starts with an up-and-down motion, the movement gradually shifts to a twisting motion of the solid body. According to

Tomonaga, Sommerfeld explained this by inserting a coupling term into Hamiltonian and solving the canonical (or possibly Lagrangian) equations.[26]

In this case, resonance occurred between two different physical phenomena. The original motion (an up-and-down motion) was not simply replicated by resonance; rather it was replaced with a different kind of motion (a twisting motion). Similarly, the resonance between scientific activities is not necessarily a passive replication of the same activity.

Transformation of motion in the above case of resonance does not imply the decay of motion. After a certain time, the twisting motion will abate and the suspended body then begins the vertical movement. Similarly, even when accompanied by some changes, resonance of scientific practices does not necessarily mean misunderstanding or vulgarization of the original. The scientific practices and cultures of Japanese physicists might have differed from those of European physicists, but that does not mean that the Japanese physicists replicated quantum physics imperfectly.

To analyze this resonance, I tentatively identify five distinct components. First and most obviously, there is the component of the original phenomenon, the original sound in the tuning fork metaphor, namely, scientific practices and cultures of Euro-American quantum physicists. However, I do not spend many pages on this component except for the scientific culture of the Copenhagen physicists, which I discuss in Chapter 5.

Second, there is the component of the original tuning fork, or the social, cultural, and institutional background of quantum mechanics in Europe. Since this

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26. Sin-itiro Tomonaga, "Ryôshirikigaku no akebono," in *Ryôshirikigaku to watashi*, vol. 11 of *Tomonaga Sin-itiro chosakushû*, reprint, 1975 (Tokyo: Misuzu Shobô, 1983), 86-87. I will discuss this lecture and Tomonaga's reaction to it in Chapter 5.

subject is too vast and there are already many excellent works were devoted to it, I do not dwell on this subject.

Third, there is the component of the resonating phenomena, the scientific practices and cultures, which occupy most of this work. How was physics practiced in Japan? What kinds of cultural values were attached to physics? What was its disciplinary identity in relation to other disciplines, especially mathematics and engineering, and how did expertise in these adjacent disciplines affect physicists' understanding and skills in quantum mechanics?

Fourth, there is the component of the resonating tuning fork. The scientific cultures in Japan should be understandable in the broader context within which they were situated. How did the political culture in this newly modernized nation affect the way physicists conducted and conceived the new physics? How did the perceived role of intellectuals in the society define the meaning and practice of physics? How could modern physics be compatible with Japanese nationalism, whose core was the mythical emperor ideology? How did Japanese physicists and other intellectuals react to the philosophical and interpretative issues of quantum mechanics?

Finally, there is the component of the medium of the resonance. I pay special attention to the principal human medium, Nishina Yoshio. Although this work is not intended to be a biography of Nishina, I have incorporated detailed biographical materials of Nishina's life up to 1940.

Outline

In order to understand the scientific cultures relevant to the introduction of quantum mechanics into Japan, it is convenient to distinguish three phases. The first phase is the first half of the 1920s, the period before the introduction of quantum mechanics, which prepared certain preconditions for the later developments. I call this the "culture of calculating" phase, for the reason I explain bellow. The second is the time when young physicists in Japan began studying quantum mechanics through published articles and books, which I call the "student rebellion" phase. The third is the stage after Nishina Yoshio came back to Japan and organized the research activities of quantum physics in Japan, which I call the "Copenhagen" phase.

Chapter 2, "Culture of Calculating: Theory and Practice of Theoretical Physics in 1920s Japan," examines the first phase, the preconditions of the introduction of quantum mechanics into Japan. This chapter tries to ascertain what "theoretical physics" meant in Japan from the late 1910s to the early 1920s, during the time just before quantum mechanics began to be introduced there. The aim of this chapter is not simply to set up the stage for the chapters to come, but to explore a way to grasp the multiplicity of the meaning. This is a paradigmatic example of how meaning, culture, and practice interact. I explore how various meanings of "theory" and "theoretical physics" emerged in dictionaries, popular writings, institutional organizations, and the texts physicists produced, and how these normative texts prescribed (or in them physicists projected) what "theoretical physics" should be like. Then I turn to what "theoretical physicists" actually did or produced and examine how their works constituted the meaning of "theoretical physics." I point out a gap between the prescribed meaning and the practiced meaning: In principle, "theoretical physics" was supposed to be a "pursuit of the deepest principles," while in practice, it was a mathematical elaboration of known physical principles. Behind this was the domination of the "culture of calculating," in which calculational skills and knowldge of advanced mathematics were highly regarded.

This gap between the theory and practice of "theoretical physics" poses a problem when one asks what "theoretical physics" meant in Japan in the early 1920s. Was "theoretical physics" what theoretical physicists understood as "theoretical physics," that is, a pursuit of truth behind experimental phenomena by means of mathematics? Or was "theoretical physics" what theoretical physicists mostly did, that is, the application of known physical laws, lengthy calculation with arcane mathematics such as elliptic functions or group theory, and the derivation of specific results for practical use? It is meaningless and counterproductive to say that only one of these is correct. Instead, the variety of "theoretical physics" reflects the fact that the meaning of "theoretical physics" in Japan in the early 1920s had a complex structure. The meaning does not only depend on contexts and broad constraints; it also depends on the mode of the person who uses the term.

In the second phase, this "culture of calculating" was challenged by physicists of a new generation, which is the them of Chapter 3, "'Student Radicals' in Science: Youth Cultures and the Roots of Quantum Physics Research in Late-1920s Japan." While trained in advanced mathematics, young physicists in the late 1920s rebelled against their elders and began learning new physics as a way of asserting their independence. The activities of these young dissidents in physics reflected the culture of rebellion among students in the 1920s and 1930s. They tried to absorb quantum mechanics through papers in journals and books from 1927 to 1928, but their efforts did not immediately lead to fruitful results. What I present in this chapter is a species of the cultural history of science. It is a story of how a particular culture generated meanings and practices associated with theoretical physics. I start with a description of the social and cultural milieu in which these young rebels grew up. In the early 1920s, physical, industrial, political, educational, and scientific landscapes in Japan changed, or were changing dramatically. In 1923, the Kantô Earthquake destroyed many buildings in Tokyo (including the library at Tokyo University), leading to both a sense of insecurity in people's minds and a more modernized Tokyo following reconstruction. World War I had triggered vast changes in the industrial landscape, which was moving toward heavy industry. The democratization of imperial Japan, the so-called "Taisho Democracy" was reaching its high-point in the 1920s. It was also a time when higher education was being popularized, along with the inception of several new higher schools[27] and the expansion of private universities. The development of heavy and chemical industries led to the founding of several new scientific research institutes, such as the Institute of Physical and Chemical Research (Riken) and Osaka Imperial University. A more direct impact on Japanese physics came in 1922, when on November 11 Albert Einstein visited Japan. Einstein stayed in Japan for 43 days, and gave numerous lectures in several cities. His impact on Japanese society and culture was great, and even greater on physicists and would-be physicists. Many popular physics magazines were founded to match the sudden rise of interest in relativity theory. Einstein's name circulated in Japan. Ishiwara Jun's books and many articles caught the imagination of young students, including ones who later became physicists, such as Tomonaga Sin-itiro.[28] The social and cultural upheaval of this period produced radicals of both the left and of the right. Student radicalism was a dominant feature of university and high school life, where the younger generation challenged old values and thoughts. Many students were involved in social movements, and joined such organizations, as *Shinjinkai*, a leftist

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27. Higher schools in the prewar Japan were 3-year institutions of higher education for liberal arts, a prerequisite for "imperial universities." See Chapter 3 for details.

28. Kaneko Tsutomu, *Ainshutain shokku* (Tokyo: Kawade Shobô, 1981).

organization which, seeking social reforms, later became radicalized.[29] Within the academic setting, the younger generation, frustrated by the stagnancy of the universities, began their movement. Although science students were relatively less political than others, they developed their own means of rebellion: They formed independent study groups. Having experienced the "Einstein Shock" in their youth, young physicists in the late 1920s were not satisfied by what the universities had to offer. In particular, the younger generations of physicists took the initiative of digesting the original papers of quantum mechanics at the earliest stages.[30]

For the new generation of physicists, quantum mechanics was a harbinger of a new age, if not of a revolution. In 1927 young physicists in Tokyo formed a study group, "Butsurigaku Rinkôkai" (Physics Reading Seminar). They were mostly physicists working at the Institute of Physical and Chemical Research[31] or at local higher schools, having just graduated from Tokyo Imperial University. The physics department of Tokyo Imperial University had a weekly physics colloquium, but it appeared to these eager younger physicists that it had degenerated into a mere formality. Discussions lacked physical content, and with the presence of senior physicists, young physicists could not speak freely. Frustrated, they decided to form an independent study group, choosing only those people who were committed to the freer atmosphere. Originally they did not intend to focus on quantum mechanics, but with such a motivation their attention was directed to something totally new, and something unknown to senior physicists. By 1927

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29. Henry DeWitt Smith, *Japan's First Student Radicals* (Cambridge: Harvard University Press, 1972).

30. Katsuki Atsushi, "Nishina Yoshio no kikoku mae," *Butsuri* 45 (1990): 752-54; Butsurigaku Rinkôkai Dôjin, *Butsurigaku bunken shô dai 1 shû* (Tokyo: Iwanami Shoten, 1927).

31. More on the Institute of Physical and Chemical Research later.

major foundational works of quantum mechanics had appeared. This splinter group read and translated these works into Japanese, and published them in 1927 and 1928. By examining these translations, one can evaluate their understanding of quantum mechanics. These physicists freely changed details and sometimes even the structure of the papers, also correcting mistakes in the originals. This means that they did not simply mechanically translate those papers. Rather, the young physicists understood them, at least mathematically. Their conception of quantum mechanics, however, might not have been identical to what their European or American counterpart made out of quantum mechanics. The meaning that the Japanese physicists attached to quantum mechanics was locally conditioned. For these young Japanese physicists, learning quantum mechanics was an act of defiance, a revolt against the academic establishment, which included their own old professors. Around the same time in Kyoto four undergraduates interested in quantum mechanics began studying it by themselves. They were students of Professor Tamaki Kajûrô, a theoretical physicist who specialized in fluid dynamics, with little knowledge of quantum theory. Two of them were to become prominent physicists: Yukawa Hideki and Tomonaga Sin-itiro.

The "student rebellion" phase ended around 1929, giving way to what we might call the third stage of Japanese quantum mechanics, the "Copenhagen" stage. Nishina Yoshio played a central role during this stage as an organizer of the newly emerging group of physicists working on atomic physics. Although more than 10 years older than the rebellious young physicists, politically conservative, and unaffected by the upheavals of the 1920s (he was mostly abroad), he could nonetheless tame these young rebels, and henurtured many of them to become full-fledged physicists. As a junior researcher at the Institute of Physical and Chemical Research, Nishina stayed in Europe from 1921 to 1928, first in

Cambridge, then in Göttingen, but mostly in Copenhagen, under the direction of Niels Bohr. After he turned from electrical engineering to physics, he had begun conducting experimental research. That changed in 1927 when he moved to Hamburg with I. I. Rabi, apparently following Bohr's suggestion, to study theory under Wolfgang Pauli's guidance.[32] There he conducted a theoretical work with Rabi,[33] and when he returned to Copenhagen, he worked with Oskar Klein on a theoretical subject, an application of Dirac's theory of the electron.[34]

Chapters 4 through 7 describes the scientific and intellectual cultures related to this "Copenhagen" stage, during which Nishina organized the research activities of quantum physics in Japan.

In Chapter 4, "Superposing Dynamos and Electrons: Electrical Engineering and Quantum Physics in Nishina Yoshio," explores one of the roots of this Copenhagen phase, by focusing on Nishina. Here, I study Nishina's work with Oskar Klein and attempt to tie this work with the engineering cultures in which Nishina, as an undergraduate electrical engineering major, was immersed. It is an attempt to understand how a former electrical engineering major, not one of the talented graduates of the physics departments, was able to achieve a first rate theoretical physics research. It also explains the relative ease with which Nishina moved from experimental physics to theoretical physics, and from theoretical

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32. John S. Rigden, *Rabi: Scientist and Citizen* (New York: Basic Book, 1987).

33. Yoshio Nishina und I. I. Rabi, "Der wahre Absorptionskoeffizient der Röntgenstrahlen nach der Quantentheorie," Verhandlung der Deutschen Physikalischen Gesellschaft 9 (1928), 6—9.

34. Nishina Yoshio, "Die Polarisation der Comptonstreuung nach der Diraschen Theorie des Elektrons," *Zeitschrift für Physik,* 52 (1929): 869—877; Oskar Klein und Nishina Yoshio, "Über die Streuung von Strahlung durch freie Elektronen nach neuen relativistischen Quantendynamik von Dirac," *Zeitschrift für Physik,* 52 (1929): 853—868.

physics to cyclotron physics. Nishina was an advisee of Hô Hidetarô, a specialist in alternating current theory, who introduced Steinmetz's theory into Japan. I show that Nishina's education highly theoretical, but not too mathematical. I also argue that the electrical engineering department was in fact a good place to learn theory and experiment of certain physical phenomena, if not necessarily better than the physics department. This chapter suggests that some of theoretical contents that he must have learned from Hô was useful for learning quantum mechanics. At the same time, Nishina was able to inject the electrical engineering tradition of the unity of theory and experiment into physics, which turned out to be productive, both to theory and experiment.

Chapter 5 describes the scientific cultures of the physicists that Nishina recruited and trained, and discusses their implications. In this chapter, "The *Geist* in the Institute: The Production of Quantum Theorists in 1930s Japan" examines how Nishina created his research group of quantum physics at Riken. Only after his return to Japan in December 1928 did Japanese physicists begin forming a research school and producing theoretical and experimental work in atomic physics on a regular basis. Working with European physicists, Nishina had learned quantum mechanics and how to conduct research with it. What Nishina brought back to Japan was not simply the formal theory of quantum mechanics. One could learn that in Japan through journals and books, as several of the young Japanese physicists did. Nishina brought back something more elusive. Contemporary Japanese physicists, such as Hori Takeo,[35] recognized it, and called it the "Copenhagen Spirit." I will argue that it was a subtle style or culture of research

35. Hori Takeo, "Bôa gurûpu to Kopenhâgen seishin," *Mugendai*, no. 85 (1990): 53-59; Reprinted in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), pp. 46-54. Hereafter, I cite the latter version.

that students of quantum mechanics gained with Nishina's return to Japan. Yet this culture was not exactly the same as in Copenhagen, taking on, for example, a more calculation-intensive, pragmatic, and less philosophical character. By closely examining Nishina's intellectual trajectory and his role in the introduction of quantum mechanics into Japan, I depict how Nishina re-created at Riken a culture of conducting physics research based on, but not identical to, his experience in Copenhagen. In 1930, he became one of the chief researchers at the Institute of the Physical and Chemical Research and began forming a group of atomic physicists, including Tomonaga Sin-itiro, Sakai Shôichi, and Tamaki Hidehiko. Some physicists attributed the success of Nishina's group to the "Copenhagen spirit" that Nishina supposedly brought back from Bohr's institute in Copenhagen, a mentality that created a friendly atmosphere and free-flowing discussion in his division at the Institute of Physical and Chemical Research. The Institute of Physical and Chemical Research provided a unique research environment. In his later years, Tomonaga called it a "scientists' paradise."[36] Nishina's "Copenhagen spirit," however, was not identical to Bohr's. In the early 1930s, Nishina tried to lecture on foundational issues of quantum mechanics to his young disciples, but they, Tomonaga included, could hardly keep themselves awake.[37] Nishina's understanding of complementarity came from Wolfgang Pauli, whose seminar Nishina had attended, more than from Niels Bohr himself.[38] Nishina's philosophical

36. Tomonaga Sin-itiro, "Kagakusha no jiyûna rakuen" (scientists' free paradise), Bungei Shunjû (1960); reprinted in Tomonaga Sin-itiro Chosakushû, vol. 1 (Tokyo Misuzu Shobô, 1981); Translated as "Das freiwillige Vergnügen der Naturwissenschaftler," in Sin-itiro Tomonaga, übersetzt von Wolfgang Muntschick, Welt im Spiegel (Stuttgart: Franz Steiner Verlag, 1986), pp. 95-103.

37. Tomonaga Sin-itiro, et al., "Sensei wo shinonde," *Shizen* special issue (March 1971): 31.

attitude was definitely different from Bohr's. Trained as an engineer, Nishina had a much more practical mind than Bohr and never indulged in a philosophical problem for its own sake, whereas for Bohr philosophical issues, including problems concerning life and consciousness, were always central. Nishina selectively absorbed Bohr's ideas, transforming them into a workable methodology, rather than philosophical dogma. My task is to analyze as precisely as possible the "Copenhagen spirit" that Nishina brought into Japan. I argue that Nishina helped transmit and build a style of conducting physics that was inseparably attached to quantum mechanics.

Nishina's role in establishing physics in Japan can be fully understood only when one takes into account the country's political context. In Chapter 6, "Rebuilding the House, Rebuilding Physics: Norms in Nishina Yoshio's Scientific Activities and Familial Life," I show how the native political and ideological culture of the prewar Japan gives meanings to Nishina's activities for those of us who reflect on his role in Japanese physics. In addition, this chapter shows how Nishina's activities were embedded in the native Japanese context. There were two sides in Nishina's approach. While he introduced European practices of atomic physics, his activities followed the pattern of the Japanese elite in the early Meiji Era. It shows how the life and practices of this Japanese physicist were multi-layered, and how his transfer of scientific practices was partial, not global. After his homecoming, Nishina's principal role in Japan was not that of a researcher, but of a teacher and an organizer. His efforts were directed toward building a respectable physics community, a group of trained physicists, and an infrastructure

38. Nishina attended Pauli's seminar at Hamburg University and left seminar notes. These notes and Nishina's writings in the 1930s led to this conclusion. See: Nishina Yoshio, "Ryôshiron," Shizen kagaku shisô, Nijû seiki shisô , vol. 10 (Tokyo Kwade Shobô, 1938), on pp. 101—140.

within which physics could flourish. I argue that one can interpret Nishina's effort to build a modern scientific community as a scientific analog of the reconstruction of the modern state in the Meiji Era, the era when Nishina grew up, and of the reconstruction of his declining family.

Chapter 6 explores yet another aspect of the Copenhagen phase, again focusing on Nishina, but his earlier life. In one aspect, Nishina was deeply rooted in the native Japanese culture; and this very aspect enabled him to play a unique and positive role in physics. Nishina was born in 1889 in Satoshô Village in today's Okayama Prefecture, as the eighth child of an affluent farmer's family. The Nishinas are a clan deeply rooted and well respected in this small rural village, with many relatives in this area. The Nishina family's fortune, however, declined after the Meiji Restoration. To rebuild the family was the Nishinas' wish. In this environment, I argue, Nishina developed an exceptional sense of mission to be successful and to rebuild the Nishina clan. By closely studying Nishina's correspondence with his mother and brothers, I show how Nishina chose his life path driven by this sense of mission to rebuild the family's fortune. At the same time, however, Nishina's correspondence reveals his other objective: to serve the nation as a scholar, a goal widely shared by the Japanese elite. When he graduated from college and entered the Institute of Physical and Chemical Research, his oldest brother Teisaku wrote Nishina: "Your calling is not to make money but to master the profoundest truth of arts and sciences and to serve the nation. You are certainly suited for that."[39] Yet even during his stay in Europe, Nishina remained ambivalent about his choice between science as a vocation and a real job. The balance between these two goals finally began to break when his mother died in

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39. Nishina Teisaku, A letter to Nishina Yoshio, May 3, 1918 in *Nishina Yoshio hakase shokanshû* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 141-43.

October 1922.[40] As his ties with his clan weakened, Nishina shifted his interest from rebuilding the house to rebuilding the physics community in Japan.

The seventh and penultimate chapter concerns broader intellectual cultures surrounding the Copenhagen phase, by focusing on philosophical issues of quantum mechanics, in particular, Bohr's notion of complementarity. In this chapter, "Complementarity in the 'Far East': The Philosophy of Quantum Mechanics and Japanese Intellectuals in the 1930s," I discuss the diverse intellectual cultures in the 1930s. Within these intellectual cultures, scientists, scientific journalists, and philosophers discussed foundational problems of quantum mechanics, especially Niels Bohr's idea of how to interpret quantum mechanics, namely complementarity. I examine various meanings of complementarity within the contexts of these different cultural traditions. Bohr's complementarity, first published at a conference in Como in 1927, epitomizes various aspects of quantum mechanics. By looking at how people from different backgrounds perceived and treated complementarity, one can reveal the place physics occupied in Japanese scholastic and cultural spheres at that time, the relation between physics and philosophy, and the role of journalism in science.

The introduction of complementarity in Japan began in 1928 with Nishina and Sakai Takuzô. Their early attempts to introduce complementarity, however, did not reach a wide audience. The situation changed around the time when Niels Bohr visited Japan in 1937. Bohr's visit attracted a wide range of Japanese intellectuals, if not as much as Einstein's visit in 1922. Here, scientific journalism played an important role in facilitating the discussion of complementarity in Japan. From the late 1910s to the early 1930s, the number of popular science magazines

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40. Nishina Kôjirô, "Chichi Yoshio no ryûgaku seikatsu," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 266-72.

had been steadily increasing. Some physicists had close ties with publishing companies. After his retirement, the theoretical physicist Ishiwara Jun became the scientific journalist par excellence and published numerous articles on modern physics. He was the editor-in-chief of *Kagaku,* a scientific journal published by Iwanami Publishers. For scientific journalists, the philosophical issues of quantum mechanics were attractive subjects, along with Niels Bohr's visit to Japan in 1937. Journalism tracked what Bohr did in Japan and published his lectures. They also invited renowned scholars and intellectuals to write about complementarity. One strong tie between science and publishing companies was what I call the scientists-literati, scientists also engaged in literary activities.

Terada Torahiko and his followers represent this tradition. Terada started his literary career by writing haiku under Natsume's guidance. Yet, Terada's uniqueness lay in the amalgam of science and literature that he accomplished in his scientific essays. Young physicists, who had become familiar with Japanese literature in their higher school years, admired Terada, and some of them, emulating him, wrote scientific essays with various degrees of success. For these writer-scientists, philosophical discussions of complementarity appeared attractive, since they could write literary essays on it. However, some of the younger Japanese physicists, those who had learned quantum mechanics as a mathematical formalism from the beginning, found the philosophical considerations of Bohr superfluous.

In the broader intellectual scene, two groups dominated the philosophical thoughts in the prewar Japan. One was the so-called Kyoto School, represented by Nishida Kitarô and Tanabe Hajime. The other was the Marxist philosophers, such as Tosaka Jun, Nagai Kazuo, and Taketani Mituo. These opposing groups, one conservative, the other revolutionary, waged battles in all of the academic disciplines where the issues related to science and technology were of central importance. Both paid close attention to the recent development in science, especially physics, and Bohr's visit to Japan provided each group with a good opportunity to challenge the opponent. The Kyoto School philosophy was a unique amalgam of European philosophy, especially the Southwest German School of Neo-Kantianism, and Japanese traditional thoughts, such as Buddhist philosophy. They were politically conservative, and generally anti-West. One of their goals was to overcome the problems of modernity by criticizing the tradition of the European philosophical thoughts. Kyoto school philosophers found Bohr's complementarity and other philosophical reflections on quantum mechanics congenial to their project because these considerations fit into their own philosophical agenda to overcome the dichotomy of subject and object, a problem they regarded as fundamental in the western intellectual tradition. In the 1930s, Marxism was probably the only intellectual movement that could compete with the Kyoto School. Marxist philosophers of science, represented by Nagai Kazuo and Taketani Mituo, attacked what they perceived as the subjectivism of the Kyoto School philosophers. For them, Bohr's idea was a "Machian idealist bourgeois" philosophy, and hence to be rejected.

The last and concluding chapter discusses methodological implications of this work. This work shows how place matters, and not whether or not it does. All-or-nothing claims about the relation between science and cultures seem to be tied to what I call "cultural essentialism" and "scientific essentialism." By "cultural essentialism" in the history of science, I mean a view that a certain cultural sphere such as Japan had a specific way of doing science based on its unique culture. In this view, scientific cultures are essentially tied to the specific culture of which they are a part. According this view, place not only matters, but determines scientific practices. By "scientific essentialism," I mean a view that scientific knowledge consists of its "essence," and as far as the essence is concerned, science is same everywhere. In this view, place does not matter to science.

These views are not so trivial as they appear. These views or certain related tenets are in less obvious and less extreme ways shared by many, including some contemporary historians of science. This work shows that both of these positions fail, as I demonstrate using examples in the earlier chapters. I then show various approaches that can be used to avoid these two maladies, and I recapture the notion of "resonance" that I have proposed in this chapter, discussing its implications. Finally, I end by outlining what happened after the period discussed in this work.

Chapter 2
"Culture of Calculating":
Theory and Practice of Theoretical Physics in 1920s Japan

> It is extremely difficult to speak about meaning and to say something meaningful about it.
>
> - A. J. Greimas

1. What is "Theoretical Physics"?

Do we know what "theoretical physics" means? In 1967, an American physicist, John Van Vleck, explained his view of "theoretical physics":

> For some reason or other, more a matter of accident than logic, it is fairly well established usage to employ the term "applied mathematics" for the part of mathematical physics that does not involve Planck's constant *h,* and the term "theoretical physics" for the portion that does.[1]

Relativity theory, in particular general relativity, was considered to be applied mathematics as David Kaiser shows.[2]

This suggests two things: First, the meaning of "theoretical physics" could have been different in the past; and, second, this difference was not simply a matter of linguistics, but instead it was closely tied to practices of physicists. In order to understand what "theoretical physics" meant, it is not enough to extract textual meanings of "theoretical physics." One needs to study the totality of the situation, consisting of the use of the word "theoretical physics" and the activities into which

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1. John H. Van Vleck, "Non-Mathematical Theoretical Physics," *Science of Light* 16, no. 1 (1967): 43.
2. David Kaiser, "Making Theory: Producing Physics and Physicists in Postwar

this word is woven. In other words, one must study the "language-game" of "theoretical physics."[3] This "language-game" should include not only the use of the word, but also the whole set of activities, the forms of life, into which the use of the word was embedded.[4] Through such a study, one can capture certain aspects of the physicists' *Lebenswelt* that shaped the meanings of terms they used and their subcultures.

This chapter attempts to capture this variety of meanings of "theoretical physics" in Japan from the late 1910s to early 1920s, during the time just before Japanese introduced quantum mechanics. The goal of this chapter is to answer the question, "What did 'theoretical physics' mean in Japan?" In the same way as Peter Galison examined the "cultural meaning" of *Aufbau* in the German-speaking world after World War I, and as David Kaiser similarly discussed the meanings of the Feynman diagram in the postwar United States, one can consider the Japanese word for "theory" as having a cultural meaning specific to a particular time.[5] This chapter excavates such a meaning of theoretical physics from old dictionaries, academic institutions, pedagogy, scientific practices, and the cultures of physicists.

This is not a comparative study, although differences and similarities between specific Japanese and European scientists are described. I do not claim that the meaning of "theoretical physics" in Japan was different from or similar to

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America," Ph. D. Diss. (Cambridge, Mass.: Harvard University, 2000), 568-70.

3. Ludwig Wittgenstein, *Philosophical Investigations*, 3rd ed., translated by G. E. M. Anscombe (Englewood: Prentice Hall, 1958), Paragraph 7.

4. Ibid., Paragraph 23.

5. Peter L. Galison, "Constructing Modernism: The Cultural Location of Aufbau," in *Origins of Logical Empiricism*, edited by Ronald N. Giere and Alan Richardson (Minneapolis: University of Minnesota Press, 1996), 17-44; David Kaiser, "Stick-Figure Realism: Conventions, Reification, and the Persistence of Feynman Diagrams, 1948-1964," *Representation*, no. 70 (2000): 49-86.

the ones in Europe. I also do not claim that what I call the "culture of calculating" was unique to Japan, although I assume that if scientific practices of Japanese theoretical physicicsts were locally conditioned, their cultures should differ from others to some extent.

Nor does this study explain the formation of the Japanese concept of theoretical physics in regards to social and cultural conditions. Descriptions of social and cultural contexts of theoretical physics in Japan appear here, but only with an intention to illustrate what "theoretical physics" meant in Japan, not to explain how this term came to have a certain meaning as a esult of particular conditions.

In addition, this chapter tries to avoid evaluating the practices or ideas of Japanese theoretical physicists. My intention is not to belittle early Japanese theoretical physicists' efforts for the dissociation of their theory and practice, nor to praise them for launching this field so early. I also do not intend to argue whether theoretical physics in Japan was less significant than experimental physics.[6]

2. Introducing "Theory" and Redefining *Riron*

Japanese intellectuals eventually came to translate "theory" as *riron* by 1880[7] In addition to the philosophical implication of *ri* in traditional Chinese and

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6. Cf. Dong-Won Kim, "The Emergence of Theoretical Physics in Japan: Japanese Physics Community Between the Two World Wars," *Annals of Science* 52 (1995): 383-402.

7. *Riron* consists of two Chinese characters, *ri* and *ron.* This word has a very long history, which originated from a Chinese word, *lilun*. The word *lilun* appeared in the Tang Dynasty (A. D. 7-10c) in a poem by Zeng Gu. See: Morohashi Tetsuji, ed., *Dai kan-wa jiten*, revised 2nd ed. (Tokyo: Taishûkan Shoten, 1989-90). Also

Japanese thought, it became closely associated with the discussion in the early Meiji concerning the appropriate form of science and technology to be introduced into and conducted in Japan. Amidst the tension between utilitarian approaches toward the Western science and more scholarly attitudes, *riron* was assumed to stand for the latter, and its values were stressed in defense of "pure" science. In this way, *riron* as the translation of "theory" contained three elements: the concepts of "theory," the concept of *ri* in Chinese natural philosophy,[8] and the on-going Westernization of Japan in the nineteenthcentury.

Translating activities dominated the early stage of the introduction of Western sciences into Japan in the late nineteenth century, and they kept a central place in Japanese scholarship for many years thereafter, as Scott Montgomery has pointed out.[9] Furthermore, translating activities matter, not only because they kept

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see: Lydia H. Liu, *Translingual Practice: Literature, National Culture, and Translated Modernity. China, 1900-1937* (Stanford: Stanford University Press, 1995). The Chinese character *li* originally stood for "patterns." See the next footnote. *Lun* means "to discuss" or "to argue." Therefore, *lilun* could mean "to discuss principles" or "discussion of principles." In Japan, an old dictionary, *Iroha ruiji sh*ô, published in the twelfth century, recorded this word. See: Tachibana Tadakane, *Iroha jirui shô*, reprint (Tokyo: Koten Hozonkai Jimusho, 1926-28). The oldest Western language dictionary in Japan, *Nippo jisho*, a Japanese-Portuguese dictionary published by Jesuit missionaries in 1600, defined *riron* as *disputa* (dispute). See: *Nippo jisho*, reprint (Tokyo: Iwanami Shoten, 1960). By then, therefore, *riron* seemed to have lost its connotations associated with any specific meanings of *ri (*or *li).*

8. The Chinese character *li* stood for the pattern appearing on precious stones. It came to mean organizing principles of the universe. As Joseph Needham points out, it is similar to the Aristotelian "form," but not different from *li* (the same pronunciation with a different character), man-made laws. See: Joseph Needham, *History of Scientific Thought*, vol. 2 of *Science and Civilization in China* (Cambridge: At the University Press, 1956), 557-62.

9. Scott L. Montgomery, "Science by Other Means: Japanese Science and the Politics of Translation," in *The Scientific Voice* (New York: Guilford Press, 1996),

Japanese scholars busy, but also because they provide us with clues to figure out how Western concepts acquired their Japanese equivalents and shaped a modern Japanese conceptual framework. Translating Western words into Japanese often involved tremendous difficulty and confusion.[10] Since many Western scientific and philosophical concepts did not have counterparts in native Japanese scholarship, Japanese intellectuals had to coin new words or redefine old ones to express them. Several translators proposed different words for one Western term. Many Western concepts underwent such a process in the 1870s. Standardizing forces in the late 1870s, such as well-circulated books, university curricula, and government ordinances, rendered many of the proposed words obsolete. Japanese words for Western concepts acquired relative stability and established a network of meaning. Through this process, however, Japanese equivalents for Western concepts picked up meanings not necessarily identical to their original meanings.

A part of transformation of meanings through translation occurred by the very act of translating. To translate Western philosophical and scientific terms, Japanese intellectuals often used words consisting of two or more Chinese characters, as they usually did to express scholarly ideas. Each Chinese character had a meaning (often a few different meanings), and by combining a couple of

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294-359; see also: Scott L. Montgomery, *Science in Translation: Movements of Knowledge Through Cultures and Time* (Chicago: The University of Chicago Press, 2000), especially Part II.

10. For example, Inoue Tetsujiô, a philosopher wrote, "As the occidental philosophy was for the first time introduced into Japan not long after the Restoration, it has been very difficult for us to find exact equivalents in our own language for the technical terms employed in it. One and the same term had sometimes been translated by various expressions which might be considered quite distinct in their signification by readers unacquainted with original. It was, therefore, very necessary to settle finally the Japanese equivalents of the European technical terms" (the original is in English). In Hida Yoshifumi, *Tetsugaku jii yakugo sôsakuin* (Tokyo: Kasama Shobô, 1979), 227.

Chinese characters, Japanese translators tried to express the meaning that they understood in Western terms. However, these Chinese characters expressing philosophical or scientific concepts often carried implications understood in the framework of the tradition of Chinese studies. This resulted in a "complex blending of Chinese and Western sensibility," as Montgomery points out.[11]

For example, let us see how the Japanese translated the word "experiment," following the work by Itakura Kiminobu and others. Japanese now use the word *jikken* as the standard equivalent of "experiment." China in the sixth century and Japan in the tenth century had this word, *jikken*, but it meant "to confirm something by actually seeing or testing."[12] When the Japanese encountered the notion of "experiment," however, they did not use *jikken*. In the early Meiji era, scholars used several different words for "experiment," but by the early 1880s, *shiken*, which today means "to test," acquired the status of the standard Japanese equivalent to "experiment," whereas *jikken* meant at that time "practice," especially in pedagogical contexts. In 1886, however, the Ministry of Education used the same word *jikken* in the curricula of physics and chemistry. Student "practices" in chemistry and physics were nothing other than student experiments. At that time the word *jikken* began to mean "experiment."[13]

Like the term "experiment," "theory" traveled a crooked path until it acquired its standard equivalent in the Japanese language. Since early translators of

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11. Montgomery, "Science by Other Means," 316.

12. Some readers may wonder whether this word, *jikken,* is a noun or a verb. With a suffix, most Japanese nouns composed of Chinese characters can work as verbs. Therefore, in this paper, I often use infinitives to explain Japanese nouns.

13. Itakura Kiyonobu, Sugawara Kunika, and Nakamura Mitsukuni, "Jikken gainen to sono kotoba no rekishi," in *Seiô kagaku gijutsu dônyôki niokeru gairai gakujutsu yôgo no nihongoka katei no sôgôteki kenkyû*, Heisei 5 nendo Kagaku

Western learning did not have a word in their vocabulary that would match "theory" precisely enough, they experienced much trouble and confusion in their efforts to convey it.

Various English-Japanese dictionaries from the late nineteenth century show how diversely Japanese scholars translated the word "theory." Many of the words used to express "theory" in these dictionaries published in the 1860s and 1870s are now obsolete. Some examples include: "kokoro bakari wo tanren suru shugyo" (training that only practices mind),[14] "ri nomi wo kokyu suru koto" (to only study principle),[15] "omoi-nashi" (speculation),[16] "hôhô, suiri, gaku, setsu" (method, speculation, learning, thesis),[17] "rikutsu" (logic).[18] [19] This diversity of translation clearly indicates that the concept of "theory" did not have any specifi

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Kenkyûhi Hojokin rept. 03301095, edited by Hiroshi Ishiyama (Tokyo, 1994), 15-34.

14. Yanagawa Hoshû, *Oranda jii*, edited by Tsutomu Sugimoto, reprint, 1856-59 (Tokyo: Waseda Daigaku Shuppankai, 1974), 2940.

15. Sugiyama Tsutomu, ed., *Edo jidai hon'yaku nihongo jiten*, reprinted from *A Pocket Dictionary of the English and Japanese Language*, reprint, 1862 (Tokyo: Waseda Daigaku Shuppanbu, 1981), 886 (207).

16. J. C. Hepburn, *Japanese and English Dictionary: With an English and Japanese Index* (Shanghai: American Presbyterian Mission Press, 1867), 114.

17. M. Shibata and T. Koyas, *English and Japanese Dictionary, Explanatory, Pronouncing, and Etymological, Containing All English Words in Present Use with an Appendix* (Yokohama: Nisshûsha, 1873), 1195.

18. Ernest Mason Satow, *English-Japanese Dictionary of the Spoken Language*, second ed. (London: Trübner, 1879), 363.

19. Explaining the meanings of these Japanese words in English is obviously a very dubious practice, because they were all meant to mean "theory." Moreover, it is not necessary to know what they mean, because just listing the words meets my need here, namely, to show the diversity of translation. Nevertheless, I have made tentative attempts to indicate what these words probably meant.

counterpart in the Japanese language. The dictionary editors, who included both Japanese and English-speakers, apparently experienced a considerable difficulty in translating this word.

The difficulty of understanding and translating the notion of "theory" can be best illustrated by the efforts of Nishi Amane, one of the most important Japanese scholars toiling over the translation of Western learning. Probably the first Western-style philosopher in Japan, with a strong bent toward the philosophies of August Comte and J. S. Mill, Nishi was at the same time well-versed in Chinese studies and familiar with the writings of Japanese scholars, such as Ogyû Sorai. Many of the most important Western concepts, including "philosophy" and "science," received their standard translations from Nishi.[20]

Nishi's translation of "theory" changed from time to time, yet this notion occupied an important place within Nishi's classification of learning. He struggled to incorporate "theory" into the Japanese vocabulary, using the available intellectual resources and bringing in Chinese philosophical notions.

Around 1870, at his private school in Tokyo, Nishi gave a lecture on the classification of knowledge at his private school.[21] In this lecture, entitled *Hyakugaku renkan* (literary, "a chain of one hundred studies"),[22] Nishi translated "theory" as *kansatsu,* a word that Japanese use today to refer to "observation," offering the following warning note: "In Britain, people erroneously use the word

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20. Thomas R. H. Havens, *Nishi Amane and Modern Japanese Thought* (Princeton: Princeton University Press, 1970).

21. Ôkubo Toshiaki and Kuwaki Gen'yoku, "Kaisetsu," in *Nishi Amane zenshu*, vol. 1 (Tokyo: Nihon Hyôronsha, 1945).

22. Nishi Amane, "Hyakugaku renkan," in *Nishi Amane zenshü*, vol. 1, edited by Ôkubo Toshiaki (Tokyo: Nihon Hyôronsha, 1945), 3-294.

'theory' for 'speculation' or 'hypothesis.' One must be careful."[23] Nishi, probably aware that the Greek root of theory, θεωρια, meant "observation," was, therefore, not only linguistically translating the contemporary word for theory. In addition, he was attempting to understand the notion of theory in the Western intellectual tradition, and appropriate it into his system of learning.

Indeed, the notion of *kansatsu* (theory) had an essential importance in Nishi's classification of knowledge. With "practice" (which Nishi translated as *jissai*), it constituted a duality fundamental to Nishi's system of learning, a classifying principle of scholarly disciplines. Nishi categorized both the sciences and the arts according to this duality. In parallel to theory and practice, there were "pure" science (*tanjun gaku*) and "applied" science (*tekiyô gaku*). Similarly, according to Nishi, there were two kinds of "arts": practical "mechanical arts" (*kikai waza*) and theoretical "liberal arts" (*jôhin gei*).[24]

Although Nishi's lecture, entitled *Hyakugaku renkan* was the most systematic presentation of his translation and classification of Western philosophical terms, he gave this lecture at a tiny private school, and therefore these ideas did not receive wide exposure and did not led many people to adopt the terminology of *Hyakugaku renkan*. In fact, Nishi himself did not adhere to this word in later works. In *Seisei hatsuun,* published in 1873,[25] Nishi translated

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23. Ibid., 14.

24. Nishi Amane, "Hyakugaku renkan," 15-16. See also: Koizumi Takashi, *Nishi Amane to ôbeishisô tono deai* (Tokyo: Mitsumine Shobô, 1989).

25. Nishi Amane, "Seisei hatsuun," in *Nishi Amane zenshû*, vol. 1, edited by Ôkubo Toshiaki (Tokyo: Munetaka Shobô, 1960), 29-158; It was a free translation of popular accounts of Western philosophy and Comtian positivism by George Henry Lewes: George Henry Lewes, *Comte's Philosophy of the Sciences: Being an Exposition of the Principles of the Cours de Philosophie Positive of August Comte* (London: H. G. Bohn, 1853); George Henry Lewes, *The*

"theory" as *risetsu* (*ri* means "principle" and *setsu* "argument" or "discussion"). He did use *riron*, the contemporary term for "theory," but here it meant "hypothesis." In addition, he used *kansatsu* for both "contemplation" and "observation," the latter being today's standard meaning of *kansatsu*.[26]

These works by Nishi indicate the extent to which he relied on Chinese philosophical concepts in his effort to introduce Western ideas as well as the subsequent confusion that it caused. *Seisei* of *Seisei hatsuun* came from a work by Mencius, roughly meaning "psychology" or "epistemology" (or at least Nishi understood so). The concept of *ri* in *rirsetsu* occupied a central place in Chinese philosophy. Nishi discussed this notion at length in his "Shôhaku tôki," an unpublished manuscript. According to Nishi, *ri* appeared in two ways in European languages, reflecting subjective and objective sides of its meaning. First, *ri* corresponded to "reason," the human ability to make judgment, which belonged to the subject. Second, it meant "principle," which belonged to the object.[27] Based on this understanding of *ri* in Chinese philosophy, Nishi used the word *risetsu* as the equivalent for "theory."

Even if Nishi's words for "theory" were not widely received, there persisted exactly the same concern over the tension between "theory" and "practice" that Nishi had formulated. Nishi himself returned to his distinction between "theory" and "practice" in his article, "Ronri shinsetsu"("A New Account of Theory"), published in 1884. There, he distinguished the use of logic in two ways: theoretical

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Biographical History of Philosophy from Its Origin in Greece Down to the Present Day (London: John W. Parker, 1857).

26. Nishi Amane, "Seisei hatsuun," 84, 85, 125, 127.

27. Nishi Amane, "Shôhaku tôki," in *Nishi Amane zenshû*, vol. 1, edited by Ôkubo Toshiaki (Tokyo: Munetaka Shobô, 1960), 167-70.

("to clarify *ri*") and practical ("to discuss actions").[28] This tension of between "pure" research and application repeatedly appeared in the discussion about how to introduce Western sciences.

While Japanese intellectuals were working on the translation of Western philosophical and scientific terms in the 1870s, Meiji bureaucrats were building new Western-style educational institutions, which naturally required new curricula and new terminology. A series of imperial ordinances and other governmental regulations defined the new school system. These regulations demonstrate the process of introducing and promulgating Western concepts into Japan and also reveal what I call the "institutional semantics" of those concepts.

In 1873, the Meiji government founded Kaisei Gakkô, a predecessor of Tokyo University.[29] The second annual report of Kaisei Gakkô carried the curriculum of the school, and there "theory" had three different Japanese

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28. Nishi Amane, "Ronri shinsetsu," in *Nishi Amane zenshû*, vol. 1, edited by Ôkubo Toshiaki (Tokyo: Munetaka Shobô, 1960), 575.

29. The name of this university has a very complex history of its own. Kaisei Gakko, founded in 1873 was renamed as Tokyo Kaisei Gakkô in the next year. It merged with Tokyo Igakkô (Tokyo Medical School) in 1886, and became Tokyo Daigaku (Tokyo University or the University of Tokyo). Teikoku Daigaku (Imperial University) was founded in 1886 by integrating Tokyo Hô Gakkô (Tokyo Law School) in 1885 and Kôbu Daigakko (University of Engineering). In 1897, when a university was founded in Kyoto, it was again renamed as Tokyo Teikoku Daigaku (Tokyo Imperial University or the Imperial University of Tokyo). After the war, in 1947, "Imperial" was omitted. Currently the official name is "the University of Tokyo." For the sake of brevity, I call it "Tokyo University" or "Tôdai," regardless of what it was called at a given time. Similarly, I generally omit the pompous "Imperial" when I refer to other imperial universities (e.g., I use Kyoto University for *Kyoto Teikoku Daigaku*, instead of Kyoto Imperial University), unless their very pompousness is relevant. For more details about the history of Tokyo University, see: Nakayama Shigeru, *Teikoku daigaku no tanjô* (Tokyo: Chûô Kôronsha, 1978).

equivalents: *ronri,*[30] *riron,* and *risetsu*. For example, "theoretical and applied mechanics" was *jûgaku ronri oyobi ôyô* (*jûgaku* meant "mechanics" and *ôyô* "application").[31] In different places in the same report, however, they used expressions like *jûgaku riron* (theory of mechanics) and *tenmon riron* (theory of astronomy).[32] In addition, the Department of History translated "theory of history" as *shigaku riron,* with *shigaku* meaning "history."[33] In one instance, *ronri* was explicitly written as the Japanese equivalent for "logic."[34] The Department of Law used the word *risetsu* for "theory." For example, the subject "law and theory of evidence" was *shôko, hô oyobi risetsu* (*shôko* means evidence, *hô*, "law," and *oyobi*, "and").[35] Tokyo Igakkô (Tokyo Medical School), the antecedent of the Faculty of Medicine of Tokyo University, translated "theory of anatomy" as *kaibô riron* (*kaibô* means "anatomy") in 1874.[36] This confusion continued for a few years, but in the late 1870s, the word *riron* seemed to have acquired the status of the standard equivalent of "theory."

The Department of Mathematics, Physics, and Astronomy did not have any courses referring to "theoretical physics" or "experimental physics." In 1881,

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30. The world *ronri* consists of the same two Chinese characters as in *riron* but in the reverse order.

31. *Tokyo Kaisei Gakkô daini nenpô*, vol. 1 of *Tokyo Daigaku Nenpô*, edited by Tokyo Daigaku Shi Shiryô Kenkyûkai, reprint, 1874 (Tokyo: Tokyo Daigaku Shuppankai, 1993), 6-21; *Tokyo Teikoku Daigaku gojûnenshi* (Tokyo: Tokyo Teikoku Daigaku, 1932), 301.

32. *Kaisei Gakkô daini nenpô*, 9.

33. *Gojûnenshi*, 311.

34. *Kaisei Gakkô daini nenpô*, 11.

35. Ibid., 12.

36. *Gojûnenshi*, 377.

however, when the Department split into three separate departments of the respective disciplines, there was a course in the Department of Astronomy entitled *seigaku riron oyobi jikken* ("astronomy: theory and experiment").[37]

English-Japanese dictionaries of the mid-1880s indicate that the Japanese word, *riron* had stuck by that time as one of the terms for "theory." All of the dictionaries included *riron* as one of the Japanese words for "theory," even though it did not appear in any of earlier dictionarie; other terms included "ron, riron, setsu, kôsatsu" (argument, theory, thesis, reflection),[38] "suiri, setsu, hôhô, riron, gaku" (speculation, thesis, method, theory, science),[39] "hito no suiryô no setsu, gaku, setsu, riron" (a theory that a person surmises, learning, thesis, theory).[40] I have already mentioned, "ron," "setsu," "gaku," "suiri," and "hôhô" ; "kôsatsu" is usually used for "reflection," "discussion," or "consideration."

Although *riron* did not (and does not) enjoy the status of the sole equivalent to "theory," in scientific or academic contexts, this word overwhelmed other possible translations for "theory." For example, in *Tetsugaku jii* (Vocabulary of Philosophy) written by Inoue Tetsujirô, a professor of philosophy at Tokyo University in 1881, the word "theory" had a single translation, *riron*.[41] Similarly, in

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37. Ibid., 618.

38. Simpachi Sekey, *English and Japanese Dictionary for the Use of Junior Students* (Tokyo: Rikugôkan, 1884).

39. Ichirô Tanahashi, trans., *English and Japanese Dictionary of the English Language by P. Austin Nuttall*, reprint, 1885 (Tokyo: Yumani Shobô, 1995).

40. J. C. Hepburn, *Japanese and English Dictionary: With an English and Japanese Index*, 7th ed. (Tokyo: Maruzen, 1903), 940.

41. Inoue Tetsujirô, ed., *Tetsugaku jii* (Tokyo: Tokyo Daigaku Sangakubu, 1881). This was a translation of the following book: William Fleming, *The Vocabulary of Philosophy, Mental, Moral, and Metaphysical; with Quotations and References; for the Use of Students* (London: Griffin, 1857).

1888, when Yamagawa Kenjirô and other physicists published a dictionary of terms in physics, "theoretical physics" received today's standard Japanese term, *riron butsurigaku*.[42]

How, then, did Japanese scholars understand *riron* and *riron butsurigaku*? During the period right after the Meiji Restoration, Japanese intellectuals redefined the word *riron* as a Japanese word for "theory." The redefinition of *riron* in the 1880s laid a stronger emphasis on *ri.*[43] In the new usage, *riron* meant "discussion of principles" rather than just "discussion." We have already seen in Nishi, who wrote on *ri* on a couple of occasions, how Japanese intellectuals were concerned with this concept in relation to the introduction of Western learning.

A similar concern was held by another of the most important cultural figures in Meiji Japan, Fukuzawa Yukichi.[44] He, too, used the term, *riron,* but as the equivalent to a different European term. In his well-circulated book, *Bunmeiron no gairyaku* (Outline of a Theory of Civilization) published in 1875, *riron* appeared as one of his key concepts. Curiously, though, he used this word not as the equivalent to "theory." Here, *riron* meant "philosophy." By "philosophy," Fukuzawa referred to something formless, abstract, and pure, in contrast to things more concrete and tangible such as politics and history. More specifically, Fukuzawa contrasted political philosophy and real politics or the

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42. Morioka Kenji, ed., *Meijiki senmon jutsugo shû*, reprint, 1888 (Tokyo: Yûseido, 1985).

43. See Footnote 7 above.

44. Fukuzawa Yukichi (1837-1901) was an influential educator and writer in the Meiji Era. He played an essential role in introducing Western ideas into Japan through his numerous writings. There are numerous studies on him. For an introductory biography of Fukuzawa in English, see: Carmen Blacker, *The Japanese Enlightenment: A Study of the Writings of Fukuzawa Yukichi* (Cambridge: University Press, 1964).

history of politics. Fukuzawa claimed that one should distinguish actual political matters from philosophical principles, and criticized Confucianism for not being purely "theoretical," but mixing "theoretical" and "political" matters.[45]

Although Fukuzawa's *riron* did not stand for "theory," the dichotomy that he saw between *riron* and concrete matters bore a close parallel to the duality between "theory" and "practice" that Nishi had formulated. This dichotomy persisted. Meiji thinkers repeatedly warned against the tendency to adapt Western science and technology superficially just in terms of their utilities. Principal debaters in the controversy included Fukuzawa himself. As Maruyama Masao shows, Fukuzawa urged his readers to understand Western sciences as more than just useful knowledge.[46] By distinguishing the visible products of Western learning and their invisible "spirit" or philosophy, Fukuzawa stressed that it was essential to introduce the latter, which he called *riron*.

Policy makers in Japan's educational system must have even more acutely sensed such a concern about the relation between "theory" and "application.". In 1877, the government reorganized Tokyo Kaisei Gakkô into Tokyo Daigaku (Tokyo University). Among the founders of this first "university" in Japan, the tension between "theory"(*riron*) and "application"(*ôyô*) constituted the central issue, and the word *riron* became a key term in their education policies. In *Tokyo Daigaku Hô-Ri-Bun sangakubu dai-roku nenpô* (Tokyo University, Colleges of Law, Science, and Literature, the sixth annual report) published in 1878, Katô Hiroyuki, the president of the university, called for a balance between "theory and application" (*riron jitsuyô*):

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45. Fukuzawa Yukichi, *Bunmeiron no gairyaku* (Tokyo: Iwanami Shoten, 1995), 86-87,91-92.

46. Maruyama Masao, "Fukuzawa niokeru 'Jitsugaku' no tenkai," in *Maruyama Masao Shû*, vol. 3 (Tokyo: Iwanami Shoten, 1995).

> Some argue that since this school has assumed the name of "university," it should focus on advanced and specialized pure learning and train distinguished scholars, just as European universities do. Some insist that to the present Japanese, it would be better to give easy and useful knowledge. Both are unbalanced views. The former view neglects the current status of popular education in Japan. Even if we could train brilliant scholars, given the present situation of Japan, they could hardly make a living from their expertise. The latter view contradicts the original purpose of the university. Following it would preclude the possibility of developing advanced knowledge and inevitably make Japan unable to compete in sciences with other countries in the future. In sum, the former view overstresses theory (*riron*), and the latter, practice (*jitsuyô*).[47]

Since imperial ordinances outlined the structures and workings of universities, we can see in them how these laws institutionalized this duality between "theory" and "practice." The second article of the Imperial University Ordinance on March 1, 1886 stated:

> The imperial university is to consist of a graduate school and an undergraduate college. The graduate school is the place to pursue profound truths in arts and sciences, while the college is the place to teach theories (*riron*) and applications of arts and sciences.

This firmly inscribed the mission of the prewar Japanese university as a place to teach theories and applications, codifying the standard meaning of "theory" as the opposite of "application." It also invites us to interpret "profound truth" that people were supposed to pursue at the graduate school as another word for "theory."

Thus, by the 1880s, Japanese intellectuals had redefined the term *riron* to mean "theory," and reinstalled its connotation to the notion of *ri.* In the context of the rapid Westernization, this word *riron* had strong implications of philosophical

47. *Tokyo Daigaku Hô-Ri-Bun San Gakubu dairoku nenpô*, vol. 1 of *Tokyo Daigaku Nenpô*, edited by Tokyo Daigaku Shi Shiryô Kenkyûkai, reprint, 1877 (Tokyo: Tokyo Daigaku Shuppankai, 1993), 79-80.

thought, and was supposed to be antithetical to application and practical matters. The latter point will turn out particularly important. *Riron* was stipulated to be antithetical to practice, in opposition, or in resistance to the general tendency of rapid and shallow introduction of practical knowledge from the West. This general tendency could, however, penetrate the realm of *riron*, and potentially change its nature.

3. Theoretical Physics "in Theory"

We can now turn to what "theoretical physics" meant, in particular to physicists. First, I discuss what I call the "institutional semantics" of this "theoretical physics," in other words, how institutional structures "defined" its meaning. Second, I examine how Japanese physicists talked about "theoretical physics."

By incorporating words like "theoretical physics" into its institutional vocabulary, the university, with its very organization, contributed much to defining these words. An organizational structure inevitably involves taxonomy, through activities of setting boundaries, creating dichotomies, and building a hierarchy of its functions. These institutional definitions of "theory" constituted the official discourse of its meanings at these institutions (i.e., imperial universities and, later, other universities), which daily constrained people at the university, including physicists, to adopt certain standardized meanings of "theoretical physics."

We find the institutional usage of "theoretical physics" in two instances. I can clarify them by indicating what was different from "theoretical physics." First, the word "theoretical physics" meant something similar to, but distinct from, "applied mathematics." When the Meiji government implemented the chair system in 1893, the Ministry of Education did not authorize a chair for "theoretical physics."[48] Instead, it gave the College of Science at Tokyo University a "Chair of Applied Mathematics," which Kikuchi Dairoku, a Cambridge-educated mathematician, occupied. In 1896, Nagaoka Hantarô, an assistant professor of physics, who just came back from Europe, took that post. In 1901, the chair acquired a new name, "Chair of Theoretical Physics." The official request for this renaming stated the reason as follows: "Since applied mathematics is a part of theoretical physics, this change of name will hopefully broaden the scope of the chair."[49] This indicates that Nagaoka wanted to work on a part of "theoretical physics" not included in "applied mathematics." It symbolizes the uneasy relation between theoretical physics and mathematics. Physicists distinguished theoretical physics from applied mathematics, but the fact remained that the chair of "theoretical physics" was originally created for "applied mathematics."

Second, "theoretical physics" referred to a kind of physics in contradistinction to experimental physics. In 1901, Tokyo Imperial University divided the Department of Physics into the Department of Theoretical Physics and the Department of Experimental Physics. The reason was:

> The progress of physics can be complete only when theory and experiment complement each other . . . Although these two are mutually related and cannot be separated, because of recent achievements, the range of physics has become too broad for one person to conduct researches on the both of them and to produce good results. Hence, among physicists, there are those who are specialized in theory and those who in experiment. Similarly,

48. Unlike the German system, there was more than one chair for each scientific discipline (there were two physics chairs in 1893, for example). Chairs belonged to the college, not to the department, which grouped students, not faculty. I discuss the chair system later.

49. Tokyo Daigaku Hyakunenshi Henshû Iinkai, *Tokyo Daigaku Hyakunenshi, Shiryô II* (Tokyo: Tokyo Daigaku Shuppankai, 1985), 1215.

> if a student learns both of them, it is unavoidable that he cannot learn either of them sufficiently . . .[50]

These changes indicate that Tokyo University officially recognized "theoretical physics" as a distinct subject of study in 1901. Since physicists were working for these changes, the changes indicate that these physicists wanted theoretical physics to be a specialized field of study different from applied mathematics and experimental physics.

Now we need to turn to physicists and see what they conceived as theoretical physics. Nagaoka occupied the first post of theoretical physics and, due to his productivity and the quality of his work, he was the most influential physicist in Japan until the mid-1920s. One can see Nagaoka's view of theoretical physics in his short biography of Gustav Kirchhoff in 1893. Nagaoka described Kirchhoff as a master of "mathematical physics" (*sûri butsurigaku*), whose goal was to mathematically describe "phenomena" (*genshô* in Nagaoka's word, or *die in Natur vor sich gehenden Bewegugen* in Kirchhoff's words quoted by Nagaoka). Nagaoka, however, turned to Maxwell and Boltzmann, and praised their atomistic approaches over Kirchhoff's what we now might call phenomenological works. As Nagaoka's biographers infer, mathematical description of phenomena did not satisfy him. He acknowledged the necessity of pursuing the entities behind phenomena, such as atoms and molecules.[51] In other words, while Nagaoka identified two distinct approaches (one, a mathematical and phenomenological approach represented by Kirchhoff, and the other, an approach represented by Boltzmann that emphasized building physical models, such as the atom), his

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50. *Gojûnenshi*, 444-45.

51. Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô den* (Tokyo: Asahi Shimbunsha, 1973), 146-47.

preference was for the physical approach. He wanted to pursue a kind of physics that would treat phenomena mathematically, but with physical models.

Tamaki Kajûrô, a professor at Kyoto University, stated physics' relation to mathematics more explicitly. He wrote a widely used textbook of theoretical physics, entitled, of course, *Riron butsurigaku.* Since Tomonaga Sin-itiro, an advisee of Tamaki, later wrote that it was "the most convenient for students' use at that time,"[52] it must have been fairly well-circulated. In the first edition of this book published in 1918, Tamaki wrote:

> Needless to say, physics should be based on facts acquired from experimental works. However, I would not be satisfied with relying merely on experiments, discovering facts, and listing them up. It is extremely important to organize many facts, find truths behind them, and thereby to conjecture more new facts. In order to achieve such goals, it is very advantageous to use mathematics.[53]

In the third edition of this book published in 1926, Tamaki was more emphatic in clarifying the relation between mathematics and theoretical physics:

> It is extremely important to organize the many and complex new facts that experiments provide, to grasp the truth among them, infer new facts on the basis of the known truth, and to give guidance to experiments. These are the goals of theoretical physics. We use mathematics to achieve these goals of theoretical physics. Yet, mathematics in this case is just like a variety of tools that an architect uses to build a palace, not the palace itself.[54]

52. Tomonaga Sin-itiro, "Tamaki sensei no tsuioku," in *Scientific papers of Tomonaga, vol. 2*, edited by Tatsuoki Miyazima (Tokyo: Misuzu Shobô, 1976), 472.

53. Kajûrô Tamaki, *Riron butsurigaku dai ikkan: Shitsuten oyobi gôtai no rikigaku*, 1st ed. (Tokyo: Uchida Rôkakuho, 1918), 1-2.

54. Tamaki Kajûrô, *Riron butsurigaku dai ikkan: Shitsuten oyobi gôtai no rikigaku*, 3rd ed. (Tokyo: Uchida Rôkakuho, 1926), 1. Tamaki had already made a similar point in 1918: "Needless to say, physics should be based on facts acquired from experimental works. However, I would not be satisfied with relying merely

Aichi Keiichi, whom I shall present as the quintessential Japanese "theoretical physicist," gave more credit to mathematics, but similarly viewed it as a tool of physics. In his *Shizen no bi to megumi* (Beauty and Grace of Nature), a collection of popular and aesthetic accounts of science, Aichi wrote:

> In this kind of research, we first set up a hypothesis. Of course we don't know what is really the case, and some may not agree with that hypothesis. In any case, we carry on calculations based on the hypothesis. Since the results of calculations are unambiguous, they immediately decide whether the hypothesis is correct or not. Then, it is difficult to contradict the conclusions of calculations. If the matter is too ambiguous to express in a mathematical form, an opinion cannot be very persuasive, nor objections to it. Therefore, in physics mathematics is essential. It is just as one needs rulers and saws to build a house.[55]

In sum, the meaning of "theoretical physics" prescribed by the institutional semantics and physicists' normative writings (such as textbooks) concurred with the meaning of "theory" implied by early Meiji intellectuals. Japanese physicists perceived "theoretical physics" as being different from mathematical physics. Theoretical physics was about the physical reality behind phenomena, or about the truth, and mathematics was just a tool for calculating it.

4. "Theoretical Physics" According to Aichi Keiichi

What Japanese "theoretical physicists" actually did as "theoretical physics," however, deviated from what they thought they should do. In their works, one

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on experiments, discovering facts, and listing up facts. It is extremely important to organized many facts, find truths behind them, and thereby conjecture new facts. In order to achieve such goals, it is very advantageous to use mathematics." Tamaki, *Riron butsurigaku*, 1-2.

55. Aichi Keiichi, *Shizen no bi to megumi* (Tokyo: Maruzen, 1918), 76.

finds the use of advanced mathematics and meticulous calculations more often than the discovery of "truths" behind phenomena or "profound principles" in nature. This meaning of "theoretical physics" was embedded in what I call the "culture of calculating."

Theoretical physics in 1920s Japan is often represented by two figures: Ishiwara Jun and Nagaoka Hantarô. Among Japanese physicists, Ishiwara most closely followed the development of relativity and quantum theory in Europe. He produced many works in these fields. As I discuss below, well-known European physicists quoted some of these works. Nagaoka Hantarô allegedly produced the first important theoretical work among Japanese physicists, namely his Saturnian model of the atom. He inaugurated the Chair of Theoretical Physics at Tokyo University. I argue, however, that the impression that these two physicists gave us about the situation of physics in 1920s Japan is misleading. For different reasons, neither of them provides a useful case for studying what "theoretical physics" was like in Japan in 1920s Japan.

Ishiwara Jun was born in 1881, and graduated from the Department of Theoretical Physics of Tokyo University in July 1906.[56] From 1909 to 1918, he produced more than 40 papers on special and general relativity theory, quantum theory, and the theory of specific heat.[57] His works on relativity theory included

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56. Tetsu Hirosige, "Ishiwara, Jun," in *Dictionary of Scientific Biography*, vol. 4, edited by Charles Gillispie (New York: Scribner, 1974). For studies on Ishiwara's life written in Japanese, see: Yajima Suketoshi and Nisio Sigeko, "Tenbô: Ishiwara Jun seitan 100-nen," *Kagakushi Kenkyû, Series II* 20 (1981): 129-35; Sugai Jun'ichi, "Ishiwara Jun: Toku ni sono Nihon kagakushi jô no chii," *Kagaku* 11 (1947): 96-99; Hirokawa Shunsuke, "Ishiwara Jun: Sono butsurigaku kenkyû wo chûshin ni," *Kagaku* 50 (1980): 768-74. On Ishiwara's quantum condition, see: Ogawa Tsuyoshi and Arakawa Hiroshi, "Zenki ryôshiron ni okeru Ishiwara no ryôshi jôken," *Butsurigakushi Kenkyû* 6 (1970): 80-85.

the derivation of energy-momentum tensor through the principle of the least action and a generalization of the constancy of the speed of light.[58] Ishiwara worked on the quantum theory of light quanta in the 1910s, when many physicists were still resisting this theory of Einstein's. Some historians regard Ishiwara's 1912 paper[59] as the origin of "light molecule theory," which, they claim, eventually led to Louis de Broglie's matter wave.[60] In his 1911 paper,[61] Ishiwara attempted to develop a theory of specific heat by modifying Einstein's theory. This turned out to be a failure, but the theory was still impressive, as noted by a Japanese historian, Nisio Shigeko.[62] Among his works, the paper on the quantization condition became probably the best known,[63] because Arnold Sommerfeld cited it in his important paper on line spectra.[64] His presence was particularly visible overseas, because he

57. Sigeko Nisio, "The Transmission of Einstein's Work to Japan," *Japanese Studies in the History of Science*, no. 18 (1979): 6.

58. Jun Ishiwara, "Über das Prinzip der kleinsten Wirkung in der Elektrodynamik bewegter ponderabler Körper," *Annalen der Physik, 3rd Series* 42 (1913): 986-100; Jun Ishiwara, "Univerlseller Bedeutung des Wikrkungsquantens," *Proceedings of the Physico-Mathematical Society in Japan, Series III* 8 (1915): 106-16.

59. Jun Ishiwara, "Das Photochemische Gesetz und die Moleküle Theorie der Strahlung," *Physikalische Zeitschrift* 13 (1912): 1142-51; Ishiwara, "Photochemische Gesetz."

60. Silvio Bergia, Carlo Ferrario, and Vittorio Monzoni, "Side Paths in the History of Physics: The Idea of Light Molecule from Ishiwara to de Broglie," *Rivista Di Storia Della Scienza* 2 (1985): 71-97.

61. Jun Ishiwara, "Beiträge zur Theorie der Lichtquanten," *Science Reports of the Tôhoku University, Series I* 1 (1911-12): 67-104.

62. Nisio, "The Transmission of Einstein's Work," 8.

63. Ishiwara, "Universeller Bedeutung des Wirkungsquantens," 106-16.

64. Arnold Sommerfeld, "Zur Quantentheorie der Spektrallinien," *Annalen der Physik* 51 (1916): 10.

published many papers in well-circulated German journals.

However, the apex of Ishiwara's scientific activities occurred in the 1910s. In 1921, his scientific career was suddenly terminated, when he resigned the professorship after his extramarital love affair became public.[65] After that time, Ishiwara could only contribute to Japanese physics through scientific journalism (See Chapter 7), and he never recovered an academic position. Ishiwara's retirement nipped off the possibility for a theoretical physics tradition that he might have created. No one took up what Ishiwara left unfinished.[66] We should, therefore, regard Ishiwara as a singular figure, rather than a mainstream "theoretical physicist" in 1920s Japan. Hence, we cannot use him as a representative of Japanese"theoretical physicists."

Another physicist under consideration, Nagaoka Hantarô, exerted the greatest academic and political influence over the Japanese physics community until the late 1920s. He occupied the chair of theoretical physics until he retired from Tokyo University in 1927. He taught virtually all of the theoretical physicists trained in Japan until that time (except for those who graduated from Kyoto University and Tôhoku University). He produced far more works than any other Japanese physicist at that time.[67] In particular, his work on the Saturnian atomic

65. The 40-year-old Ishiwara fell madly in love with a beautiful poetess, Hara Asao, and decided to leave his wife and children. See: Ôhara Tomie, *Hara Asao* (Tokyo: Kôdansha, 1996); Murayama Iwao and Nishida Kôzô, eds., *Ishiwara Jun to Hara Asao: Koino tenmatsu* (Kesennuma: Kôfûsha, 1997); Ono Katsumi, *Ruikon: Hara Asao no shôgai* (Tokyo: Shigei Shuppansha, 1995). There is an anthology of Hara's poems: Hara Asao, *Jojô kashû* (Tokyo: Heibonsha, 1929).

66. This contrasts with the case of Aichi Keiichi. His career was terminated by his death two years after Ishiwara's retirement, but he had a disciple who considered Aichi as a mainstream figure.

67. Eri Yagi, "Nagaoka, Hantaro," in *Dictionary of Scientific Biography*, vol. 9,

model was considered an important contribution to theoretical physics. Published in 1904, Nagaoka's theory proposed to treat the atomic nucleus and its electrons as analogous to Saturn and its ring. In this paper, Nagaoka discussed the stability of the electron in this model and tried to link the model with spectroscopic data.[68]

Yet, there is a practical reason for why he should not be chosen as a representative of "theoretical physics" in Japan. His research areas included experimental subjects such as spectroscopy. Nagaoka was not only concerned with theoretical accounts of spectroscopic data; he himself carried out spectroscopicl observations. Therefore, Nagaoka does not make an appropriate case with which to investigate "theoretical physics" in Japan.

Instead of Nagaoka and Ishiwara, I shall tentatively choose Aichi Keiichi as a typical theoretical physicist.[69] First, we can safely regard him as a "theoretical physicist" in the local sense. I do not have a convenient formula for the question of who counted as "theoretical physicist" at that time. Yet, there are two natural places to look for a theoretical physicist:

1) Those who held academic positions explicitly dedicated to theoretical physics

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edited by Charles Gillispie (New York: Scribner, 1974), 29-41; Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô Den*.

68. Hantarô Nagaoka, "Motion of Particles in an Ideal Atom Illustrating the Line and Band Spectra and the Phenomena of Radioactivity," *The Proceedings of the Physico-Mathematical Society of Japan, Series II* 2 (1904): 92-107; Hantarô Nagaoka, "On a Dynamical System Illustrating the Spectrum Lines and the Phenomena of Radioactivity," *Nature* 69 (1904): 392-93. The model was first presented at the Physico-Mathematical Society meeting in 1903. For studies on this work, see: Eri Yagi, "On Nagaoka's Saturnian Atomic Model (1903)," *Japanese Studies in the History of Science*, no. 3 (1968): 29-47.

69. By "a typical theoretical physicist," I do not mean an average theoretical physicist, but a physicist, whose works we can use to illustrate the trends of "theoretical physics" in Japan.

2) The graduates of the Department of Theoretical Physics at Tokyo University

The only position explicitly named "theoretical physics" existed at Tokyo University. Kyoto and Tôhoku just had chairs titled "Physics One," "Physics Two," and so on.[70] As mentioned above, the first chair of theoretical physics was inaugurated in 1901, occupied by Nagaoka Hantarô. The chair of "Theoretical Physics Two" was added in 1907, and Tamaru Takurô was in charge of it.

The Department of Theoretical Physics at Tokyo University existed from 1903 to 1919, and produced 57 graduates.[71] Obviously, not all of them pursued academic career. We can, however, expect that at least those who became physicists probably became "theoretical physicists," unless they decided to change their careers. In the 1920s, three imperial universities had a department of physics: Tokyo, Kyoto, and Tôhoku. In addition, the College of Engineering at Kyûshû University had a position for a physicist (the Chair of Applied Mechanics). Among the graduates of the Department of Theoretical Physics, the following physicists gained a full or associate professorship at one of the four imperial universities:[72]

Aichi Keiichi (1903, Tôhoku)[73]

Ishiwara Jun (1906, Tôhoku)

Terazawa Kwan-iti (1908, Tokyo)

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70. Those numbers were simply intended to designate different chairs, and there was no (formal) hierarchy among them.

71. *Tokyo Daigaku sotsugyôsei shimeiroku* (Tokyo: Tokyo Daigaku, 1950), 552-53.

72. This list may not be complete, but it serves our purpose here.

73. The first number is the year of graduation. Tokyo, Kyoto, Tôhoku indicate the location of the university where these physicists obtained a job in the 1920s.

Fujiwara Sakuhei (1909, Tokyo)

Kobayashi Iwao (1910, Tôhoku)

Takahashi Yutaka (1915, Tôhoku)

Okaya Tokiharu (1916, Kyoto)

Sakai Sukeaki (1919, Tokyo)

Adding the two professors of theoretical physics (Nagaoka and Tamaru), there are then ten candidates for a representative "theoretical physicist."

Aichi produced a significant amount of work. A more productive physicist is likely to exert more influence upon other physicists, and is more likely to define the mainstream of the research tradition. In addition, for the purpose of analysis, we need a significant amount of works to examine.

The Japanese Journal of Physics, published since 1922, included abstracts of papers in physics published within Japan. I have counted the number of publications for each of the above ten "theoretical physicists" in these abstracts for the years 1922 through 1927, when when Japanese physicists began introducing quantum mechanics. The numbers for the physicists are as follows:

Nagaoka, Hantarô 53

Tamaru, Takurô 3

Aichi, Keiichi 12

Terazawa, Kan'ichi..2

Takahashi, Yutaka 7

Okaya, Tokiharu 3

Sakai, Sukeaki 2

Others...0

Nagaoka produced more papers than anyone else. However, as I discussed above, I did not choose to study Nagaoka's papers because they are mostly observational. (Indeed, of the 52 papers, more than 30 of them were reports of spectroscopic measurements.) Besides Nagaoka, Aichi Keiichi[74] produced largest number of works. In fact, when one looks at the previous five years, Aichi appears an even more dominant figure. He had published more than 20 papers during that period in the *Proceedings of the Physico-Mathematical Society* (hereafter, *Kizi*, following what people used to call this journal in Japan). Therefore, it makes sense to use his works in order to examine what "theoretical physics" meant in Japan at that time.[75]

Aichi Keiichi was born in Tokyo in 1880, as a son of Aichi Nobumoto.[76] Nobumoto taught mathematics at Gakushûin, the Peers' College, a school for children from the newly created Japanese aristocracy. Nobumoto's writings included textbooks on calculation and bookkeeping. In his *Hissan kyôju shidai*, a textbook on calculation using Western mathematical notation, Nobumoto introduced Arabic numerals, explaining how to translate Japanese numerals into them and how to calculate with these numerals. Starting with addition, subtraction, multiplication, and division, he moved on to more advanced calculations, such as fractions and ratios. At the end of the third volume, he included a set of two

74. Pronounced "eye-chi."

75. For Aichi's list of publications, see the appendix.

76. *Dai jinmei jiten* (Tokyo: Heibonsha, 1953-55); Sächsischen Akademie der Wissenschaften zu Leipzig, ed., *1904 Bis 1922*, vol. V of *J. C. Poggendorffs Biographisch-Literarisches Handwörterbuch Für Mathematik, Astronomie, Physik, Chemie und Verwandte Wissenschaftsgebiete* (Leipzig: Verlag Chemie, 1926), 12.

hundred calculation problems.[77]

Very likely, Nobumoto educated Keiichi with his own textbooks and drilled him in such mathematical problems and calculations. Indeed, Keiichi excelled in mathematics even in his higher school days.[78] When Nobumoto was stuck with a problem, he would ask his son for his help.[79] Aichi Keiichi graduated from the Department of Theoretical Physics at Tokyo University in July 1903, apparently with excellent grades.[80] In the next year, he gained a position at Kyoto Imperial University as an associate professor (*jokyôju*). In 1907, backed by Nagaoka, Aichi was chosen as one of the professors for a new national university for scientific research in Sendai, Tôhoku University.[81] To prepare him for the job, the Ministry of Education sent Aichi and other prospective faculty members to study in Europe. After Aichi returned to Japan in 1911, he worked at Tôhoku University, until he died of heart failure on June 20, 1923 at the age of 42,[82] first occupying the Third Physics Chair and then the Chair of Applied Dynamic after 1919.[83]

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77. Aichi Nobumoto and Ôhira Toshiaki, *Hissan kyôju shidai* (Kumagaya: Chôki Gakkô, 1876).

78. A higher school was an institution of higher education in prewar Japan. It was a three-year liberal arts college that provided preliminary education for those who planned to enter a university. See Chapter 3.

79. Aichi Kiichi, *Mirai karano yobikakeni kotaete* (Tokyo: Fumaidô Shoten, 1967), 5.

80. In the directories of alumni of Tokyo University, names are in the order of grades. Aichi's name was listed at the top of the department.

81. Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô Den*, 324.

82. Aichi Kiichi, *Mirai*, 14.

83. *Tôhoku Daigaku gojûnenshi* (Sendai: Tôhoku Daigaku, 1960), vol. 1, p. 547.

Throughout his life, Aichi published 38 papers in *Kizi*, which constituted most of his works. By studying Aichi's papers, I claim that Aichi's works were highly mathematical. By "being mathematical," I mean the following:

1. Aichi did not have a particular physical problem or a particular physical subject as his specialty.

2. Aichi was interested in developing mathematical tools and applying them to a wide range of problems.

3. Aichi lacked interest in the physical aspects of problems, as compared with other physicists.

4. Aichi was inclined to meticulous calculations.

5. Aichi produced papers by making physical conditions (and the mathematics of the problem) more complicated while applying the same physical principle.

6. Aichi often cited works of mathematicians, or the mathematical works of physicists.

First, Aichi did not have a particular physical problem or a particular physical subject as his specialty. That is clear from the diversity of subjects on which Aichi wrote papers in *Kizi.* The heat theory (conduction and distribution of heat) was his favorite topic, on which he wrote 14 papers. After he became the Chair of Applied Dynamics, he wrote extensively on applied dynamics, with eight papers on this subject. Other subjects included: optics, electromagnetism, acoustics, fluid dynamics, seismology, and applied mathematics. Such a wide range of research was possible because what interested Aichi was mathematical techniques, rather than a particular physical problem or subject.

Second, Aichi was interested in developing mathematical tools and applying them to a wide range of problems. In a paper entitled, "Note on Vibrations of a Liquid Contained in a Cylindrical Vessel," Aichi used Rayleigh's calculation of the vibration of a membrane in a circular or nearly circular boundary to address the problem described in the title.[84] Rayleigh's calculation appeared in his *Theory of Sound*, and Rayleigh carried out this calculation to understand the behavior of a percussion instrument. Aichi developed and used a similar mathematical technique for a problem that was mathematically close but physically completely different.

Similarly, although the title of his paper, "Scattering of Electromagnetic Waves by a Small Elliptic Cylinder," addressed a particular physical problem, solving a mathematical problem involved with an elliptic cylinder occupied most of the paper.[85] According to Aichi, "to obtain complete solutions for various problems concerning an elliptic cylinder is usually very difficult, owing to the circumstance that the theory of elliptic-cylindrical functions is now very obscure." However, he continued, " in some special cases, elliptic cylindrical functions become manageable." Then, Aichi showed his mathematical adeptness in his discussions of these "manageable" elliptic cylindrical functions. Once he solved difficult and complicated mathematical problems, Aichi could apply the results to the actual physical problem of the scattering of electromagnetic waves much more smoothly. The mathematical part constituted the essence of the paper, and the physical part just served as an application.

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84. Keiichi Aichi, "Note on Vibrations of a Liquid Contained in a Cylindrical Vessel," *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4 (1907-08): 220-27.

85. Keiichi Aichi, "Scattering of Electromagnetic Waves by a Small Elliptic

Aichi's textbook, *Riron butsurigaku* (Theoretical Physics), posthumously published in 1924, epitomized what counted as "theoretical physics" for him. This book consisted of seven parts: mechanics, fluid dynamics, acoustics, conduction of heat, thermodynamics, mechanics of elastic bodies, and theory of potentials.[86] The last part was the most characteristic of Aichi. This chapter contained a general and highly mathematical theory of potentials applicable to any system with an inverse-square force.

Compared with other physicists, Aichi was less interested in the physical aspects of problems. To support this point, I turn to Aichi's work on underground heat.[87] Aichi received inspiration for this work from a paper by William Thomson. In this paper, Thomson tried to calculate the conductivity of underground heat from annual variations of temperature at various depths. Thomson started from what he called "Fourier's solution." According to "Fourier's solution," in an ideal condition, the phase difference of the heat variation equaled the diminution of the logarithm of the amplitude. This amount per unit of distance equaled a constant depending on the conductivity of heat, the period of the wave, and the specific heat of the substance per unit of volume. Using observational data, Aichi calculated this constant in two ways (from the amplitude and the phase), compared the results, considered physical causes of different values, modified the data on this consideration, and concluded with the most probable value for the conductivity of

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Cylinder," *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4 (1907-08): 266-78.

86. Aichi Keiichi, *Riron butsurigaku* (Tokyo: Shôkabô, 1924).

87. Keiichi Aichi, "On the New Method of Reduction of Observations of Underground Temperature," *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1 (1919): 2-7.

heat.[88]

Aichi's approach to the problem differed considerably. He started immediately from the equation of heat conduction and derived formulae to calculate from observed data the constants in the solutions of the equation. The whole process consisted of a series of mathematical procedures, leaving little room for physical discussion.

More striking is Aichi's apparent lack of interest in the geological and cosmological implications of Thomson's paper. The above mentioned paper by Thomson was the basis of his next, and much more famous, paper, "On the Secular Cooling of the Earth," in which the conductivity of the underground heat played an essential role.[89] Aichi, apparently free of any cosmological, theological, or political commitments here, was interested in the mathematical inaccuracy of Thomson's paper, which Aichi criticized.[90]

Aichi was inclined to meticulous calculations. The work that Aichi conducted with Tanakadate, published right after their graduation, indicated well his skill in, and tendency toward, meticulous calculations. In Maxwell's kinetic

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88. William Thomson, "On the Reduction of Observations of Underground Temperature; with Application to Professor Forbes' Edinburgh Observations, and the Continued Calton Hill Series," in *Mathematical and Physical Papers, by Sir William Thomson: Collection from Different Scientific Periodicals from May, 1841 to the Present*, vol. 3 (Cambridge: University Press, 1890), 261-94.

89. William Thomson, "On the Secular Cooling of the Earth," in *Mathematical and Physical Papers, by Sir William Thomson: Collection from Different Scientific Periodicals from May, 1841 to the Present*, vol. 3 (Cambridge: University Press, 1890), 295-311. See also: Crosbie Smith and M. Norton Wise, *Energy & Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989).

90. Aichi, "On the New Method of Reduction of Observations of Underground Temperature," 7.

theory of gases, for example, one must numerically evaluate two complicated integrals to calculate the viscosity of gases:[91]

$$A_1 = 4\sqrt{2}\pi\int_0^{\frac{\pi}{4}} \frac{\sin^2\theta}{\sin^2 2\phi} d\phi$$

$$A_2 = \sqrt{2}\pi\int_0^{\frac{\pi}{4}} \frac{\sin^2 2\theta}{\sin^2 2\phi} d\phi$$

$$\theta = \frac{\pi}{2} - \sqrt{\cos 2\phi}K(\sin\phi)$$

(K is the complete elliptic integral of the first kind with modulus sinφ)

Aichi and Tanakadate carried out calculations of these integrals by expanding the integrand into the power series. After a long (and tedious, according to Nagaoka, who reported the results of their work to *Nature*) calculation,[92] they reached slightly different values from those of Maxwell. Whereas Maxwell's values were:

$A_1 = 2.6512,$

$A_2 = 1.3682.$

Aichi and Tanakadate obtained:

$A_1 = 2.6595,$

$A_2 = 1.3704.$

This paper contained nothing more than this calculation. It shows Aichi's willingness to carry out lengthy calculations. Most of his other papers included

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91. Stephen G. Brush, "Development of the Kinetic Theory of Gases. VI. Viscosity," *American Journal of Physics* 30 (1962): 274.

92. Hantarô Nagaoka, "On Two Constants A1 and A2 in the Kinetic Theory of Gases," *Nature* 79 (1903): 79.

more than evaluations of integrals. Yet, they usually contained long calculations of various sorts.

Fifth, even when Aichi was working on a particular physical problem, his approach was to make physical conditions more complicated to get a result closer to empirical data. In other words, he kept physical principles unchanged, but solved more mathematically complicated problems. This aspect of Aichi's work appeared in his very first publication, a work on rainbows co-authored by Tanakadate Torashirô, a result of their graduation research under Nagaoka's supervision. They started with Airy's theory on rainbows, in which the source of the light is regarded as a point. Then they proposed that the source of light should be a disc, because the actual source (the sun) is not point-like. They carried out a lengthy calculation, both algebraic and numerical. By examining the table they produced, the authors confirmed that their theory gave a result closer to the actual observation of rainbows than Airy's theory.[93]

Finally, Aichi often cited works of mathematicians, or mathematical works of physicists. One of the authors Aichi cited most often was Rayleigh, both his famous *Theory of Sound* and papers from the *Scientific Papers*.[94] However, as we have seen above, Aichi's interest in Rayleigh's works was not particular physical theories, but the mathematical handling of physical problems. In later works, Aichi more often cited works of mathematicians, such as Émile Picard and Carl

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93. Keiichi Aichi and Torashirô Tanakadate, "Extension of Airy's Theory of Rainbow to That Due to a Circular Source," *Proceedings of the Physico-Mathematical Society in Japan, Series II* 2 (1903-05): 79-86. Also see: Saijô Satomi, *Niji: Sono bunka to kagaku* (Tokyo: Kôseishakôseikaku, 1999), especially Chapter 6, Section 8.

94. John William Strutt, *Scientific Papers by John William Strutt, Baron Rayleigh* (Cambridge: University Press, 1899-1920); John William Strutt, *Theory of Sound*, 2nd ed. (London: Macmillan, 1894-96).

Neumann. Picard was a leading mathematician in late nineteenth century France, who was known for a variety of works in analysis and algebraic geometry, including Picard's theorem in complex analysis. Carl Neumann, the son of Franz Neumann,[95] taught mathematics at Leipzig. Although he was principally a mathematician, he learned physics and played the role of intermediary between physics and mathematics, by producing mathematical works useful in physics, writing textbooks, and giving mathematical training to physicists.[96]

5. Other "Theoretical Physicists"

Saigusa Hikoo, a disciple and colleague of Aichi, who edited Aichi's textbook, reviewed it as being "in the mainstream of theoretical physics."[97] He was not exaggerating. Several other physicists at key Japanese research institutions shared some of the characteristics that we saw in Aichi's works in "theoretical physics."

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95. As for Franz Neumann, see: Kathryn M. Olesko, *Physics as a Calling: Discipline and Practice in the Konigsberg Seminar for Physics* (Ithaca: Cornell University Press, 1991).

96. For more about Carl Neumann, see: Christa Jungnickel and Russel McCormmach, *The Torch of Mathematics 1800-1870*, vol. 1 of *Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein* (Chicago: The University of Chicago Press, 1986), 181-85. In the same book, there is a comparison between Neumann and Boltzmann: "[Otto] Wiener explained to the Leipzig faculty that Boltzmann's work belonged to 'theoretical physics' rather than 'mathematical physics,' since it stressed 'physical content' and the 'connection with experimental physics.' Boltzmann did not treat mathematics as an end in itself, which was done by others, notably by Carl Neumann, at Leipzig." Christa Jungnickel and Russel McCormmach, *The Now Mighty Theoretical Physics, 1870*, vol. 2 of *Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein* (Chicago: The University of Chicago Press, 1986), 176.

97. Aichi Keiichi, *Riron butsurigaku*, 2.

At Tokyo University, Nagaoka stood out from other "theoretical physicists," although beginning in the 1920s he worked increasingly more in experimental fields. Nagaoka's earlier works on magnetostriction and optics contained highly mathematical aspects. His Saturnian model of the atom differed from Aichi's works, because it proposed a physical model, rather than mathematical calculation. Yet, in contrast to Ernest Rutherford's papers on the atom model, Nagaoka presented his works on this model as highly mathematical papers, discussing the stability of the ring composed of electrons.[98] One of Nagaoka's important works was his derivation of "Nagaoka coefficients" for inductance, on which he worked from 1903 to 1922. This was a table to calculate inductance for a solenoid coil of a finite length. It required intensive calculation, in which Nagaoka had to struggle with elliptic functions both analytically and numerically.[99]

Subsequent generations of theoretical physicists inclined toward mathematics even more strongly (with some exceptions, such as Ishiwara Jun). Other "theoretical physicists" at Tokyo University included Tamaru Takurô, Sano Shizuwo, Terazawa Kwan-iti. (Tamaru was the "Chair of Theoretical Physics II" begining in 1907 when this chair was inaugurated. Sano and Terazawa were graduates of the Department of Theoretical Physics.) I exclude Tamaru from consideration, because he produced so few papers, and I cannot consider him as a

98. Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô den*, 342. In the same book, the authors mention his lack of interest in modifying his theory in comparison with experimental data: Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô den*, 283. As for Nagaoka's Saturnian model, see also: Yagi, "Saturnian Atomic Model".

99. Nihon Butsuri Gakkai, *Nihon no butsurigaku shii* (Tokyo: Tokai Daigaku Shuppankai, 1978), 200-01.

research physicist. Sano and Terazawa, however, shared some aspects of Aichi's characteristics.

Sano Shizuwo was born in 1872 and graduated from the Department of Physics of the Tokyo University in 1896. He taught at his alma mater from 1907 to 1925, and died in 1926. A short biographical note in his posthumously published *Scientific Papers* described Sano as having had a "special aptitude for mathematical analysis involving harmonic functions" and:

> [He] was so much interested in it that, according to his own words, mathematical calculation was one of his after-dinner recreations.[100]

Students also rumored that Sano Shizuwo would not feel well when he had no chance to play with equations during the course of a day.[101] Indeed, Sano filled his papers with lengthy equations, some of which barely fit on one page, as if he were cherishing them. (Fig. 1. 1)

In addition, some of Sano's papers extended other scientists' work, by making the physical conditions of the problems a little more complex. For example, in a paper entitled "An Extension of Fontaine's Theory on the Heat of Vaporization of a Liquid Charged with Electricity," Sano dealt with the problem proposed and solved by Émile Fontaine about the heat of vaporization of a liquid charged with electricity on the surface of liquid and its vapor.[102] Whereas Fontaine assumed that

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100. Shizuwo Sano, *Scientific Papers* (Tokyo: Iwanami Shoten, 1926), vii.

101. Tsuboi Chûji, "Yayoichô kara Nishikatachô made," in *Kaisô Tokyo Daigaku Hyakunen*, edited by Ken'ichi Hayashi (Tokyo: Tokyo Daigaku Shuppankai, 1969), 138.

102. Émile Fontaine, "Influence de l'état électrique d'une surface liquide sur la chaleur de vaporisation de ce liquide," *Journal de physique theorique et appliquée* 4 (1897): 16-18.

the dielectric constant of the vapor was same as that of the vacuum, Sano made it different.[103] His other paper, "On the Electric Force at Any Point in a Liquid in Which the Process of Diffusion is Going On," was based on Walther Nernst's work on the electric potentials in a dilute solution of an electrolyte. Sano generalized Nernst's calculation to the case in which the solution was not necessarily dilute.[104] Sano, therefore, shared some of Aichi's characteristics (interest in mathematics and inclination toward meticulous calculation).

Sano, however, differed from Aichi in one respect: He had a specific physical problem as his research topic. He was interested in thermodynamics and the fluid dynamics of electromagnetic phenomena. Early papers discussed magnetostriction (from 1902 to 1904). After 1905, however, most of his papers focused on the intersections of electromagnetism and thermodynamics or electromagnetism and fluid dynamics, such as "On the Equilibrium of a Fluid with Its Vapour in a Magnetic Field," "Theory of Thermoelectricity," and "On Diffusion in an Electric Field."[105] This interest was a central concern among European theorists, such as Boltzmann and Planck. In fact, in his "Theory of Thermodynamics," Sano confessed that his theory was "a humble imitation of Boltzmann's" and a "mere reproduction of it on the principal points."[106]

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103. Shizuwo Sano, "An Extension of Fontaine's Theory on the Heat of Vaporization of a Liquid Charged with Electricity," in *Scientific Papers* (Tokyo: Iwanami Shoten, 1926), 70-72.

104. Shizuo Sano, "On the Electric Force at any Point in a Liquid in Which the Process of Diffusion is Going On," in *Scientific Papers* (Tokyo: Iwanami Shoten, 1924), 97-109.

105. Sano, *Scientific Papers*.

106. Shizuwo Sano, "Theory of Thermoelectricity," in *Scientific Papers* (Tokyo: Iwanami Shoten, 1924), 110-39, on p. 111. Boltzmann's paper in question is:

Terazawa Kwan-iti was born in 1882, and graduated from the Department of the Theoretical Physics in 1908. Then he inaugurated the Chair of Dynamics in the College of Engineering. Talented young physicists, such as Yamanouchi Takahiko, Kotani Masao, Inui Tetsurô, and Husimi Kôdi, gathered under him, forming a research group extraordinarily strong in mathematics. He also wrote a textbook on mathematics for physicists, read by most physics and engineering students in prewar Japan.

Terazawa's works in the 1910s and 1920s dealt with electromagnetism and fluid dynamics. His earliest research interest originated from one of Nagaoka's projects: calculation of inductance. Following Nagaoka, Terazawa calculated self and mutual inductance in various cases.[107] Unlike Nagaoka, Terazawa did not compile a table, but instead derived formulae "in a form convenient for practical use."[108] These works only required lengthy and/or clever calculation, starting from known physical principles of electromagnetism, and while the results would give little physical insight, they had a practical value as mathematical tools. Terazawa also conducted researches on hydrodynamic problems connected with deep-sea surface waves.[109] He examined how a local disturbance at various depths would

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Keiichi Aichi, "Heat distribution on a radiating plane," *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1 (1919): 308-18.

107. Kwan-iti Terazawa, "Note on the Mutual Inductance Between a Helix and a Coaxial Circle; a Helixand a Coaxial Cylindrical Current Sheet," *Tôhoku Mathematical Journal* 10 (1916): 73-80; Kwan-iti Terazawa, "Note on the Self-Inductance of a Ring of Small Circular Section," *Proceedings of the Physico-Mathematical Society in Japan, Series II* 5 (1909): 84-94.

108. Terazawa, "Note on the Mutual Inductance," 73.

109. Kwan-iti Terazawa, "On Deep-Sea Water Waves Caused by a Local Disturbance on or Beneath the Surface," *Proceedings of the Royal Society in London* 92 (1915): 57-77; Kwan-iti Terazawa, "On the Oscillations of the Deep-

cause oscillations of surface water at the center of the disturbance. This, again, did not go beyond an application of physical principles (this time, the equation of fluid dynamics) with extensive calculations. The results potentially had great practical value. Terazawa noted one special case in which the displacement occurred at a finite depth from the surface, "i. e., where the surface wave is produced by an explosion like that of a mine under water."[110] This problem of hydrodynamics, therefore, had similar characteristics to that of Terazawa's work on inductance. It contained numerous calculations, a great practical (engineering or military) value, and no discussion of physical principles. Furthermore, Terazawa was able to work on these two physically different issues, using his vast knowledge of special functions and adeptness to solve equations, just as Aichi was capable of working on several different branches of physics.

The situation was similar at Kyoto University. Although his position did not explicitly refer to "theoretical physics," we should count Tamaki Kajûrô as a theoretical physicist. He was in charge of teaching "theoretical physics" at Kyoto University, until he died in 1939 and Yukawa Hideki succeeded him. Graduated from the Department of Physics at Kyoto University in 1909, Tamaki specialized in electromagnetism, relativity theory, and fluid dynamics. The 1910s marked his most active period. During that decade, he published 15 papers, mostly on or related to relativity theory. His research bore the sixth characteristic that we found in Aichi's works: Tamaki applied the principle of relativity to various problems and derived this principle's mathematical implications. The paper he published in 1911, "Note on General Equations for Electromagnetic Fields in a Moving System," was

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Sea Surface Caused by a Local Disturbance," *Science Reports of Tôhoku University, Series I* 6 (1917): 169-81.

110. Terazawa, "Deep-Sea Water Waves," 57.

typical.[111] Tamaki derived the transformation rules of electromagnetic fields between two systems, one moving with a constant velocity relative to the other. The merit of his paper was that he derived formulae for the case in which the direction of velocity did not coincide with one of coordinate axes. Tamaki wrote:

> Lastly it is here desirable to note that, motions occurring in nature, in general, are not always of so simple a character that they take place along one of a given system of coordinate axes. When we have to deal with some problems concerning motions with component velocities, it will be found very convenient to use general equations . . .[112]

Indeed, Tamaki applied his formulae in his later papers, such as "Reflexion and Refraction Phenomena relating to a Moving Medium."[113] Even if deriving these formulae (in modern terms, to apply a general Lorentz transformation) did not need much ingenuity to be carried out, and the result did not come out in a beautiful form, Tamaki, it seems, implicitly justified its value by its theoretical and calculational convenience.

The five theoretical physicists that I have mentioned so far occupied positions in important Japanese universities, and represented a significant portion of the physicists in Japan. In 1926, the Department of Physics of Tokyo University had six full or associate professors. The College of Engineering had one physics professor (Terazawa) and two associate professors. Similarly, there were eight full

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111. Kajûrô Tamaki, "Note on General Equations for Electromagnetic Fields in a Moving System," *Memoirs of the College of Science and Engineering, Kyoto Imperial University* 3 (1911): 103-11.

112. Ibid., 111.

113. Kajûrô Tamaki, "Reflexion and Refraction Phenomena Relating to a Moving Medium," *Memoirs of the College of Science, Kyoto Imperial University* 2 (1916-17): 59-104.

and associate physics professors at Kyoto University, thirteen at Tôhoku University, five at Kyûshû University, and one at Hokkaidô University. The total number of physics professors at imperial universities, therefore, amounted to 36.[114]

In short, science in Japan before the early 1920s had a gap between the theory and practice of "theoretical physics." In principle, "theoretical physics" was supposed to be a "pursuit of truths." In practice, however, the "culture of calculating" dominated theoretical physics. By "the culture of calculating," I mean the set of values and mentality that paid more attention to mathematical skills and techniques in physics than physical phenomena or principles. In such a culture, doing "theoretical physics" meant carrying out lengthy calculations and working out specific applications of known physical laws.

6. Further Remarks on the "Culture of Calculating"

In prewar Japan, physics was closely tied with mathematics. Institutionally, physics and mathematics were not completely separated. During the time of Tokyo Daigaku (1877-1886), mathematics, physics, and astronomy were all housed in a single department.[115] As we saw, the Chair of applied mathematics was transferred from mathematics to physics. Moreover, Japanese physicists and mathematicians

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114. These numbers are based on the *Annai* (Catalogue) of each university in 1926. *Tokyo Teikoku Daigaku ichiran, Shôwa ninen yori sannen ni itaru* (Tokyo: Tokyo Teikoku Daigaku, 1926); *Kyoto Teikoku Daigaku Ichiran, Shôwa Ninen yori Sannen niitaru* (Kyoto: Kyoto Teikoku Daigaku, 1926); *Tôhoku Teikoku Daigaku ichiran, Shôwa ninen yori sannen niitaru* (Sendai: Tohoku Teikoku Daigaku, 1926); *Kyûshû Teikoku Daigaku ichiran, Shôwa ninen yori sannen niitaru* (Fukuoka: Kyûshû Teikoku Daigaku, 1926); *Hokkaidô Teikoku Daigaku ichiran, Shôwa ninen yori sannen niitaru* (Sapporo: Hokkaidô Teikoku Daigaku, 1926).

115. See, for example: *Gojûnenshi*; or *Tokyo Daigaku Hô-Ri-Bun San Gakubu dairoku nenpô*.

during this period shared one academic society, the Physico-Mathematical Society, and Japanese physicists did not have an independent society until after World War II.[116] Originally, mathematicians founded this society, and they ruled during its early years. Only later did physicists overwhelm mathematicians by numbers and take charge of its management (the secretariat of this society was located in the Physics Department library at Tokyo University).[117] At meetings of this society, physicists and mathematicians gave their talks in the same conference room to an audience consisting of members from both discipline, and they published their papers in the same journal, the *Proceedings of the Physico-Mathematical Society of Japan*.

The training provided by the physics department of Tokyo University shows that the physicists there deemed mathematics singularly important. Its curriculum in the mid-1920s placed more emphasis on calculus than any other subject. All of the first-year physics students were required to attend the same "Calculus" course as mathematics students. This one-year course consisted of five hours of lectures and two "Exercise" (problem solving) classes per week.[118] These problem-solving classes started at 1 p.m. and usually ended three hours later.[119]Other requirements for the first year students included: four hours a week for electromagnetism, three hours of lectures and one problem solving class for mechanics, and three hours for "Thermodynamics and Solid State Physics." In

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116. "Tokushû: Nihon butsurigakkai 50shûnen kinen," *Butsuri* 51, no. 1 (1996): Entire issue. See also: Nihon Butsuri Gakkai, *Nihon no butsurigaku shi*.

117. Mochizuki Seiichi, "40nen no omoide," *Butsuri* 51 (1996): 95-99.

118. *Gojûnenshi*, vol. 2, 948-49.

119. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade: "Butsurigaku Rinôkai" soshikisha no hitori Suzuki Hajime sensei ni kiku* (Tokyo: Seirinsha, 1991), 45.

addition, two hours of "application of differential equations" were mandatory, and students of theoretical physics had to attend for a year-long course on the "Theory of General Functions and Elliptic Functions," which took place three hours per week.[120]

An early professor at Tokyo University justified such a curriculum. In a lecture at Tokyo Butsuri Gakkô (Tokyo Physics School) in 1889, Yamagawa Kenjirô, the first Japanese professor of physics, reaffirmed the strict mathematical training in the physics department of Tokyo University:

> Once a man asked a scholar of Japanese literature what he should read to make good *waka*.[121] The scholar answered that he should read the *Tale of Genji*.[122] The man asked what should come next. The scholar answered that the next should be the *Tale of Genji.* The man asked what he should read thereafter. The scholar's answer was the *Tale of Genji*. Since I am a layman about literature, I don't know if that is true. But if someone asks me what he should learn in order to master physics, I answer that to master physics he should learn, first, mathematics, second, mathematics, and third, mathematics.[123]

Moreover, mathematics in Japan received more recognition than physics in the early 1920s, and therefore deserved to be modeled by the latter.[124] Japanese

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120. *Gojûnenshi*, vol. 2, 948-49.

121. *Waka* is a kind of Japanese traditional poetry.

122. The *Story of Genji* is a novel written by Murasaki Shikibu in the 11th century (supposedly the oldest novel in the world). See: Murasaki Shikibu, *The tale of Genji*, translated by Royall Tyler (New York: Viking Press, 2001).

123. Yamagawa Kenjirô, "Butsurigaku wo manabu mono no kokoroe," in *Danshaku Yamagawa sensei ikô*, edited by Shinjô Shinzô (Tokyo: Sanshûsha, 1937), 668.

124. As for the situation of mathematics in early Meiji Japan, see: Chikara Sasaki, "The Adoption of Western Mathematics in Meiji Japan, 1853-1903," in *The Intersection of History and Mathematics*, edited by Chikara Sasaki, Mitsuo

mathematicians had arguably reached an international standing in the first decades of the twentieth century. For example, the mathematician Takagi Teiji published his proof of a special case of Kronecker's conjecture (so-called "Kronecker's *Jugendtraum* theorem") in 1903,[125] apparently a first-rate piece of work by any standard.[126] This problem was one of the famous 23 problems that David Hilbert, Takagi's mentor at Göttingen, proposed as the most important problems of mathematics in his famous lecture at the International Congress of Mathematicians in Paris in 1900.[127] By 1903, Japanese physicists had not produced anything comparable.

The calculational approach appeared most evident in theoretical physics' relation to engineering. In a country where rapid industrialization was a national priority, theoretical physicists offered their calculational prowess in engineering problems. For example, Nagaoka's work on the inductance of the coil, the so-called "Nagaoka coefficient" discussed above, is a case in point. Similarly, optics, fluid dynamics, and aerodynamics, which formed the basis of the leading military

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Sugiura, and Joseph W. Dauben (Basel: Birkhäuser, 1994), 165-86, especially, pp. 181-184.

125. Teiji Takagi, "Ûber die Im Berichte der Rationalen Komplexen Zehlen Abel'schen Zahlkörper," *Journal of the College of Science, Imperial University of Tokyo* 19 (1903): 1-42.

126. Kronecker's theorem states that every Abelian number field arises from the realm of rational numbers by the composition of fields of roots of unity. Kronecker's conjecture concerned extending this theorem to the case of the realm of the imaginary quadratic numbers. Takagi proved Kronecker's conjecture positively in the case where imaginary quadratic field was the one obtained by adjoining *i*. For more on Takagi, see: Harold M. Edwards, "Takagi, Teiji," in *Dictionary of Scientific Biography, Vol 13*, edited by Charles C. Gillispie (New York: Scribner, 1970), 890-92.

127. David Hilbert, "Mathematische Probleme," *Archiv der Mathematik und Physik, 3. Reihe* 1 (1901): 217.

technology in Japan, provided works for theoretical physicists. Nagaoka's repeatedly emphasized the military importance of optics and sent his graduate student to the Navy as an engineer.[128] A Japanese optical instrument company, Nihon Kôgaku (today's Nikon), was founded in 1917 in a response to the Navy's demand; one his students and even one his sons (Nagaoka Masao) took a job in this company.[129] To fulfill such demands from industry and military, calculational approaches toward theoretical physics were more appropriate than truth-seeking or principle-questioning approaches, at least for the short run.

Such a trend seems to have started in the earliest days of Japanese physics. Kimura Shunkichi studied physics at Tokyo University, Harvard, and then Yale from 1888 to 1895, under J. M. Peirce and J. W. Gibbs. He received a doctoral degree from Yale in 1896 for his dissertation on the general spherical function and came back to Japan, eventually obtaining a professorship at the Naval Academy. Although he wrote a textbook on spherical harmonic functions, and founded "the Association of Quaternion Method"(*Shigenhô Kyôkai*), Kimura, one of the best-trained physicists and mathematicians in Japan at that time, focused his effort, not on theoretical studies of these subjects, but on developing wireless telegraphy technology, mainly for military use.[130]

As for physicists in the 1920s, Terazawa Kwan-iti exemplifies this trend toward fulfilling industrial and military needs. After securing a job in the College of Engineering, this graduate of the Theoretical Physics Department created a

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128. Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô den*, 443-44.

129. Ibid., 445.

130. Komatsu Atsuo, *Meiji shoki hen*, vol. 2 of *Bakumatsu Meiji shoki sûgakusha gunzô* (Kyoto: Yoshioka Shoten, 1991), 388-429.

"colony" of physicists and mentored a couple of the most mathematically deft disciples. Yamanouchi Takahiko, who joined Terazawa's group in 1926, stated very explicit his intent:

> With some professional conscience, and in an attempt to open a way for other physics graduates to get a position at the College of Engineering, I intentionally chose as my research topics problems of mathematical physics, which were applications of established theories on known physical problems, rather than problems of physics proper, explorations of uninvestigated areas.[131]

As I mentioned, Aichi Keiichi, too, took charge of the Chair of Applied Mechanics in the College of Engineering at Tôhoku University during his final years. As these cases show, theoretical physicists often had posts requiring them to teach mechanics at a college of engineering, and the works of such physicists tended to be mathematical and calculational.

7. Conclusion: Multiplicity of Meaning

We have seen that when in the late nineteenth century Japanese intellectuals translated the word "theory" as *riron*, this Japanese term had a connotation of philosophy and principle, which was understood as antithetical to practical matters. While the Japanese understanding of "theory," and the terms for "theory" were changing at that time, an examination of dictionaries, popular writings, and curricula of educational institutions will show that a Japanese word *riron* became a standard equivalent to "theory" during the 1870s, and that this word *riron* had a strong connotation of notions like "philosophy" and "principle."

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131. Yamanouchi Takahiko, "Genshishôtotsu no nihon deno hôga," *Butsuri* 32 (1977): 272.

In agreement with this meaning of "theory," the organizational structure and Japanese physicists defined "theoretical physics," as different from applied mathematics, with mathematics being characterized as tools for physics. In textbooks and popular writings, we saw how Japanese physicists conceived "theoretical physics." They wrote that theoretical physics aimed to discover hidden truths by organizing experimental data, and that theoretical physicists use mathematics only as a useful tool to achieve such a goal, implying that mathematical studies themselves would not constitute "theoretical physics."

In practice, however, theoretical physics in 1920s Japan had a strong inclination toward mathematics and calculation, as we have seen in the work of Aichi and others. Instead of philosophical consideration of the physical world, discussion of the principles of physics, and exploration of the truth behind phenomena, appreciation of mathematical complexity and calculational dexterity dominated, forming what I call the "culture of calculating." Moreover, physicists used their calculational prowess in practical matters of civil and military engineering, which should have been antithetical to the prescribed meaning of "theory." As the examination of the quintessential Japanese theoretical physicist, Aichi Keiichi, revealed, Japanese theoretical physicists were more interested in mathematical techniques and in the mathematical sophistication of known physical problems than finding or developing physical principles. Japanese theorists favored heavy use of esoteric mathematics and lengthy calculation over discovery of new physical principles. I call this tendency among the Japanese "theoretical physicists" to value and practice calculations, the "culture of calculating."

This apparent dissociation between the meanings of "theoretical physics" in theory and practice poses a conundrum when one asks what "theoretical physics" meant in Japan in the early 1920s. Was "theoretical physics" what theoretical physicists understood as "theoretical physics," that is, a pursuit of truth behind experimental phenomena for which mathematics was just a tool? Was "theoretical physics" what theoretical physicists mostly did, that is, the application of known physical laws, lengthy calculation with arcane mathematics such as elliptic function or group theory, and the derivation of specific results that had practical uses?

Analytic philosophers might have different answers (they will probably attribute this to the ambiguity of the word "meaning"). For historians, however, it seems more interesting and productive to embrace this multiplicity of meaning, and to view it as reflecting how organizational structures, translating activities, industrializing contexts, scientific practices, and cultures of physicists inflected the meaning of the word "theoretical physics." The culture of calculating prevailed. The dichotomy of "theory" and "practice" persisted. The ideal of "theoretical physics" became widely known as the pursuit of the truth behind phenomena, or the contemplation of non-practical abstract matters. Theoretical physics in 1920s Japan revealed its multi-faceted meanings in practice and theory.

This chapter leaves, at least, two questions unanswered. They are not relevant to this work, but it might be of interest to spell them out. The first question concerns the relation between what I call the "culture of calculating" and theoretical physics traditions in other countries. Cambridge wranglers,[132] Göttingen mathematicians and physicists,[133] students of Franz Neumann,[134]

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132. Smith and Wise, *Energy & Empire*; Andrew Warwick, *Masters of Theory: A Pedagogical History of Mathematical Physics at Cambridge University, 1760-1930* (Chicago: University of Chicago Press, forthcoming); P. M. Harman, ed., *Wranglers and Physicists: Studies on Cambridge Mathematical Physics in the Nineteenth Century* (Manchester: Longwood, 1985).

133. Lewis Pyenson, *Neohumanism and the Persistence of Pure Mathematics in Wilhelmian Germany* (Philadelphia: American Philosophical Society, 1983).

134. Olesko, *Physics as a Calling*.

theoretical physicists in Soviet Russia,[135] some of the American theoretical physicists,[136] and French mathematicians with a strong interest in physics around the turn of the century[137]— all of these seem to have shared (to various degrees) some aspects the "culture of calculating." A comparative study about how they were similar and different would answer one question that I have avoided dealing with squarely here.

The second question is related to the first: What shaped such a culture of Japanese theoretical physicists? I have suggested some possible factors: physics' close relation to mathematics, industrial and military demands for theoretical physics, and the pedagogical structure. A comparative study may provide insight into how different conditions of theoretical physics led to different cultures among its practitioners.

135. Karl Hall, "Purely Practical Revolutionaries: A History of Stalinist Theoretical Physics," Ph. D. Diss. (Cambridge, Mass.: Harvard University, 1999).

136. S. S. Schweber, "The Empiricist Temper Regnant: Theoretical Physics in the United States 1920-1950," *Historical Studies in the Physical Sciences* 17 (1994): 55-98.

137. While I am not aware of any good work on French mathematical physics, there is at least a new study on Poincaré: Peter L. Galison, *Einstein's Clock, Poincaré's Map* (Forthcoming).

Aichi Keiichi's Works

Optics (2 papers)

Aichi, K., and T. Tanakadate. 1903-05. Extension of Airy's theory of rainbow to that due to a circular source. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 2:79-861.

------. 1920. On the theory of mirage. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:130-36.

Electromagnetism (5 papers)

------. 1903-05. The effect of temperature on the electrical conductivity of selenium. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 2:217-21.

Aichi, K. 1907-08. Note on the capacity of a nearly spherical conductor and especially of a Ellipsoidal conductor. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:243-46.

------. 1907-08. Note on the electrical oscillations of a metallic cylinder surrounded by a dielectric.

------. 1907-08. Remarks on Prof. Homma's paper "Distribution of electricity in the atmosphere". *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:248-51.

------. 1907-08. Scattering of electromagnetic waves by a small elliptic cylinder. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:266-78.

Fluid Dynamics (4 papers)

------. 1907-08. Note on vibrations of a liquid contained in a cylindrical vessel. *Proceedings of the Physico-*
Mathematical Society in Japan, Series II 4:220-27.

------. 1917-18. Calculation of the period of the internal seiches for various lakes, sea. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 9:478-85.

------. 1917-18. On the internal seiches. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 9:464-78.

------. 1920. On the distribution of the wind velocity, when the abnormal propagation of sound occurs. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:63-69.

Acoustics (2 papers)

------. 1907-08. On the correction for open end of a tube with infinite flange. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:377-82.

------. 1907-08. Remarks on Dr. Terada's paper, "Note on resonance box". *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:396-97.

Applied Mechanics ***(9 papers)***

------. *1909-10. Remarks on Terada and Ôkôchi's paper "On the motion of projectile after penetration". Remarks on Terada and Ôkôchi's Paper* 5:197-99.

------. 1919. On a formula giving critical load for a strut having non-uniform sectional area. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:174-79.

------. 1919. Note on the solution of the problems of plane stress. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:262-67.

------. 1919. On the forced vibration of a circular plate. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:365-77.

------. 1919. On the shape of the beams of the uniform strength, taking its own weight into consideration. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:10-14.

------. 1921. Equation of motion of a string and membrane, as derived from "l'Ènèrgie d'Accèlèration". *Proceedings of the Physico-Mathematical Society in Japan, Series III* 3:70-76.

------. 1922. On the shape of a piston packing ring. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 4:149-54.

------. 1922. On the strength of a circular plate, the thickness of which is not uniform. *Journal of the Japan Society of Mechanical Engineering* 25(75):1-11.

------. 1922. Some case of the stationary vortex motion on a spherical surface. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:143-48.

Conduction and Distribution of Heat (14 papers)

------. 1917-18. On the penetration of the periodic temperature waves into a substance, having no uniform constitution, especially into the soil. *Proceedings of the Physico-Mathematical Society in Japan, Series II* 9:527-41.

------. 1919. Heat distribution on a radiating plane. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:308-18.

------. 1919. On the conduction of heat in gas confined between circular cylindrical walls. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:164-73.

------. 1920. Heat distribution on a radiating plane, and especially when the boundary is circular. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:20-26.

------. 1919. On the new method of reduction of observations of underground temperature. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:2-7.

------. 1920. Some correction and addition to my paper "heat distribution on a radiating plane and especially when the boundary is circular". *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:136-38.

------. 1920. Stationary heat distribution on a radiating spherical surface. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:196-208.

------. 1921. Green's function in the problem of heat distribution on a radiating plane. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 3:12-19.

------. 1921. Heat distribution on a radiating spherical surface, asn an illustration of the theory of integral equation. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 3:5-10.

------. 1921. Stationary heat distribution on a radiating plane, diffusion of heat and Laplacian equation. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 3:31-40.

------. 1922. A doubly periodic solution of $\delta U=k^2U$, with some reference to the problem of conduction of heat. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:25-27.

------. 1922. Heat distribution on a radiating plane. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:33-34.

------. 1922. Heat distribution on the radiating surface of a torus. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:29-32.

------. 1922. Some remarks on the method of reduction of the underground temperature observation. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:35-42.

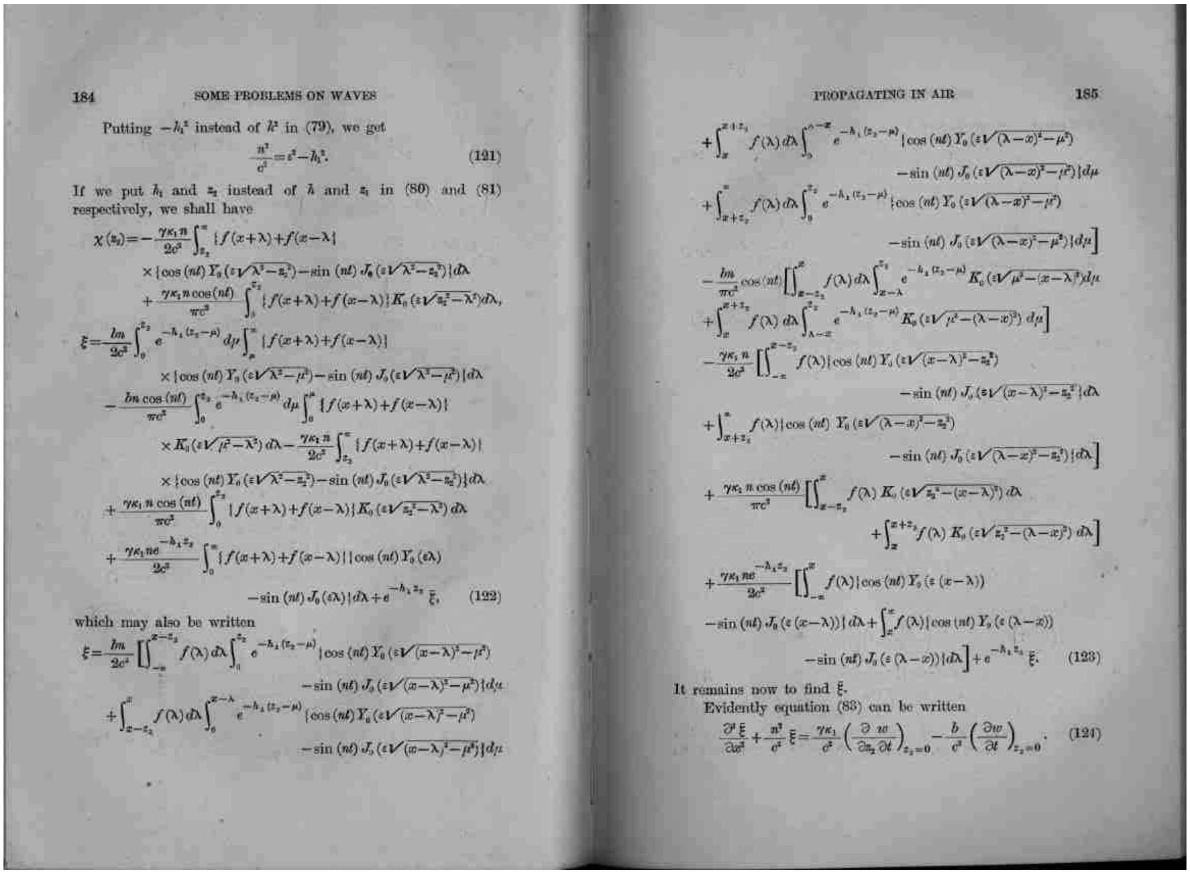
Applied Mathematics (2 papers)

------. 1919. On Picard's solution of $\delta\theta = k^2\theta$. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 1:318-20.

------. 1920. Note on the function $K_m(x)$, the solution of the modified Bessel's equation. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 2:8-19.

Seismolog (1 paper)

------. 1922. On the transversal seismic waves travelling upon the surface of heterogeneous material. *Proceedings of the Physico-Mathematical Society in Japan, Series III* 4:137-42.



Putting $-h_1^2$ instead of k^2 in (79), we get

$$\frac{n^2}{c^2}=\varepsilon^2-h_1^2. \qquad (121)$$

If we put h_1 and z_2 instead of h and z_1 in (80) and (81) respectively, we shall have

$$\chi(z_2)=-\frac{\gamma\kappa_1 n}{2c^2}\int_{z_2}^{\infty}\{f(x+\lambda)+f(x-\lambda\}$$
$$\times\{\cos(nt)\,Y_0(\varepsilon\sqrt{\lambda^2-z_2^2})-\sin(nt)\,J_0(\varepsilon\sqrt{\lambda^2-z_2^2})\}d\lambda$$
$$+\frac{\gamma\kappa_1 n\cos(nt)}{\pi c^2}\int_0^{z_2}\{f(x+\lambda)+f(x-\lambda)\}K_0(\varepsilon\sqrt{z_2^2-\lambda^2})d\lambda,$$

$$\xi=\frac{bn}{2c^2}\int_0^{z_2}e^{-h_1(z_2-\mu)}d\mu\int_\mu^\infty\{f(x+\lambda)+f(x-\lambda)\}$$
$$\times\{\cos(nt)\,Y_0(\varepsilon\sqrt{\lambda^2-\mu^2})-\sin(nt)\,J_0(\varepsilon\sqrt{\lambda^2-\mu^2})\}d\lambda$$
$$-\frac{bn\cos(nt)}{\pi c^2}\int_0^{z_2}e^{-h_1(z_2-\mu)}d\mu\int_0^\mu\{f(x+\lambda)+f(x-\lambda)\}$$
$$\times K_0(\varepsilon\sqrt{\mu^2-\lambda^2})\,d\lambda-\frac{\gamma\kappa_1 n}{2c^2}\int_{z_2}^\infty\{f(x+\lambda)+f(x-\lambda)\}$$
$$\times\{\cos(nt)\,Y_0(\varepsilon\sqrt{\lambda^2-z_2^2})-\sin(nt)\,J_0(\varepsilon\sqrt{\lambda^2-z_2^2})\}d\lambda$$
$$+\frac{\gamma\kappa_1 n\cos(nt)}{\pi c^2}\int_0^{z_2}\{f(x+\lambda)+f(x-\lambda)\}K_0(\varepsilon\sqrt{z_2^2-\lambda^2})\,d\lambda$$
$$+\frac{\gamma\kappa_1 n e^{-h_1 z_2}}{2c^2}\int_0^\infty\{f(x+\lambda)+f(x-\lambda)\}\{\cos(nt)\,Y_0(\varepsilon\lambda)$$
$$-\sin(nt)\,J_0(\varepsilon\lambda)\}d\lambda+e^{-h_1 z_2}\bar{\xi}, \qquad (122)$$

which may also be written

$$\xi=\frac{bn}{2c^2}\Big[\int_{-\infty}^{x-z_2}f(\lambda)\,d\lambda\int_0^{z_2}e^{-h_1(z_2-\mu)}\{\cos(nt)\,Y_0(\varepsilon\sqrt{(x-\lambda)^2-\mu^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(x-\lambda)^2-\mu^2})\}d\mu$$
$$+\int_{x-z_2}^{x}f(\lambda)\,d\lambda\int_0^{x-\lambda}e^{-h_1(z_2-\mu)}\{\cos(nt)\,Y_0(\varepsilon\sqrt{(x-\lambda)^2-\mu^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(x-\lambda)^2-\mu^2})\}d\mu$$

$$+\int_x^{x+z_2}f(\lambda)\,d\lambda\int_0^{\lambda-x}e^{-h_1(z_2-\mu)}\{\cos(nt)\,Y_0(\varepsilon\sqrt{(\lambda-x)^2-\mu^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(\lambda-x)^2-\mu^2})\}d\mu$$
$$+\int_{x+z_2}^{\infty}f(\lambda)\,d\lambda\int_0^{z_2}e^{-h_1(z_2-\mu)}\{\cos(nt)\,Y_0(\varepsilon\sqrt{(\lambda-x)^2-\mu^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(\lambda-x)^2-\mu^2})\}d\mu\Big]$$
$$-\frac{bn}{\pi c^2}\cos(nt)\Big[\int_{x-z_2}^{x}f(\lambda)\,d\lambda\int_{x-\lambda}^{z_2}e^{-h_1(z_2-\mu)}K_0(\varepsilon\sqrt{\mu^2-(x-\lambda)^2})d\mu$$
$$+\int_x^{x+z_2}f(\lambda)\,d\lambda\int_{\lambda-x}^{z_2}e^{-h_1(z_2-\mu)}K_0(\varepsilon\sqrt{\mu^2-(\lambda-x)^2})\,d\mu\Big]$$
$$-\frac{\gamma\kappa_1 n}{2c^2}\Big[\int_{-\infty}^{x-z_2}f(\lambda)\{\cos(nt)\,Y_0(\varepsilon\sqrt{(x-\lambda)^2-z_2^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(x-\lambda)^2-z_2^2}\}d\lambda$$
$$+\int_{x+z_2}^{\infty}f(\lambda)\{\cos(nt)\,Y_0(\varepsilon\sqrt{(\lambda-x)^2-z_2^2})$$
$$-\sin(nt)\,J_0(\varepsilon\sqrt{(\lambda-x)^2-z_2^2})\}d\lambda\Big]$$
$$+\frac{\gamma\kappa_1 n\cos(nt)}{\pi c^2}\Big[\int_{x-z_2}^{x}f(\lambda)\,K_0(\varepsilon\sqrt{z_2^2-(x-\lambda)^2})\,d\lambda$$
$$+\int_x^{x+z_2}f(\lambda)\,K_0(\varepsilon\sqrt{z_2^2-(\lambda-x)^2})\,d\lambda\Big]$$
$$+\frac{\gamma\kappa_1 n e^{-h_1 z_2}}{2c^2}\Big[\int_{-\infty}^{x}f(\lambda)\{\cos(nt)\,Y_0(\varepsilon(x-\lambda))$$
$$-\sin(nt)\,J_0(\varepsilon(x-\lambda))\}d\lambda+\int_x^\infty f(\lambda)\{\cos(nt)\,Y_0(\varepsilon(\lambda-x))$$
$$-\sin(nt)\,J_0(\varepsilon(\lambda-x))\}d\lambda\Big]+e^{-h_1 z_2}\bar{\xi}. \qquad (123)$$

It remains now to find $\bar{\xi}$.

Evidently equation (83) can be written

$$\frac{\partial^2\bar{\xi}}{\partial x^2}+\frac{n^2}{c^2}\bar{\xi}=\frac{\gamma\kappa_1}{c^2}\left(\frac{\partial w}{\partial z_2\,\partial t}\right)_{z_2=0}-\frac{b}{c^2}\left(\frac{\partial w}{\partial t}\right)_{z_2=0}. \qquad (124)$$

Fig 1.1 An example of Sano's paper

Chapter 3
"Student Radicals" in Science:
Youth Cultures and the Roots of Quantum Physics Research in Late-1920s Japan

> If the practices of the members of the same group or class are more and better harmonized than the agents know or wish, it is because, as Leibniz puts it, "following only [his] own laws," each "nonetheless agrees with the other." The habitus is precisely this immanent law, *lex insita,* laid down in each agent by his earlier upbringing . . .
>
> \- Pierre Bourdieu

1. In a Seminar Room of Riken

Although Japan's physics under the "culture of calculating" had some merits, it fit best within the domain of classical mechanics. In the social and cultural climates of the 1920s, some Japanese physicists developed what I call the culture of rebellion" in science, which played a role in the early phase of quantum physics research in Japan.

On the evening of March 18, 1926, twelve physicists gathered in a room in the Institute of Physical and Chemical Research in Komagome, Tokyo. They came there to launch a voluntary "study group," which they called the Physics Reading Group,[1] to read and discuss recent scientific papers. They were young, except for the two senior professors Terada Torahiko and Nishikawa Shôji. These twelve men met every Thursday and discussed the latest physics papers, many of which dealt with the newly emerging physical theory: quantum mechanics. They were thus making one of the earliest efforts to introduce this theory into Japan.[2]

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1. In Japanese, *Butsurigaku rinkôkai.*
2. Katsuki Atsuhi ascertained the date of the first meeting of this group. See:

Similarly, four Kyoto University students of Professor Tamaki Kajûrô began studying quantum mechanics around 1926. Since this professor, specialized in relativity theory and fluid dynamics and knew nothing about quantum mechanics, those four students had to learn this new discipline on their own.

These images of young physicists voluntarily studying a new physical theory might not appear particularly interesting. After all, one might say that there was nothing special about young physicists studying new publications.

If, however, we look at the cultural and social contexts of the Taishô Era,[3] the time when these physicists spent their student years, a totally different meaning of this picture emerges. From the late 1910s to the early 1920s, industrial, political, cultural, educational, and scientific landscapes in Japan changed, or were changing dramatically.

The changes brought by the 1923 earthquake were merely some of the many transitions in different areas at that time, even if the earthquake symbolically marked these transitions in people's perception. The First World War had triggered a structural shift of the industrial landscape toward heavy industry.[4] Since the war severed the supply of German chemical products, Japan had to develop its own

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Katsuki Atsushi, "Ryôshirikigaku zenya no nihon," *Sûrikagaku* special issue (October 1984): 6-10, reprint, Originally published in 1979. The details of this group will be discussed in a later section.

3. The Taishô Era spanned from July 30, 1912 to December 25, 1926, the period when the Taishô Emperor reigned Japan. There is, of course, no reason to suppose that the reign of an emperor would affect the culture and society, or could make a meaning periodization. I use this word to designate roughly the time of the 1910s and the first half of the 1920s. This Chapter is mainly concerned with the period after World War I until the early Showa Era.

4. Hashimoto Jurô, *Dai kyôkôki no nihon shihonshugi* (Tokyo: Tokyo Daigaku Shuppankai, 1984), 30-47.

chemical and pharmaceutical industry.[5] While European powers were fighting, Japan expanded its military influence and market in Asia, and began exporting its industrial products. Politically, the democratization of imperial Japan, the so-called "Taishô Democracy" started after World War I, and was reaching its high-point in the 1920s. The progress of industrialization created an urban middle class, and, at the same time, aggravated the social problems of the poor. Social reformist movements gained force and became radicalized. Workers began organizing nation-wide labor unions around 1920, and communists founded Japanese Communist Party in 1922. In 1925, the Diet passed a bill for male universal suffrage. Although the emperor still kept the power to appoint the Prime Minister, he, in most cases in this period, appointed the leader of the majority party in the Diet; hence, an unusual form of democracy, "imperial democracy" ran the country.[6] Along with democratization, higher education was becoming popularized, which I will discuss later in detail. Finally, the development of heavy and chemical industries resulted in several new scientific research institutes, such as the Institute of Physical and Chemical Research (Riken) in 1917.[7]

This chapter aims to interpret these young physicists' activities within such contexts. By locating their experience in the social conditions and youth cultures in the 1920s, in the context of the emerging "modernism" in Japan, we will see that learning quantum mechanics meant an act of rebellion against the old generation.

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5. Barbara Molony, *Technology and Investment: The Prewar Japanese Chemical Industry* (Cambridge: Harvard University Press, 1990).

6. Andrew Gordon, *Labor and Imperial Democracy in Prewar Japan* (Berkeley: University of California Press, 1991).

7. On the establishment of scientific institutes in Japan around World War I, see: James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition* (New Haven: Yale University Press, 1989), Chapters 7 and 8.

To show that quantum mechanics had such a local meaning to the young physicists is the goal of this chapter. In order to excavate the meaning (or meanings) of quantum mechanics, I describe what the world of 1910s and 1920s Japan looked like to them. What experiences must those physicists have encountered? In what microcosms did they live? What cultural resources were available to them when they were trying to digest quantum mechanics? These are some of the first questions that I try to answer in this chapter.

The local meanings of quantum mechanics matter for at least two reasons. First, local meanings contributed to the experiences of historical actors, and, therefore, they comprise an integral part of historical reality. A local meaning might appear to be just a matter of nuance. Nevertheless, it can be real for contemporaries, and as far as that is the case, it matters to historians.

Second, this particular case illustrates how the differences of local meanings did not "matter" in terms of communicating and evaluating scientific ideas. We now know that European and American physicists later recognized works by Japanese quantum physicists, and even awarded them with the most prestigious prizes. The fact that quantum mechanics had a local meaning did not prevent it from functioning across different cultures. The emergence of local meanings does not necessarily mean a breakdown of communication. As Peter Galison shows partial understanding is possible between different cultures, where the same word has different meanings.[8] This is even the case between presumably vastly separated cultures, say, Europe and Japan.

The subject matter of this chapter has its own merits. An examination of the youthful scisntists in Japan or elsewhere provides a good foundation for the

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8. Peter L. Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997).

developments to come because, obviously, the younger generation would come to dominate the future. Examining education would reveal the *habitus* of a social group At the same time, most physicists in the nineteenth and twentieth centuries devoted much of their attention to their pedagogy. Burgeoning literature on pedagogy and science, in particular physical sciences, developed by Kathryn Olesko, Andew Warwick, David Kaiser, and others, amply attests how studies of pedagogy can help us understand the practices of scientists.[9]

Moreover, student and young physicists provide an interesting venue for watching how scientific and outside cultures interacted. Being a half scientist and half non-scientist, physics students and young physicists stood between the two cultures. In this sense, the youth in the scientific community were boundary persons, inherently undermining the integrity of the community. They smuggled in values and norms from outside, as, for example, shown by David Kaiser about young physicists in postwar America.[10]

To these studies on pedagogy and physics, the present study, along with Karl Hall's work,[11] adds another dimension. Young people's tendency toward novelty and radicalism is, if not a universal truth, at least a reasonable expectation in many instances because often they do not have vested interests in the current

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9. Kathryn M. Olesko, *Physics as a Calling: Discipline and Practice in the Kônigsberg Seminar for Physics* (Ithaca: Cornell University Press, 1991); Andrew Warwick, "A Mathematical World on Paper: Written Examinations in Early 19th Century Cambridge," *Studies in the History and Philosophy of Modern Physics* 29 (1998): 295-319; David Kaiser, "Making Theory: Producing Physics and Physicists in Postwar America," Ph. D. Diss. (Cambridge: Harvard University, 2000).

10. David Kaiser, "Postwar Suburbanization of American Physicists" (Forthcoming).

11. Hall Karl, "Purely Practical Revolutionaries: A History of Stalinist Theoretical Physicists," Ph. D. Diss. (Cambridge: Harvared University, 1999).

system or its values. This tendency of the youth to radicalize can constitute one of sources of dynamism that can change the course of science and its practices.

The student and youth culture in 1920s Japan makes a part of the subject of this chapter. Although the history of education is a relatively large and influential discipline in Japan (probably larger than the history of science) and there are scholars specialized in the history of higher education, most of existing studies deal with the organizational aspects of education. Except for Karasawa Tomitarô's *Gakusei no rekishi* (The History of Students) in 1955,[12] most works on student cultures in prewar[13] Japan written in Japanese were more journalistic than scholarly. There are more important works written in English relevant to the topic of this chapter. In particular, Donald Roden's *Schooldays in Imperial Japan* in 1980 discusses the student culture of prewar higher schools.[14] In addition, Henry Dewitt Smith's *Japan's First Student Radicals* in1972 and Earl H. Kinmonth's *The Self-Made Man in Meiji Japanese Thought* in1981 illuminate some aspects of student life in prewar Japan.[15]

More recently, however, interest in student life and culture in prewar Japan has soared especially among sociologists of education. For example, Takeuchi Yô describes the life and culture of university or higher school students and

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12. Karasawa Tomitarô, "Gakusei no rekishi: gakusei seikatsu no shakaishiteki kôsatsu," in *Chosakushû, vol 3* (Tokyo: Gyôsei, 1991), 3-396.

13. "Prewar" in this dissertation means "pre-WWII."

14. Donald Roden, *Schooldays in Imperial Japan: A Study in the Culture of a Student Elite* (Berkeley: University of California Press, 1980); Following what appears to be the current standard of Japanese studies, I translate "kôtôgakkô" as "higher school."

15. Henry DeWitt Smith, *Japan's First Student Radicals* (Cambridge: Harvard University Pres, 1972); Earl H. Kinmonth, *The Self-Made Man in Meiji Japanese Thought* (Berkeley: University of California Press, 1981).

examinees.[16] Terasaki Masao, in his recent works on history of university, studies students' lives in prewar Japan.[17] Finally, Ito Akihiro, in his definitive work on the higher education during interwar Japan, discusses in detail the students and their mentality, values, and lives.[18] This chapter follows these recent developments in historical and sociological studies of Japanese higher education.

Based on these works, I try to locate the activities of these physicists in the context of the Taishô youth cultures and to understand the meanings of their practices. In particular, I show how we can understand the cultures and behaviors of these groups of physicists better within broader culture of their time.

2. Splinter Groups in Tokyo and Kyoto

The Physics Reading Group amassed 16 participants overall (See Table 3.1). Many of them were experimentalists and had no apparent logical reason to study quantum mechanics. The two senior physicists, Terada Torahiko and Nishikawa Masaharu, were professors of experimental physics at Tokyo University and chief researchers of the Institute of Physical and Chemical Research (called Riken).[19] Doi Uzumi graduated from the physics department[20] in 1920, specializing

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16. Takeuchi Yô, *Gakureki kizoku no eikô to zasetsu*, Nihon no Kindai (Tokyo: Chûô Kôronsha, 1999); Takeuchi Yô, *Risshin, kugaku, shusse: jukensei no shakaishi*, Kôdansha gendai shinsho (Tokyo: Kôdansha, 1991).

17. Terasaki Masao, *Puromunâdo tokyo daigakushi* (Tokyo: Tokyo Daigaku Shuppankai, 1992); Terasaki Masao, *Daigaku kyôiku no sôzô: rekishi, shisutemu, karikyuramu* (Tokyo: Tôshindô, 1999).

18. Ito Akihiro, *Senkanki no kôtô kyôiku* (Tokyo: Tamagawa Daigaku Shuppanbu, 1999).

19. For more on Riken, see Chap 4.

20. The "physics department" here means the one at Tokyo University.

in quantum theory. He was the most well-known (in fact, infamous) for his objections to relativity theory. He was then a non-regular researcher at Riken.[21] Konkô Masamichi, Shiba Kamekichi, and Suzuki Akira graduated from the physics department in 1922, and then they were graduate students there. Nakaya Ukichirô and Fujioka Yoshio were experimental physicists, who graduated from the physics department in 1925, and then became research associates at Riken. Sasaki Jirô and Nitta Isamu graduated from the chemistry department in 1922 and 1923, respectively. Fukuda Mitsuharu, the only graduate of Kyoto University's physics department in this group, finished his undergraduate studies in 1918 and then became a research scientist[22] at Riken.

Among the additional members, Kikuchi Seishi, graduated from the physics department in 1926 and became a graduate student. He later became an important experimentalist in atomic physics at Osaka University, constructing a cyclotron there.[23] Tsuboi Chûji also graduated in the same year, and became a research associate in the Institute of Seismology as well as a research student at Riken. He was to become a leading geophysicist in Japan..[24]

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21. *Shokutaku* in Japanese.

22. *Kenkyûin* in Japanese, which roughly corresponded to an associate professorship at a university.

23. *Kikuchi Seishi: Gyôseki to tsuisô* (Tanashi: Kikuchi Kinen Jigyôkai Henshûiinkai, 1978). Kimura Tôsaku Itakura Kiyonobu, Yagi Eri, *Nagaoka Hantarô den* (Tokyo: Asahi Shimbun Sha, 1973), 554-56; Kumagai Hiroo, *Jikken Ni Ikiru* (Tokyo: Chûôkôronsha, 1974). This cyclotron can be considered as the first working cyclotron outside the United States. It was completed one month before the cyclotron at Riken. See Chapter 5.

24. Although his biography is yet to be written, there are some obituaries of Tsuboi: Tomoda Yoshibumi, "Tsuboi Chûji sensei to chikyû kagaku," *Kagaku* 53 (1983): 132-34; Tomoda Yoshibumi, "Tsuboi Chûji sensei wo shinobu (Tsuitô)," *Jishin* 36 (1983): front pages; Husimi Kôdi, "Tsuboi Chûji sensei no omoide," *Sûgaku seminâ* 22, no. 3 (1983): 44-46.

Among the four in Kyoto, Nishida Sotohiko was the second son of Nishida Kitarô, the most important philosopher in prewar Japan. He graduated from Kyoto University in 1926 and became a physics teacher of Kônan Higher School in Kobe in 1929. Tamura Matsuhei, who graduated 1927, became a lecturer at Kyoto University and gave the earliest systematic course in quantum mechanics there.[25] Later, he turned to the history of science.[26] Yukawa Hideki (then Ogawa Hideki) and Tomonaga Sin-itiro graduated from Kyoto University in 1929, and became unpaid assistants of Tamaki Kajûrô. Yukawa became a lecturer at Kyoto University in 1932. He is known now for his meson theory, published in English in 1935,[27] for which he was awarded a Nobel Prize. Tomonaga joined Nishina Yoshio's group at Riken in 1932. He, too, was awarded a Nobel Prize in 1965, for his work on renormalization theory.[28]

In what follows, I describe the experiences of some of these young physicists and a few chemists: Tomonaga, Yukawa, Suzuki, Nakaya, Tsuboi, Nitta, and others. Their experiences were by no means similar, and their microcosms were not homogeneous. I will not try to abstract a denominator of their worlds; rather, I present sketches of what appear to have been relevant and

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25. Tamura's book on quantum mechanics was probably a product of this course. See: Tamura Matsuhei, *Ryôshiron* (Tokyo: Kôbundô, 1939).

26. For example, he wrote a biography of Max Planck: Tamura Matsuhei, *Puranku* (Tokyo: Kôbundô, 1950).

27. Hideki Yukawa, "On the Interaction of Elementary Particles I," *Proceedings of the Physico-Mathematical Society in Japan, Series III* 17 (1935): 48-57.

28. For Tomonaga's work, see: Sylvan S. Schweber, *QED and the Men Who Made It: Dyson, Schwinger, Feynman, and Tomonaga* (Princeton: Princeton University Press, 1994).

important to their conception of quantum mechanics.[29]

3. Einstein's Visit to Japan in Late 1922

On November 17, 1922, Albert Einstein visited Japan, and stayed there for 42 days, giving lectures in several cities. Japanese people welcomed Einstein enthusiastically. His talks, trips, and other things he did in Japan received extensive newspaper coverage. The organizer, the publishing company Kaizôsha, took the best advantage of Einstein's visit, advertising Einstein-related events through its well-circulated magazines, making his visit a commercial success. Responding to sudden rise of interest in relativity theory, new scientific magazines and popular books on science appeared.[30]

Einstein's talks, or rather their repercussions, stimulated many young or would-be physicists in Japan and redirected their interest to new physics. Tamura Matsuhei, then a student of the Seventh Higher School[31] in Kumamoto, had a chance to attend one of Einstein's lectures. Excited, Tamura, who was an extensive reader, began reading a popular book on relativity theory by Ishiwara Jun, then Kaizôsha's collected works of Albert Einstein translated by Ishiwara, and eventually he started reading Herman Weyl's *Raum, Zeit, Materie*.[32]

Tomonaga Sin-itiro was then still studying at a middle school in Kyoto. Stimulated by the journalism, young Tomonaga read Ishiwara's book on relativity theory. He did not necessarily understand it, but it greatly excited him:

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29. For the organization of this chapter, I owe much to Bruno Latour's comments.

30. Kaneko Tsutomu, *Ainshutain shokku* (Tokyo: Kawade Shobo, 1991).

31. As for "higher school," see below.

32. Kaneko Tsutomu, *Ainshutain Shokku*, vol. 2, 220.

> Relativity of time and space, the world of four dimensions, and the world of non-Euclidian geometry. These mysterious things fascinated this ambitious high-school student. What wonderful worlds there are in physics! How wonderful it would be to study such worlds![33]

Yukawa Hideki did not go to Einstein's talks, but his friends did. Later, while he was doing a student experiment with a classmate at the Third Higher School in Kyoto, his partner suddenly told him that Yukawa " would become a person like Einstein." Yukawa wrote in his autobiography, *The Traveler*:

> At that moment, I had no idea what he was talking about, as I had no thought of becoming a physicist. However, after the experiment was over, I became very happy for some reason unknown to me. I was in the kind of confused state mentioned by Chuang-tzu. . . .
> Dr. Einstein was a great figure, who was very remote from me. Kudo's words did not seem to apply, and yet his words appear to have made an invisible crack in the icefloe that blocked my ship. The French poet, Proudhon, had written: "A vase was struck lightly with a fan, which did not leave a visible mark. The crack grew with time, and one day the vase broke by itself."[34]

In Tokyo, Suzuki Akira was attracted by the "new world" that relativity theory seemed to indicate. He was then a graduate student working with Nagaoka. He was among several physicists admitted to Einstein's lectures for specialists. Stimulated by Einstein's visit, he read Einstein's works and Ishiwara's books on relativity theory. Later, he said that he felt Einstein's theory as "poetic":

> I was very much attracted by it, because I felt a world behind it, which resembled what I felt from a poem. Although not written in poetical language, it appeared to inspire in me something I might want call a "world." Not Einstein's differential equations, or its transformations, but

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33. Tomonaga Sin-itiro, "Wagashi wagatomo," in *Chôjûgiga*, vol. 1 of *Tomonaga Sin-itiro chosakushû*, reprint, 1962 (Tokyo: Misuzu Shobô, 2001), 194.

34. Hideki Yukawa, *"Tabibito" (The Traveler)*, translated by Laurie. Brown and R. Yoshida (Singapore: World Scientific, 1982), 113.

> the world they mediate appeared to have something in common with poetry and fascinated me.[35]

Nakaya Ukichirô entered the physics department of Tokyo University in April 1922. When he was a third year student of the Fourth Higher School in Kanazawa, Einstein was not in Japan, but relativity theory had already been widely advertised by Kaizôsha. Momotani Kashirô, a friend of Nakaya's, remembers that more than 10 third year students suddenly wished to major theoretical physics in that year. Most of them thought twice, remembering that the job prospects of a physics graduate would not be great. Only Momotani and Nakaya applied for the physics department. Nakaya, who originally intended to study biology or medicine, and therefore did not study mechanics, suddenly decided to go to the physics department. With Momotani's help, he intensively studied mechanics so that he could pass the entrance examination of the physics department.[36]

Nitta Isamu, then a second year student of the chemistry department of Tokyo University, attended Einstein's lectures at Tokyo University and Keio University. Greatly stimulated by Einstein and Ishiwara Jun, who served as interpreter, Nitta, although his major was chemistry, enthusiastically studied relativity theory by reading Ishiwara's books, which later helped him absorb quantum mechanics.[37]

At least one young physicist went so far as to doubt Einstein's authority. Doi Uzumi, then a physics graduate student and later a participant in the *Rinkôkai*,

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35. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade* (Tokyo: Seirinsha, 1991), 69.

36. Momotani Kashirô, "Kôkô, daigaku jidai no nakaya kun," in *Nakaya Ukichirô: Yuki no monogatari*, edited by Keiji Higuchi (Kaga: Nakaya Ukichirô Yuki no Kagakukan, 1994), 131.

had been voicing (and writing to Einstein himself) his reckless attempts to refute relativity theory, despite all the advice against it that he received from his teachers and friends, including his mentor, Nagaoka Hantarô. Upon Einstein's visit to Japan, he was given chances to talk to Einstein, and withdrew, at the moment, his criticisms of relativity theory.[38]

Einstein's visit to Japan inspired young physicists and future physicists, indicating to them that a revolution was underway in physics. At the same time, Einstein's distinction implicitly revealed the relative paucity of the Japanese universities. After losing Ishiwara because of his scandal,[39] there was virtually no internationally recognized expert in the field of relativity theory and quantum theory. Moreover, this Japanese champion of the new physics was also a poet, who threw away his prestigious status as a professor of Tôhoku Imperial University because of his passionate love affair. The ostentatious "imperial" universities and their pompous professors probably appeared to ambitious would-be physicists as lagging behind the new developments in their field.

4. Becoming a Theoretical Physicist in Prewar Japan

We have already seen in the previous chapter some aspects of Japan's higher education and training of physicists. Here, I would like to summarize the general process of the making of a Japanese physicist.

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37. Nitta Isamu, *Nagareno nakani: kagakusha no kaisô* (Tokyo: Tokyo Kagaku Dôjin, 1973), 154-55.

38. Kaneko Tsutomu, *Ainshutain shokku*, 190-97. As for Doi, see also: Yoshida Seiko, *Doi Uzumi ni miru 'ryôshiron' no kaishaku* (Tokyo: Tôkai Daigaku Shuppankai, 1995).

39. See Chapter One.

In prewar Japan, a three-tier system of higher education produced most physicists. Potential scientists first received preliminary higher education, usually liberal arts education at a "higher school" (*kotôgakko*; see Chapter 3), after they graduated from a middle school. Next, they received more specialized education in science (or sometimes in engineering) at an "imperial university." Finally, they developed themselves as professional scientists through various forms of post-graduate training. There were several possibilities for this stage of training, such as becoming a graduate student, or a research associate, at an imperial university or at Riken.

Except for a short period after World War II, higher schools accepted only male students. Since most students of imperial universities attended a higher school first, the higher school system worked effectively as a gatekeeper for the gender segregation of Japan's higher education. In addition to higher schools, there were a few other options for preliminary higher education. One was to attend a higher normal school. Even female students could take advantage of this option by attending the Women's Higher Normal School.[40] Another option for a science-minded young man was to go to a higher engineering school.[41] Since, very few

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40. Yuasa Toshiko, probably the only important Japanese female physicist before World War II, took this path. She graduated the Women's Higher Normal School, and made herself an experimental physicist in Paris under Irène Curie. See, for example, Sugiyama Shigeo, *Nihon no kindai kagakushi* (Tokyo: Asakura shoten, 1994), 166; Ochanomizu Joshi Daigaku Joseibunka Kenkyû Sentâ, ed., *Yuasa Toshiko shiryô mokuroku* (Tokyo: Ochanomizu Joshi Daigaku Joseibunka Kenkyû Sentâ, 1993). Yuasa's own writings include: Yuasa Toshiko, *Pari zuisô: Ra mizêru do ryukkusu* (Tokyo: Misuzu Shobô, 1973); Yuasa Toshiko, *Pari zuisô zoku: Ru reiyon vêru* (Tokyo: Misuzu Shobô, 1977); Yuasa Toshiko, *Pari zuisô 3: Musuka nowâru* (Tokyo: Misuzu Shobô, 1980).

41. Takeuchi Masa, for example, the first disciple of Nishina, was a graduate of Tokyo Higher Technical School. He managed to enter Riken as a non-paid research fellow (kenkyûsei), and probably as an assistant to Nishina Yoshio, who

theoretical physicists took such an unconventional educational path, I will not go into details about these alternative paths.

The liberal arts education at higher schools enabled the students to explore their interests free of their future occupational concerns. They were able to indulge themselves in high brow culture and esoteric philosophy of little practical use to the existing problems in Japanese society. Nurturing *Bildung* and personality and creating the elite marked by such impractical knowledge were, if not the goals, some of the consequences of higher school education. Theoretical physics, with its philosophical implications, fit into this culture of the higher school.[42]

The second stage of physicists' training was an undergraduate education at an "imperial university." For our purpose, it is enough to understand imperial universities as national universities with multiple colleges. In the 1920s, three imperial universities had a department of physics: Tokyo, Kyoto, and Tôhoku. With Ishihara Jun, Tôhoku University was an important center of theoretical physics in Japan but after Ishihara's retirement in 1921 and Aichi Keiichi's death in 1923, theoretical physics at Tôhoku University was considerably weakened, and its physics department produced very few important physicists. Most Japanese theoretical physicists were, therefore, trained either in Tokyo or Kyoto.[43]

Entering a physics department from a higher school was easier than entering many other departments. Very few students made the unusual choice to pursue physics, for which the Japanese society did not have much use at that point.

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was not yet a group leader but one of the members of Nagaoka's group: Takeuchi Masa, "Nishina kenkyûshitsu monogatari," in *Nihsina Yoshio: Nihon no genshi kagaku no akebono*, Hidehiko Tamaki and Hiroshi Ezawa (Tokyo: Misuzu Shobô, 1991), 209.

42. For more on higher school education, see the next section.

43. See Chapter 2.

To study physics, students needed to be prepared to be jobless after the graduation. At Kyoto University, for example, the department of physics implemented an entrance examination for the first time in 1926.[44] Until then, the number of applicants for the physics department never exceeded the allotted limit, and therefore all of the applications were accepted. At Tokyo University, the department of theoretical physics (or later, the theory major of the physics department) accommodated many students who failed to enter the college of engineering. Those students went to learn theoretical physics, which provided a good basis for engineering and to prepare for the next year's entrance examination.[45] The environment within these programs, as we saw in Chapter 2, was dominated by a "culture of calculating," one in which advanced mathematics and meticulous calculation were valued above much else.

In the third year, students were supposed to work with an adviser and conduct research. Department did not assign advisers. Instead, students chose their advisers according to their interests, and would ask the professor in mind to become their adviser. If the professor accepted, a mentor-disciple relation was established. Students were supposed to carry out a research project in that year, and submit a thesis.[46] Usually the adviser gave a topic to the student, but not always. The choice of the adviser at this point had potentially life-long consequences, because it virtually determined student's research direction. In addition, the adviser was responsible for the student's career immediately after the

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44. Tomonaga Sin-itiro, "Taidan kagaku no imi," in *Butsurigaku to watashi*, vol. 2 of *Tomoanga Sin-itiro chosakushû* (Tokyo: Misuzu Shobô, 1982), 343.

45. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade* (Tokyo: Seirinsha, 1991), 40.

46. For example, the work by Aichi Keiichi and Tanakadate Torashirô that was in Chapter 1 was probably such a study conducted under Nagaoka.

graduation, no matter whether he chose to take an academic or non-academic career. If, for example, the adviser had a strong tie with a certain type of job, the student would have a better chance of gaining employment.[47]

The last stage of the making of physicists was an indefinite period of postgraduate training. There was no formal protocol about the training at this stage. When recent graduates of physics departments wished to become physicists, they had a few choices. The luckiest became paid assistants or lecturers at their alma mater or at Riken. The less fortunate went to a higher school or other institutes of higher education, such as private universities, higher normal schools, military academies, or higher technical schools. A talented higher school professor could receive an offer of a job at an imperial university. An economically less fortunate, but academically more promising path was to become an unpaid assistant to a professor, or to become a graduate student. This of course was only possible for those who could economically (and socially) afford such a position.[48] In some cases, graduate students had another appointment (such as a teaching job at a higher school, or a research fellowship (*kenkyûsei*) at Riken), which was allowed by the school's regulations, as we will see in a later section.

The best possible option for a recent college graduate in science was to work at Riken. The Institute of Physical and Chemical Research, or Riken, established in 1917, was one of a few research institutes in physics at that time,

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47. For examples, see Chapter 6.

48. For example, both Yukawa and Tomonaga had a father who was a professor at Kyoto University. Their families were naturally supportive of their choice to pursue an academic career, and their decision to be an unpaid assistant in science caused no apparent conflict. This would not be the case for a person from a poor or non-academic family.

and certainly the most important one.[49] Riken was a prestigious institution, even more than Tokyo University. In contrast to those at imperial universities, Riken's scientists enjoyed ample research budgets and were freed from teaching obligations and the university bureaucracy. Many leading scientists of the institutes were also professors at imperial universities. Takamine Toshio, a senior spectroscopist, for example, originally held positions both at Tokyo Imperial University and Riken, but later retired from the former before the ordinary year of retirement. The advantage was obvious; he was then able to concentrate on his research.[50]

Under the dynamic directorship of its second director Ôkouchi Masatoshi,[51] Riken expanded during the first half of the 1920s. The notion of "scienticist industry" summarizes his policy. Instead of the ordinary conception, that science was something to be applied to industry, Ôkouchi proposed a form of industry that would serve science, by marketing scientific achievements and returning the profit to science for further research.[52] Although the initial expansion

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49. For the establishment of Riken, see: Kiyonobu Itakura and Eri Yagi, "The Japanese Research System and the Establishment of the Institute of Physical and Chemical Research," in *Science and Society in Modern Japan: Selected Historical Sources*, Shigeru Nakayama, David L. Swaine, and Eri Yagi (Tokyo: University of Tokyo Press, 1974), 158-201.

50. As for Takamine, see: Fujioka Yoshio, ed., *Takamine Toshio to bunkôgaku* (Tokyo: Ôyôkôgaku Kenkyûjo, 1964).

51. As for Ôkouchi's accession to Riken's directorship, see: Itakura Kiminobu, *Kagaku to shakai: Sôzôsei wo umu shakai, shisô, soshiki*, reprinted (Tokyo: Kisetsusha, 1988). For Ôkouchi's life, there is a biography (though more journalistic than scholarly): Miyata Shimpei, *"Kagakusha no rakuen" wo tsukutta otoko: Ôkouchi Masatoshi to Rikagaku Kenkyûjo* (Tokyo: Nihon Keizai Shimbunsha, 2001). There is a volume of collected articles to commemorate him, which contains biographical episodes: Ôkouchi Kinenkai, ed., *Ôkouchi Masatoshi: Hito to sono jigyô* (Tokyo: Nikkan Kôgyô Shimbun, 1954).

52. For a study of Riken as a newly rising industrial concern, see: Saitô Satoshi,

of the research budget drove Riken to the edge of bankruptcy, one of the groups in Riken enabled the mass-production of vitamin B, which enabled Riken to recover and further expand its research and manufacturing. The financial basis of Riken was never secure, yet it was able to survive until the end of the war, thanks to the sale of military-related products.[53]

Ôkouchi also reorganized the structure of Riken and made it more "egalitarian." Formerly Riken had consisted of two divisions, chemistry and physics. Each was headed by two elder physicists, Nagaoka Hantarô and Sakurai Jôji, and every individual research group belonged to one of them. There was a hierarchical structure between a division leader and group leaders. In this system, a researcher at Riken was either a chemist or physicist, and necessarily either an underling of either Sakurai or Nagaoka. Ôkouchi abolished the division and made all group leaders equal in status, which also enabled Riken's scientists to conduct interdisciplinary research incorporating both physics and chemistry.[54]

A recent graduate of university could be hired as a research student (*kenkyûsei*) or a research associate (*joshu*). A graduate student of an imperial university could also work at Riken at the same time, as a "research student," which, as a paid position, served as a form of graduate scholarship. Group leaders[55] could employ research associates at their discretion within budgetary

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Shinkô kontsuerun Riken no kenkyû (Tokyo: Jichôsha, 1987). For Ökouchi's own formulation of "scienticist industry," Ôkouchi Masatoshi, *Shihonshugi kôgyô to kagakushugi kôgyô* (Tokyo: Kagakushugikôgyosha, 1938).

53. Itakura and Yagi, "Japanese Research System," 295-96.

54. "Tokushû: Rikagaku Kenkyûjo 60-nen no ayumi," *Shizen*, no. 394 (December 1978): entire issue.

55. Officially, they were called *kenkyûshitsu shunin taru kenkyûin,* research scientists in charge of a research group, or *shunin kenkyûin*, chief research scientists.

limits, and research associates with the approval of the administrative board. Salaries did not differ much between the two posts,[56] and both paid about twice as much as that of an imperial university research associate or a lecturer. A drawback of the junior positions at Riken was insecurity, however. In addition to the Riken's insecure financial foundation,[57] young physicisits would not necessarily be promoted to higher positions in Riken. Since a group leader hired more than one (some times many) research associates, younger scientists could not always succeed their boss, and most of them had to leave Riken eventually.

In contrast to Riken's junior positions, a job at an imperial university was very secure. Even a research associate position was virtually a tenured (virtually, because there was no concept of tenure process in the Japanese academic system). Moreover, in most departments, a full professor usually had only one assistant professor or lecturer and one or two research associates, which meant a research associate had a good chance of succeeding the assistant professor and eventually the full professor.

The postgraduate training of physics in prewar Japan was unstructured and situations differed case by case. It is, therefore, difficult to discuss it in any systematic way. Many of these young physicists were trained through individual tutoring from their mentors, or they trained themselves. There are, however, three instances of postgraduate training that together make a relatively coherent account. The first is the school of Terazawa Kwan-iti in the 1920s and 1930s in

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56. According to Nitta Isamu, both of them received 80 yen per month in 1923: Nitta Isamu, *Nagare no nakani*, 169-70.

57. That was the reason Tomonaga joined the faculty of Tokyo Bunrika Daigaku in 1941, following Fujioka's advice. See: Tomonaga Sin-itiro, "Taidan kagaku no imi," in *Hirakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomoanga Sin-itiro chosakushû* (Tokyo: Misuzu Shobô, 1982), 207.

the College of Engineering at Tokyo University, as discussed in Chapter 2. The second is the activity of self-tutoring groups in Tokyo and Kyoto in the late 1920s to be discussed in this chapter. The third is Nishina Yoshio's group in Riken in the 1930s, which I describe in Chapter 5.

5. Higher School Experiences and Physicists in the 1920s

Higher schools in prewar Japan were three-year colleges of liberal arts education, which aimed to prepare students for more specialized education at a three-year imperial university. Most university students went to a higher school. Although possible, it was unusual for an imperial university to accept a student from other schools than higher schools, such as one of normal schools or technical high schools.[58] Therefore, almost all of the prewar Japanese physicists spent three years at a higher school. A relatively closed environment of higher schools enabled students to develop their own culture.

Entering a higher school, especially the most prestigious First Higher School in Tokyo, was extremely difficult. Students had to pass a very competitive entrance examination, or had to receive a recommendation from a middle school principal. A higher school was, therefore, at least in theory, an elite institution.[59] Once accepted, students enjoyed freedom from future worldly concerns. Until the end of the Taishô Era, a graduate of a higher school was usually guaranteed an

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58. It was, however, difficult for graduates of these schools to enter Tokyo University. Kyoto University, being less prestigious than Tokyo University, accepted more graduates from normal schools. Graduates of Higher Technical School (presently Tokyo Institute of Technology) could only enter Tôhoku University at that time. See: Takeuchi Yô, *Gakureki Kizoku*; Kaya Seiji, "watashi no rirekisho," in *Watashi no rirekisho bunkajin 15* (Tokyo: Nihon Keizai Shimbunsha, 1984), 131.

59. On the elitist nature of the higher school, see: Takeuchi Yô, *Gakureki kizoku*.

opportunity to enter one of the imperial universities. Some competitive departments required entrance examinations, some accepted students according to their grades at higher schools, and others departments accepted any graduates of the higher school.

Higher school students, including future physicists, received an intensive liberal arts education, with strong emphasis on languages. Nitta Isamu who entered the First Higher School in 1917 later remembered that "there were ridiculously many hours of English and German."[60] If a first-year science student in the 1920s chose to take a second foreign language, his total class time per week amounts to 32 hours. These included four hours for Japanese and literary Chinese, eight for the first foreign language, and four for the second foreign language. In sum, one half of the classroom hours were devoted to language education.[61]

An important aspect of the higher school life was *kyôyôshugi* or "culturalism."[62] By culturalism, I mean an obsessive appreciation for what the Japanese called *kyôyô,* which roughly meant *Bildung* in German. Since students in higher schools did not have to worry about imminent entrance examinations or job hunting, they had plenty of time to spend on reading books and absorbing impractical knowledge. Instead of the practical knowledge required in the real world, they could appreciate pure knowledge and culture. Until recently, language education in Japan mostly consisted of teaching how to read texts. Hence, students

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60. Nitta Isamu, *Nagare no nakani*, 103-04.

61. *Daisan Kôtô Gakkô ichiran Taishô 12-nen yori 13nen niitaru* (Kyoto: Daisan Kôtô Gakko, 1924), 63-66.

62. There is no real English equivalent to *kyôyô* or *kyôyôshugi.* I use the word "culturalism," which does not exist in dictionaries, following Roden.

became extremely well-versed in literature and philosophy, especially German philosophy.[63]

On the other hand, some higher school students developed a barbaric life style. Higher schools accepted only male students until the end of World War II. As a result, the story of Japanese physicists is a "male tale" as much as, or even more than the one described in Sharon Traweek's work.[64] Many students lived in the dormitory. Life of all-male dormitories nourished a masculine and barbaric culture. For example, one well-known phenomenon at the First Higher School dormitory was "dorm rain." The dormitory building had three floors. Students lived on the second and third floors, but the only bathroom was located on the first floor. Tired of climbing down to the first floor, students began to urinate from the windows. By the time the university built bathrooms on the second and third floors, this "dorm rain" was already firmly established as a tradition.[65]

In a strange way, culturalism and barbarism were able to coexist. "Storm" was another common practice at a higher schools. A "storm" usually took place at night. A group of yelling students would "storm" into one of dorm rooms and exert violence over its occupants. It was often an initiation ritual for the first year students. The interesting thing about the "storm" is what students yelled while doing it: "Dekanshô!" It is an abbreviation of Descartes, Kant, Schopenhauer, three of the higher school students' favorite philosophers.[66]

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63. Takeuchi Yô, *Gakureki kizoku*; Roden, *Schooldays in Imperial Japan*.

64. Sharon Traweek, *Beamtimes, Lifetimes: The World of High Energy Physicists* (Cambridge: Harvard University Press, 1988).

65. Roden, *Schooldays in Imperial Japan*.

66. Ibid., 111, 150-51.

Most of our young physicists came from Tokyo or Kyoto and did not live in a dorm. Therefore, theydid not necessarily have to subjet themselves to barbarism, although examples of barbarism were abound in higher schools. Donald Roden describes how two opposing cultures competed, a barbaric culture of student athletes and a philosophical and literary culture of introvert students.[67] Future physicists were probably closer to the latter group. Yet, barbarism accompanied by violations of conventional etiquette was certainly one of cultural resources available to them. Moreover, the introvert students were able to be no less rebellious than the physically destructive student athletes, as we shall see below.

Suzuki Akira entered the First Higher School in 1916. Later, he wrote about a scene at a school festival there. One of typical activities at a higher school festival was the "decoration," in which students decorated dorm rooms with various exhibits, mostly with some social satire, to show visitors. In a room of science students, there was an exhibit on a large board entitled "An insect that eats knotweed." This title came from a Japanese saying equivalent to "Some prefer nettles," which refers to those who prefer what others hate. On the board, "3.14159265...," namely pi, was written with number crackers, and a large beetle was suspended by a thread beside the crackers. Suzuki interpreted the message of this work by science students as follows: "We are going to learn physics and mathematics that people do not like." Those who learned law, engineering, or medicine, would be welcomed by the society and achieve success and fame. Why, then, would anyone willingly choose to major in physics? Suzuki saw the decoration as physics students' response to how people viewed them and an assertion of their contempt toward other people's worldliness and their twisted

67. Ibid.

pride as loyal followers of culturalism.[68] Those students instead chose physics, resisting or rebelling against the outside world, in order to pursue the pure knowledge of nature. Suzuki, a physics major, was also one of those "insects that eat knotweed."

Tomonaga Sin-itiro entered the Third Higher School in Kyoto in April 1923. Higher schools had changed by that time. The new Higher School Ordinance in 1918 became into effect in 1919, which introduced new measures, for example, how students were to be categorized. In the old system, students were divided into those who wished to study law, literature, science, engineering, and medicine. In this new system, students were simply divided by whether their major was a technical subjects (science, engineering, medicine) or not (law and literature), and which language they wanted to learn as their first foreign language (English, German, or French). In this new system, science students were now among engineering students. This "egalitarian" decision to mix competitive engineering and medicine students and less competitive science students on the one hand, and law students and literature students on the other, was apparently one of the various "democratic" reforms in the 1910s. This change was particularly important in the case of Nakaya. As we have seen above, he was able to change his prospective major from biology and medicine to physics with relative ease.[69]

Already motivated by his initial "Einstein shock," Tomonaga was further encouraged to study physics at the Third Higher School. In 1925, Tomonaga and

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68. Suzuki Akira, *Omoide no ki* (Tokyo: Nishio Teruo, 1990), 49.

69. See the catalogues of higher schools through this period. For example, *Daiichi Kôtôgakkô ichiran, Taishô 5nen yori Taishô 6nen ni itaru* (Tokyo: Daiichi Kôtôgakkô, 1916); *Daiichi Kôtôgakkô ichiran, Taishô 8nen yori Taishô 9nen ni itaru* (Tokyo: Daiichi Kôtôgakkô, 1919).

Yukawa,[70] who entered the same school in the same year, advanced to the third year. Both of them attended a course on mechanics by Hori Takeo. Hori, a 26-year-old spectroscopist, was Tomonaga's brother-in-law, then an assistant of Riken. He was a substitute teacher for Professor Mori Sônosuke, who went abroad that year. The young and inexperience teacher was just given the textbook to use, which was a 500-page treatise of dynamics written by Mori. Hori decided to let students study most of the materials by themselves and to use the class time for problem solving, giving students his original problem sets. Fortunately, the classroom had ample blackboard spaces, enough for twelve students to write down their solutions. This unusual approach to a higher school course (which was usually a lecture course with few exceptions), Hori suspected, might have made students overwork, yet students enjoyed solving problems on their own a great deal.[71] From time to time, at students' request, Hori talked about his own works. Hori's digressions often led to recent topics in physics, such as Louis de Broglie's matter wave, which appeared in the previous year.[72] He even mentioned Werner

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70. Then, Ogawa Hideki. He was adopted and married to the Yukawa family in 1932. Here, however, I call him Yukawa to avoid unnecessary confusion.

71. As for Hori's course and the grades of Tomonaga and Yukawa, see: Okamoto Takuji, "Sankô jidai no Yukawa Hideki to Tomonaga Sin-itiro," *Butsuri* 57 (2002): 419-20.

72. To be accurate, the crucial idea of the matter wave appeared in his short paper in 1923, Louis de Broglie, "Ondes et quanta," *Comptes Rendus de l'Académie des Sciences* 177 (1923): 507-10. As he pursued this idea, de Broglie reported the development in short papers during the same year: Louis de Broglie, "Quanta de lumiére, diffraction et interférences," *Comptes Rendus de l'Académie des Sciences* 177 (1923): 548-50; Louis de Broglie, "Les quanta, la théorie cinétique des gaz et le principe de Fermat," *Comptes rendus de l'Académie des Sciences* 177 (1923): 630-32. He then wrote down his ideas more systematically in the form of a Ph. D. thesis, which he submitted in 1924. The Ph. D. thesis was published as a journal article in 1925: Louis de Broglie, "Recherches sur la théorie des quanta," Annale

Heisenberg's just published matrix mechanics work,[73] which, he confessed, was beyond his command of physics.[74] Tomonaga later recalled:

> From what this young teacher said, I learned that there was a theory, according to which the electron was a wave, that there was a novel and extravagant theory called matrix mechanics, and that physics at Japanese universities was too old fashioned and useless.[75]

Unlike Suzuki, Tomonaga and Yukawa no longer had to pose themselves as knotweed-eating insects, once Einstein had become a cultural figure in Japan. Excited, Tomonaga decided in his third year to enter the physics department of Kyoto University. In fact, they were doubly lucky. Had they been living in Tokyo, the earthquake in 1923 would have prevented them from enjoying so happily the three years of higher school life.

6. The Great Kantô Earthquake in 1923

On September 1, 1923, around lunchtime, a potent earthquake assaulted the unsuspecting citizens of Tokyo. Although not the most powerful, this earthquake, with a conflagration that ensued, turned out to be extremely

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de physique 31 (1925): 22-128. Here, I consider his dissertation as the complete form of de Broglie's theory, and regard 1924 as the year when de Broglie published that theory.

73. Werner Heisenberg, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," *Zeitschrift für Physik* 33 (1925): 879-93. For a biography of Werner Heisenberg: David C. Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg* (New York: W. H. Freeman and Company, 1991). Any history of quantum mechanics contains some discussion of Heisenberg's paper, and what people would call "matrix mechanics," but, for example, see: Cassidy, *Uncertainty*, 181-225.

74. Hori Takeo, "Gakusei jidai no 'Sin-chan'," in *Tsuisô Tomonaga Sin-itiro*, edited by Daisuke Ito (Tokyo: Chûôkôronsha, 1981), 59-61.

75. Tomonaga Sin-itiro, "Wagashi wagatomo," 194-95.

devastating. According to the government report, fires started from more than 140. They could not be extinguished for three days. As a result, 91,344 people died, and 13,275 were lost. According to the report, 47.8 % of households in Tokyo and 86.5 % in Kanagawa Prefecture were burned down or damaged.[76]

The Kantô Earthquake dramatically changed the urban landscape of Tokyo. This city lost most of its old wooden buildings in the downtown area. The earthquake eradicated the "ambience of the Edo culture and the shadow of the Meiji Era" from the city.[77] After the earthquake, many residents of Tokyo migrated to the suburbs, expanding the metropolitan area and its railroad network.[78] Miyake Setsurei depicted how Ginza, the most fashionable area in Tokyo, drastically changed. Brick buildings before the earthquake turned out to be almost as vulnerable as wooden ones, and after the earthquake people rebuilt iron-framed buildings, which gave a new appearance to this supposedly the most "modern" district in Japan.[79]

More than physical destruction, the earthquake seemed to have deeply affected the psychology of Japanese citizens in the Taishô Era. Just as World War

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76. Naimushô Shakaikyoku, *Taishô shinsai shi* (Tokyo: Naimushô Shakaikyoku, 1926), vol. 1, 292.

77. *Tokyo hyakunenshi* (Tokyo: Gyôsei, 1972), 1224.

78. Harada Katsumasa, "Tokyo no shigaichi kakudai to tetsudômô (1): Kantô shinsai go ni okeru shigaichi no kakudai," in *Tokyo Kanto daishinsai zengo*, edited by Katsumasa Harada and Fumio Shizaki (Tokyo: Nihon Keizai Hyôronsha, 1997), 8-9.

79. Miyake Setsurei, *Daigaku konjaku tan* (Tokyo: Gakansha, 1946), 282. Miyake Setsurei (1860-1945) was a nationalistic philosopher and journalist, who left many writings on various subjects. For a (partial biography) of Miyake, see: Nakame Tôru, "Miyake Setsurei denki kô (1): Seitan to seikei wo chûshin ni," *Kindai Shiryô Kenkyû* 1 (2001): 62-83. For a bibliography of his writings: Yamano Hiroshi, "Miyake Setsurei chosaku mokuroku," *Kansai Daigaku Hôgaku Ronshû* 36 (1986): 137-216.

I marked the end of the old times and the collapse of old values and systems for Europeans, the Kantô earthquake represented the end of the first phase of the modernization of Japan since the Meiji Restoration, an installation of a Western style constitutional monarchy. In the mid-1920s, *shinsaimae* ("before the earthquake") became one of the most popular words of the time.[80] The earthquake was registered in the minds of the metropolitan area residents as a traumatic experience and became a marker between the nostalgic past and the troublesome present. The Great Earthquake impressed in people how ephemeral life and civilization were. In a book edited by the Tokyo City Municipality to commemorate the first anniversary of the earthquake, one wrote:

> One hundred thousand of us died. The imperial capital, which we had worked to build for sixty years since the Meiji Restoration, has mostly become a ruin in a day. . . . It is just natural that some of us think that, since we can never conquer nature, we had better give up our ambitions, stop working hard, and just enjoy everyday life by relying on other people's sympathy.[81]

Tezuka Tomio, who later became an eminent scholar of German literature and a translator of Goethe's works, was then studying at the First Higher School. In his autobiography, he wrote:

> An unprecedented disaster assaulted us and ruined our capital. . . . The sense of immense material loss certainly frightened us. More than that, however, the loss of confidence overwhelmed us. We had believed in our civilization, its absolute power to protect and serve us. We had thought that we stood at the apex of the progress, with which we could deal with our life in any way we would like. We had assumed that we had conquered nature completely, and took it for granted that the big earthquakes in the Kansei or Ansei Eras,[82] which we had heard in old stories, were mere

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80. Tokyo Hyakunenshi Henshû Iinkai, ed., *Tokyo Hyakunenshi*, vol. 4 (Tokyo: Gyôsei, 1972), 1224.

81. Tokyo-shi, ed., *Jûichiji Gojûhachifun* (Tokyo: Shiseidô, 1924), 289-90.

82. The Kansei Era was through 1789 to 1801; the Ansei, 1854 to 1860. There

> ghosts in the past, which would never happen again. . . . However, suddenly we were forced to know that the power of civilization, which we believed in, stood only on a very fragile foundation. Everything could be destroyed, and nothing was stable. After the earthquake, our minds had to live in the age of uncertainty.[83]

The Kantô Earthquake assailed, therefore, not only the city of Tokyo, but also the modernizing project of Japan since the Meiji Restoration. This aspect made this earthquake different from previous major quakes. By destroying the city reconstructed and modernized since the Meiji Restoration, it threatened the traditions and values of the Meiji Era. As Morito Tatsuo said, "If I say its meaning in a word, it was that the force of nature destroyed instantaneously Tokyo, the symbol of modernity that we had been building."[84]

Students' lives changed considerably in Tokyo after the earthquake. The earthquake severely damaged buildings of Tokyo University. Fires burnt down the library and incinerated most books. It destroyed the Hakkaudô Lecture Hall, where Einstein gave lectures in the previous year. After this disaster, students had to attend classes in temporary buildings.

Tsuboi Chûji, a participant in the Physics Reading Group whoentered Tokyo University in 1923, the year of the earthquake, wrote:

> The main building of the Physics Department was cracked and on the verge of collapse. The Mathematics Department building was completely burned down. Throughout my student years, classrooms were usually in hastily built shacks. There were holes on the floor, and grass was growing in the holes. Once a dog gave birth to puppies there and was panting during

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were large earthquakes in 1828 and 1854.

83. Tezuka Tomio, *Ichi seinen no shisô no ayumi* (Tokyo: Kodansha, 1966), 81-82.

84. Morito Tatsuo, *Daigaku no tenraku* (Tokyo: Dôjinsha, 1930), 129.

> lectures. When it rained, the noise of water drops hitting the tin roof drowned out teachers' voices.[85]

Nakaya Ukichirô, another participant in the Physics Reading Group, was a second year student in 1923. Fires on the day of the earthquake burned down his house, and he lost almost everything, including all of his books and lecture notes. At a loss and discouraged, he once decided to give up school and physics. He went back to his hometown, and arranged himself a job as a middle-school teacher. Momotani Kaichirô, a fellow physics student of Nakaya's, was surprised by Nakaya's decision, and invited him to his place in Osaka.[86] Eventually, Nakaya recovered from the initial shock and decided to continue his studies. Yet, Nakaya wrote, "because of the mental and material damages, my mind was never settled."[87] Nakaya was not alone. Suzuki Akira, who was a graduate student in 1923, lost his house and books by fire as well.[88] The earthquake therefore physically destroyed the Physics Department of Tokyo University, and mentally shook physics students in Tokyo. The University was now collapsing and in need of reconstruction. Students began to live in uncertainty.

7. University Life in the 1920s

Tomonaga Sin-itiro entered Kyoto University in 1926. Inspired by Einstein's visit to Japan and the young science teachers at Third Higher School, he

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85. Tsuboi Chûji, "Nishikatachô kara Yayoichô made," in *Kaisô Tokyo Daigaku hyakunen*, edited by Kentarô Hayashi (Tokyo: Bideo Shuppan, 1969), 140.

86. Momotani Kashirô, "Kôkô, daigaku jidai no nakaya kun," 132.

87. Nakaya Ukichiro, *Terada Torahiko no tsuiso* (Tokyo: Kôbunsha, 1947), 7-8.

88. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade*, 69.

was greatly excited in anticipation of studying the "mysterious" field of study, namely physics. Kyoto University, however, disappointed him greatly:

> Having entered in old-fashioned brick building, one would find a dark hallway with gray and dirty plaster walls and dusty air. This gloomy and depressed atmosphere was the first impression I had when I went to the Physics Department of Kyoto University for the first time.[89]

Unfortunately, Tomonaga's first impression was soon to be substantiated:

> In laboratories, people were doing second-hand experiments with dirty and dusty old-fashioned machines. Lectures on theories were flooded with dry equations. How boring it was to copy those equations one by one. Relativity theory, which once appeared so mysteriously attractive, became a series of manipulations of mathematics, with no mention of physical meanings or philosophical reflections. There was nothing that would stimulate young and ambitious students' curiosity. . . .[90]

Tomonaga, who was disgusted by Kyoto University, later stated that there was no single happy incident during his student days there.[91]

When people who received education before the war write about their higher school experiences, they recollect them with nostalgia. As for their life at the university, they grumble over the boredom that they had to suffer. At higher schools, students enjoyed broad cultural experiences by reading philosophical and literary classics. At an imperial university, students received more specialized training for their future professions, and tasted the dry reality for the first time.

The principal means of university education in prewar Japan was the large-class lecture course. There was a saying, "one notebook, thirty years," meaning

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89. Tomonaga Sin-itiro, "Wagashi wagatomo," 193.

90. Ibid., 195.

91. Ibid., 193.

that if a university teacher had a notebook of lectures, he could make living for 30 years by giving lectures with it. Giving lectures, of course, meant reading the lecture notes in a singsong manner. Some professors even read the same jokes from the notes every year. Students who had a chance to read the lecture notes from the previous year could predict when the professor would try to make them laugh. In class, students just wrote down everything the professor said in lectures. Outside class, they reread their lecture notes, rewrote them neatly, and made outlines or synopses. Before the examination, students reread their notes to prepare. Since the notion of reading assignment was (and still is) virtually non-existent in Japan's higher education, students did not have to read anything but their lecture notes.[92]

Without any innovative or inspiring pedagogy, professors not only kept students under control, but they also drove them to work like maniacs. Since lecture notes were so essential, students were fanatical in their effort to take good notes. In particular, they strove for a good seat. Haruna Yuzuru, in a book published in 1933, described a scene of university life in the Late Meiji and Early Taishô eras. Before a lecture began, a janitor would unlock the door to the classroom. When he opened the door, he had to withdraw himself quickly, because otherwise he would have been stamped over by a horde of students, who had been waiting outside the door and rushed into the classroom as soon as the door opened. This was all to secure a good seat. Some student even sneaked into the classroom before the janitor opened the door through a window using a rope ladder.[93]

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92. Katô Katsuji, *Beikoku daigaku to nihon gakusei* (Tokyo: Hakubunkan, 1918), 120-21.

93. Haruna Yuzuru, *Daigaku hyobanki* (Tokyo: ??? 1933), 287-88.

Competition in examinations was naturally fierce. It was rumored that a student who later became a professor read his notes 24 times.[94] Shima Gorô in his book from 1919 gave an early description of "examination hell" in Japan.

> Some start as early as in September. If not so early, those who want better grades start in the New Year holidays. They say it is too late to start during the Spring break. As the exam approaches, students begin to overwork. They stay up late, get up early, sleep little, and stop getting exercise. Bodies grow weak, mind becomes razor-sharp, and fatigue accumulates.
>
> In February, the library becomes filled with students. Many go to the library with digestives and mints. . . . Extremely nervous now, they react to and scold even a slightest voice. Everyone looks pale because of indigestion and lack of sleep.[95]

Students worked hard for two reasons. First, the university openly posted their grades. By publicly acknowledging students' performance on the exams, the university encouraged competition. The directory of alumni ordered the names of graduates not alphabetically, but in the order of their overall grades. Grades were on a 100 point scale. Thus, even a very small difference could affect a student's place on the list. Everyone was able to know everyone else's grades through newspapers, which acclaimed the top students of the year. At Tokyo University, moreover, the best graduates of the year were awarded a silver watch from the emperor himself at commencement.

Second, students expected, until the mid-1920s, that good achievements at school would ensure their future. Ozawa Masamoto, who studied at Tokyo University in the early 1920s wrote, "The social status after graduation was proportional to the height of the patiently piled up lecture notes and the ability to

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94. Shima Gorô, *Akamon dayori* (Tokyo: Tôadô, 1919), 199-200.

95. Ibid., 200.

memorize them."[96]

The situation, however, began to change in the late 1910s. In 1919, professors lost one of the means to tame students. It was decided that the university would no longer publish the results of the exams and students' grades. In addition, they abolished the emperor's award of silver watches. Instead of a ceremonial commencement attended by the emperor, graduates now just went to the department office and individually received a diploma from the department chair.[97] After 1919, the alumni directory listed students' names alphabetically. Grades were now given in letter grades, rather than as a number based on 100-point scale.

The low quality of university pedagogy, coupled with the relaxation of discipline enabled university students to develop their own interests and explore beyond the domains that the university education offered. Tomonaga's experience was a case in point. Deeply disappointed by Kyoto University, Tomonaga Sin-itiro chose to major theoretical physics anyway. There was only one theoretical physicist at Kyoto Imperial University. Professor Tamaki Kajûrô was a specialist in hydrodynamics and relativity theory, but he knew nothing about quantum mechanics. Tomonaga, nevertheless, picked up quantum mechanics, probably because relativity theory, tainted by the dry lectures at Kyoto University, no longer attracted him:

> I decided to study new quantum mechanics when I was a third year student because of my tendency to jump to new things. It was a youthful folly. No teacher in the department understood quantum mechanics at that time.[98]

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96. Ozawa Masamoto, "Sanbuntekina sankanen," in *Wakaki hi no kiseki* (Gakuseishobô), 109.

97. Tsuboi Chûji, "Nishkatachô kara Yayoichô made," 140-41.

98. Tomonaga Sin-itiro, "Wagashi wagatomo," 196.

Tomonaga therefore had to learn quantum mechanics on his own, or with other like-minded students.

At Tokyo University, where Nagaoka Hantarô, an able theoretical and experimental physicist, was teaching advanced physics seminars, the situation was somewhat better. Nagaoka offered a course on quantum theory. In addition, all of the third year students of theoretical physics had to take Nagaoka's two reading seminars on recent publications and recent papers on quantum theory were among the assignments. At some point, however, the colloquium became less fruitful, and young physicists began to grumble (more on the physics department colloquium will be discussed below).

8. Depreciation of College Graduates

When Tomonaga graduated in 1928, he remained at the school as a non-paid assistant, not because he was considered gifted and promising as a physicist, but because no job was available to him. A graduate of Kyoto University in 1928 found that many of his classmates became scholars (including himself).[99]

In the late 1920s and early 1930s, the employment situation for college graduates was grim. Tamiya Torahiko, who entered the Department of Japanese Literature at Tokyo University in 1933 described the student life in the early 1930s in his novel *Kikuzaka.* The protagonist of the novel, a student, presumably of Tokyo University, has only a very dismal prospect for the future. Living in a shabby and damp room at Kikuzaka (a street near Tokyo University), whose

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99. Akira Kobori, "Sin-Itiro Tomonaga at the Third High School," in *Sin-Itiro Tomonaga: Life of a Japanese Physicist*, edited by Makinosuke Matsui and Horoshi Ezawa, translated by Cheryl Fujimoto and Takako Sano (Tokyo: MYU, 1995), 84-87.

window overlooks a cemetery, he only hopes to finish college soon, even though he knows that there will be no chance of getting any better job than he has now as a part-timer, exploited by his employer. The city is full of jobless college graduates. "Ten years ago, a college degree helped one get a job. Such a time has long passed." Classes that the university offers seem to have nothing to do with his problems, yet he attends them, because he feels that "if I would stop attending lectures, all the hopes would be gone."[100]

University students used to be the elite of the society, whose future was firmly guaranteed. Tsubouchi Shôyô's 1886 novel, *Tôsei shosei katagi* (the mentality of contemporary students) recorded the attitudes and self-identities of the students in the Meiji Era. As Odagiri Hideo noted, students in this novel had no doubt about their future worldly success after their graduation and about the legitimacy of the political and social regime of that time.[101]

In 1887, when the Imperial University Ordinance (*Teikoku Daigaku Rei*) reorganized Tokyo University (*Tokyo Daigaku)* into the Imperial University (*Teikoku Daigaku*), it was the only university in Japan. The Minister of Education Mori Arinori intended this university to be the place to train young talents and make them useful human resources for the state.[102] In fact, until 1893, a graduate of the Imperial University could automatically become a career civil servant of the national government without taking the state examination for civil officers. Being a

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100. Tamiya Torahiko, "Kikuzaka," in *Tamiya Torahiko sakuhinshû*, vol. 3 (Tokyo: Kôbunsha, 1956), 128-47.

101. Odagiri Hideo, *Kindai nihon no gakuseizô* (Tokyo: Aoki Shobô, 1955), 17.

102. In his 1889 address, Mori Arinori said that in the matter of education at the Imperial University, national interests, rather than academic interests, were the most important and should have the first priority. See: Ôkubo Toshiaki, *Nihon no daigaku*, reprint, 1943 (Tokyo: Tamagawa Daigaku Shuppanbu, 1997), 268-69.

student meant being a student of an imperial university, which guaranteed his future success. Students assumed they were a privileged part of the regime and would remain so.

Earl H. Kinmonth depicts the changing character of the Japanese educated youth around the end of the Meiji Era. Whereas students in the Meiji Era were the elite of society, who were guaranteed to be successful in the government or in universities, students in the late Taishô and the early Shôwa eras were, though still relatively small in number, not as privileged as their Meiji counterparts. More students were to become *sararî man* (salaried men) or white-collar proletariats in private companies.[103] Yet, they could still expect jobs in the established political, legal, industrial, or academic regimes.

In the late 1920s, however, the future of university graduates became increasingly dismal as the Japanese economy sunk into a depression and the number of university graduates skyrocketed. The First World War anabled Japanese economy to grow by expanding its market in Asia, but the end of the war brought back superior goods from Europe and the United States, driving out Japanese products from the Asian market. Nouveaux riches, such as Suzuki Shôten, went banckrupt in 1927,[104] and the Japanese economy shrank into a state of chronic depression. The Kantô earthquake forced government spending, which created a short-lived business boom, but it eventually resulted in a financial crisis in the late 1920s. Without recovering, Japan entered the 1930s, the age of worldwide

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103. Kinmonth, *The Self-Made Man*.

104. Suzuki Shôten is a highly speculative general trading and manufacturing concern, which expanded rapidly during World War I. See: Katsura Yoshio, *Sôgôshôsha no genryû Suzuki Shôten* (Tokyo: Nihon Keizai Shimbunsha, 1977).

depression.[105]

In 1918, during Hara Kei's administration, the Minister of Education, Nakahashi Tokujirô, submitted to the Diet a "Plan to Establish and Expand Institutions of Higher Education," which the Diet approved. This was the most ambitious plan to expand higher education in the prewar Japan. In six years, ten higher schools, six higher technical schools, four higher agricultural schools, seven higher commercial schools, one foreign language school, one pharmaceutical school, and four new faculties at imperial universities were planned. Five medical universities and one commercial university would be promoted to universities, and six faculties of Imperial universities were to be expanded.[106]

In the same year, the University Ordinance allowed private universities to have the same legal status as that of imperial universities. Since 1902, a private institution of higher education could call itself a "university" (daigaku), but a private university was fundamentally different in terms of the students' qualifications. Whereas imperial universities accepted mostly those who had received their education at higher schools, private university belonged to the category of "specialty schools," which graduates of middle schools were eligible to enter. Therefore, students of these private universities did not count as university students until 1918. After the University Ordinance was decreed, private "universities" began to be promoted to the status of a university.[107]

As a result of the increased number of national and private universities, the number of students increased dramatically, and university teachers had to be mass-

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105. Sengo Nihon Keizai Kenkyûkai, ed., *Daikyôkô to senkanki keizai* (Tokyo: Bunshindô, 1993); Hashimoto Jurô, *Daik Kyôkôki No Nihon Shihonshugi*, 19-86.

106. *Meiji ikô kyoiku hattatsushi* (Tokyo, 1939).

107. Ito Akihiro, *Senkanki no kôtô kyôiku*.

produced as well (See Fig. 3.1).[108]

The goal of this expansion was to accommodate an ever-increasing influx of university applicants and to augment the education of the young population that previously had left school after receiving a middle school education.[109] Since the Meiji Restoration, the Japanese government had been expanding education, starting from the elementary level. In 1895, only 1170 students graduated from middle schools. In 1915, 20852 students graduated.[110] This resulted in an intensive competition to enter higher school. In the late 1910s, the difficulty of entering a higher school became a social problem. In a novel *Notes of Examinee* published in 1917, Kume Masao depicted the life of entrance exam examinees, based on a real story. In this novel, the main character, who failed the entrance examination of the First Higher School, eventually committed suicide.[111] The Ministry of Education expected that 30,000 would graduate from middle schools in 1925. If two thirds of these graduates wanted to receive higher education, the plan needed to accommodate 20,000. The plan of the Ministry of Education was to meet this number.

The expansion of higher education did not simply result in the unemployment of university graduates. It also changed the meaning of being a student, and pushed students into rebellion. In *Homo Academicus*, Pierre Bourdieu

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108. These numbers are taken from: Kaigo Muneomi and others, eds., *Nihon Kindai Kyôikushi Jiten* (Tokyo: Heibonsha, 1971).

109. The planning of this expansion of education was masterminded by *Ronji Kyôiku Kaigi* (Provisionary education council). See : Kaigo Muneomi, ed., *Rinji Kyôiku Kaigi no kenkyû* (Tokyo: Tokyo Daigaku Shuppankai, 1960), especially Hashiguchi Kiku's commentary on 346. For the background of this reform, see also: Takeuchi Yô, *Gakureki kizoku*.

110. Takeuchi Yô, *Gakureki kizoku*, 100.

111. Ibid., 103-05.

analyzes the tensions in French higher education around 1968 in terms of changes in university demographics. The number of students enrolled in French universities more than tripled from 1958 to 1968. French academia accommodated these new students by creating non-tenure jobs, which created well-divided social strata among the faculty. On one hand, this division between those who had power and those who did not caused tension between them. On the other, students were unhappy, because they were packed into over-crowded universities, educated in bad conditions, and had only grim prospects for their employment opportunities after graduation. With these considerations, Bourdieu claims, the crisis of May 1968 appeared almost inevitable.[112]

A similar analysis seems plausible in the case of Japanese students in the 1920s.[113] From 1919 to 1929, the number of students sextupled. This sudden expansion produced several important results in the 1920s and early 1930s.

First, these changes eliminated one reason for students' tolerance of boredom at the university. Meticulous note-taking no longer guaranteed students their future success. Their achievement would not receive any particular acclaim. Rather than participating in pointless competition toward higher grades, students began to devote their time to subjects that interested them. Rather than attending boring lectures, they would read books by their favorite authors.

Second, the expansion of higher education changed the meaning of being a university student. When small in number, the group of university graduates could boast their excellence. The sudden increase of quantity diluted its quality.

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112. Pierre Bourdieu, *Homo Academicus*, translated by Peter Collier (Stanford: Stanford University Press, 1988).

113. Henry DeWitt Smith also identifies the increase in the number of students as one of background factors leading to student activism in the prewar Japan. See, Smith, *Japan's First Student Radicals*, 25-18.

Moreover, when the term "student" indicated being a student at an imperial university, students could identify themselves as part of the establishment supported by the state. Now, after the reform, the category of "student" included students of private universities.

Tosaka Jun, a prominent Marxist philosopher observed in 1930 that those reforms not only promoted private universities, but also changed imperial universities in an essential manner, and consequently, imperial and private universities became similar in nature. Whereas imperial universities used to produce bureaucrats for the government, once the society secured its stability, they degenerated to become incubators of *sararîman* (salaried employees). Private universities, which originally supplied private companies with employees, lost their reason to oppose the government, as the bourgeoisie came to rule the semi-autocratic government.[114]

The reform eventually resulted in serious unemployment problems for university graduates as we have seen above. Since the politicians laid out the expansion plan of higher education mainly to match the number of middle school graduates, it completely ignored the future social demands of university graduates. Presumably, the Hara Kei administration based their expectation of future employment on the most optimistic prospects in the years of post-World War I economic boom. As the expansion of higher education proceeded, an oversupply of college graduate became inevitable. As I mentioned earlier, after a short period of a postwar economic boom, Japanese economy suffered a chronic depression starting in 1920, and university graduates had to face unemployment, which further depreciated the value of a university education.

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114. Tosaka Jun, "Daigakuron," in *Tosaka Jun zenshû*, reprint, 1930 (Tokyo: Keisôshobô, 1966), 384.

Contemporaries observed the relative depreciation of universities and their graduates. In the late 1920s, some Japanese intellectuals, especially Marxists, pointed out the decline of the universities. One of the most famous proponents of this view was Morito Tatsuo, an ex-professor of Kyoto University, expelled because of his paper on Pyotr Alekseyevich Kropotkin. *The Decline of the University,* he discussed the university's place in "cultural history." According to Morito, the university used to be a leading institution of the capitalist and militarist government, and it played a glorious role in Japan's transition from a feudal to capitalist society. Morito claimed, however, that it was able to play a leading role only "as long as capitalism meant a new world, new ideal, and new culture, after feudalism."[115] Then, however, "a new world and a new culture beyond capitalism came into sight." Therefore, the university would no longer lead the society and its people to a new ideal and society. "It is therefore going to decline," he concluded.[116]

The university facilities and faculties had to catch up with the rapid expansion of student body. The mass production of university teachers resulted in a poorer quality of education, and an increase in the number of students in an inferior educational environment. In particular, the larger number of students made the relation between students and teachers less intimate.

Aono Suekichi, for example, argued in 1930 that universities had become business enterprises whose role was to mass-produce students. He claimed that universities, which used to promote cultural developments, now restrained them.[117]

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115. Morito Tatsuo, *Daigaku no tenraku*, 10.

116. Ibid., 40.

117. Aono Suekichi, "Gakusei seizô kabushiki kaisha ron," *Chûôkôron*, May 1930, 54-62.

In the same year, Tosaka Jun deplored the low quality of university and higher school teachers. He mentioned an incident in which a theater had to modify Heinrich Mann's play, *The Blue Angel*. An association of university professors, who took the play's description of a *Gymnasium* professor as an insult to them, protested against its performance. They also mobilized the police and the Ministry of Education to force the theater to change the ending. Tosaka claimed that in fact many university and higher school professors deserved insults. He wrote, "I know two of my friends, who used to work at a provincial higher school. They became so fed up with the stupidity of their colleagues, that they gave up their jobs and came back to Tokyo. Although they received little salary, they felt much better than before."[118] In 1929, Noritaka Keijirô criticized the expansion plan of higher education as the cause of school riots and wrote:

> It was an undeniable mistake of the expansion plan that it treated schools too lightly, as if they were manufacturing factories, which would achieve expected results, if they gave buildings, rules, teachers, and students. . . . A university does not run well without men of character and learning, those who are worthy to be a professor. . . . Lacking talented persons, recent universities and higher schools often give positions to people with inadequate qualifications.[119]

Similarly, Ozusaka Hideo blamed the expansion plan as the fundamental cause of school riots, saying, "The current school system is a system of mass production, and the teacher-student relationship is nothing more than trading of knowledge with salary. Cordial relations between teachers and students can only be expected in exceptional circumstances."[120]

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118. Tosaka Jun, "Daigakuron," 388-89.

119. Noritaka Keijirô, "Kôtô kyôiku kikan kyûzô no hei to urubeki kaigi gakufû," *Teiyû rinrikai rinri kôenshû*, no. 321 (July 1929): 96.

While the total number of university teachers increased along with the number of students, the increase occurred mostly in the number of research associates, assistant professors, and teaching positions at higher schools, not full professors at imperial universities.[121]

This increase in the number of teachers made these junior faculty positions less secure. They were now less likely to become full professors at an imperial university. In particular, a teacher at a higher school had much smaller chance of obtaining a position at a university than before. At the cost of insecurity, they could enjoy more intellectual freedom and independence, being physically and institutionally away from their mentors.

In sum, the 1920s were the time when, using Martin Trow's terms, Japanese higher education began moving from "elite education" to "mass education."[122] The popularization of "university student" changed the nature of being a "student." Students in the Meiji Era were the elite of the country, who were guaranteed future employment as high-ranking government officials or teachers of higher education at universities or higher schools. After 1920, being a student had a completely different meaning. Students could no longer depend on the regime for their careers. They now had to live outside of the establishment.

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120. Ozusaka Hideo, "Gakkô sôdô ron," *Teiyû rinrikai rinri kôenshû*, no. 321 (March 1930): 101.

121. Ito Akihiro, "Kanritsu kôtô kyôiku kikan niokeru kikanbetsu gakububetsu no kyôshokuin kôsei: Joshu posuto no secchi to sono ryôteki hijû," in *Kindai nihon kôtôkyôiku niokeru joshu seido no kenkyû*, edited by Ito Akihiro, Iwata Kôzô, and Nakano Minoru (Hiroshima: Hiroshima Daigaku Daigaku Kyôiku Kenkyû Sentâ, 1990), 15.

122. Martin Trow, *Problems in Transition from Elite to Mass Higher Education*, Carnegie Commission on Higher Education (Berkeley: Carnegie Commission of Higher Education, 1973). It should be noted, however, that higher education in prewar Japan never reached the second phase.

9. Student Rebellions

The new situation after the educational reform anabled students in the 1920s to develop their rebellious cultures. They expressed their rebellion in three ways: school riots, "personalism," and Marxism.

The mid-Taishô period witnessed an increase of school riots. According to Ito Akihiro's statistics taken from newspapers of that time, the number of school riots in each year began to increase in 1920 and reached a hiatus in 1931.[123]

Typically, a school riot started with a student meeting, where students made a resolution regarding their demands to the university authority. Then representatives of the students began to negotiate with the school. When the school rejected the students' demands, students began a strike, occupying the school or the dormitory. They often made allies with other schools. They also tried to advertise their cause to the mass media, parents, the ministry of education, and alumni. The school authority would respond by expelling the leading students or negotiating through mediators (often prominent alumni).[124]

One of the earlier major school riots occurred in the Third Higher School in May 1922, a year before Yukawa and Tomonaga entered. Kaneko Sentarô, the newly appointed president of the school, was a retired army captain who tried to enforce stricter discipline in this school, which was known for its liberalism. For example, he banned unreported absences, and set a limit to the number of absences allowed to students. Students suspected that the increasingly autarchic government was attempting to destroy the liberal atmosphere of the First Higher School.[125]

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123. Ito Akihiro, *Senkanki no kôtô kyôiku*, 144.

124. Ibid., 149-55.

They therefore detested Kaneko and took pleasure in harassing him by addressing him as "Mr. Retired Captain Kaneko," rather than "Mr. President." Interestingly, students did not realize Kaneko had been in education for a long time and had been reasonably successful. Before he came to the Third Higher School, he had been the president of the Sixth Higher School in Okayama. Among the graduates of the Sixth Higher School during Kaneko's time was Nishina Yoshio, who eventually became the boss of some of the recalcitrant young physicists described in this chapter including Tomonaga.

In the spring of 1922, Kaneko fired seven professors, who, he probably thought, were too liberal for his tastes. Those professors usually came to class a little late and gave a high quality and high standard lecture, but only for half an hour, and then used the remaining half an hour to chat over more relaxed topics, such as their experiences in youth. They were extremely popular among the students, who tended to be more inspired by non-academic topics.[126] At the news of the president's decision, students rose against Kaneko, now with a good Confucian cause, namely: "For our mentors!"

The rebellion began at the matriculation ceremony in April. As soon as the president began his ceremonial address for the incoming students, the second- and third-year students began jeering at him and drowned his voice by stamping. At the school festival on May 1, student ringleaders convened an all-student rally and demanded the discharge of the president. The school authority replied with an 8-

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125. Sumitani Etsuji, Takakuwa Suehide, and Ogura Jôji, *Nihon gakusei shakaiundô shi* (Kyoto: Dôshisha Daigaku Shuppanbu, 1953), 105.

126. Kuwabara Takeo, "Mori Sotosaburô sensei no koto: Yokijidai no yoki kyôikusha," in *Kuwabara Takeo Zenshû*, vol. 4 (Tokyo: Asahi Shimbunsha, 1968), 36.

day suspension for all of the students.[127] The students then declared a strike and occupied the school. Representatives of the students went to Tokyo to protest to the Ministry of Education, and then to the official residence of the Prime Minister, to accuse the Ministry of Education.[128]

Ogawa Shigeki, Yukawa Hideki's brother, was among these rioting students. Shigeki was in his first year, but decided to join the rebels and stayed in the dormitory during the strike. Yukawa's father, worried about his son, went to the Third Higher School and negotiated with the student representatives to meet with his son, but the gate remained closed to him. Yukawa, then a middle school student, went with his father, although he did not realize the significance of the strike at that point.[129]

The faculty sided with students. Students organized a "special task force" that, with a flashlight, sneaked under the floor of the faculty council to spy its move, but since the faculty informers told all the inside information to the students, that was an unnecessary valor.[130] The alumni, whose beloved teachers were threatened with being fired, supported the rebellious students. The press and the general public also were sympathetic to the students. The isolated president had no chance to prevail. A mediation of Professor Sakaguchi Noburu at Kyoto University, an alumnus of the Third Higher School, brought an end to the strike. No disciplinary action was to be imposed on the students. The Ministery of

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127. Sakamura Tokutarô and others, *Kurenai moyuru oka no hana: Shashin zusetzu Daisan Kôtô Gakkô 80-nenshi* (Tokyo: Kôdansha, 1973), 57.

128. Sumitani Etsuji, Takakuwa Suehide, and Ogura Jôji, *Nihon Gakusei Shakaiundô Shi*, 106.

129. Yukawa, *The Traveler*, 125-26.

130. Kuwabara Takeo, "Mori Sotosaburô," 44.

Education transferred Kaneko, and replaced him with Mori Sotosaburô, a liberal educator and principal of First Middle School in Kyoto. This complete victory of the student rioters invigorated student activism throughout the country and marked an important example for future radicalism.[131] Liberalism was reinstalled in the Third Higher School, and Yukawa and Tomonaga happily entered the school the next year.

The second type of reactions aimed inwardly. Some students were interested in themselves: in improving and perfecting their personal selves, which was a natural extension of "culturalism" at the higher schools. Abe Jirô's *Santarô's Diary* published in 1913 and his "personalism" based on Theodor Lipps's ethics and aesthetics acquired an enthusiastic popularity among students after World War I.[132] Santarô's Diary was a kind of *Bildungsroman,* a pedantic confession-style novel full of German words and philosophy, and it repeatedly was a best-seller until right after World War II.[133] In themselves, "culturalism" and "personalism" were apolitical, but they could be subversive in certain contexts, especially because the individualism inherent in these ideas was antithetical to nationalism. Abe defined his personalism as follows:

> What is personalism? It is an idea that regards the development of personality as having the supreme value, as far as human life is concerned, and tries to establish values of all other things in relation to the development of personality.[134]

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131. Sumitani Etsuji, Takakuwa Suehide, and Ogura Jôji, *Nihon gakusei shakaiundô shi*, 106.

132. Abe Jirô, *Rinrigaku no konpon mondai* (Tokyo: Iwanami Shoten, 1916); Abe Jirô, *Bigaku* (Tokyo: Iwanami Shoten, 1917).

133. Takeuchi Yô, *Gakureki Kizoku*, 237-8.

134. Abe Jirô, "Jinkakushugi," in *Abe Jirô zenshû* (Tokyo: Kadokawa Shoten, 1961), 71.

Such a belief about values could easily cause conflicts with a more state-centered belief. Indeed, Abe argued that personalism contradicted three kinds of "nationalism":"absolutism" (*zettaishugi*), "statism" (*kokkachûshinshugi,* or *ukokukyôheishugi*), and "imperialism" (*teikokushugi*). "Absolutism" attempts to attain an absolute power over its people, "statism" prioritizes the welfare of the state, and "imperialism" aims at national prosperity by invading and colonizing others. Personalism, Abe contended, opposed these kinds of nationalism.[135]

Yet, Abe claimed that he was a nationalist, in the sense that he was against anarchism, as far as a state could be useful for the development of personality.[136] We cannot know Abe's intent for sure, but his argument could have implied to the students that the current regime was nationalistic in the first three senses, and that those who believed in personalism should therefore revolt against it.[137]

Other students became even more political. They were interested in social issues, but they had different perspectives from students in the Meiji Era. The new students took the side of those who were outside the regime, those who were suppressed. As the suppression of the authority became harsher, student activism became radicalized and eventually they turned to Marxism, and became what people called "Marx boys." The background of the third kind of reactions was the political movement of that time, the so-called Taishô democracy. In the late 1920s, personalism, which was only tacitly and introvertly rebellious, no longer satisfied many students, and Marxism began to overwhelm it. At Tokyo University, the

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135. Ibid., 128.

136. Ibid., 128-9.

137. See also: Ôta Masao, "Kaizô kaihô shisô no nakano chishikijin," in *Taishô dmokurashî* (Tokyo: Kikkawa Kôbunkan, 1994), 71.

center of Marxism activism was *Shinjinkai* (the New Man Society). It was born as a group of social reformist students at Tokyo University in 1918, who supported democratic ideals of Yoshino Sakuzô, a professor there who had been the leader of democratization movement in the Taishô Era. Shinjinkai, however, became radicalized in the 1920s and approached Marxism, by having Japanese Communist Party members in its core.[138] For some students, activities in Shinjinkai occupied their entire student life. For example, a remark by Hayashi Fusao, a writer, who was once a left-wing activist, shows that his college life centered on Shinjinkai rather than the university:

> I was a student of the year of the earthquake.
> In April, 1923, I graduated the Fifth Higher School and entered the Politics Department, College of Law at Tokyo Imperial University. More accurately, I entered "Shinjinkai."[139]

The fraction of students who actively participated in political movements was not large.[140] Yet, the expression of this attitude, the attitude to rebel against the establishment, was not limited to politics. Similarly, among the physics students and young physicists in question, an inclination toward Marxism was rather rare. Such a tendency became visible among young physicists in the 1930s, such as Taketani Mitsuo, Sakata Shôichi, and Tamaki Hajime.

Various forms of rebelliousness, represented by both culturalist students and Marxist youth were, therefore, part of the student cultures in 1920s Japan. Physics students and young physicists experienced similar situations as other students, giving them motives to revolt. Furthermore, various forms of rebellions

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138. Smith, *Japan's First Student Radicals*.

139. Hayashi Fusao, *Bungakuteki kaisô* (Tokyo: Shinchôsha, 1955), 1. His remark at the same time links the earthquake with the students' rebellious culture.

140. Smith, *Japan's First Student Radicals*.

gave them cultural resources to fashion themselves. This, however, does not necessarily mean that physicist youth behaved in the same way as the other students. In what follows, I look closely at what it was like to be these young physicists in the late 1920s, and how some of them eventually found their form of rebellion against the physics establishment.

10. The Physics Department and Postgraduates in Physics

The student body of the physics department was changing in the 1920s. The figure below shows the number of graduates from the Physics Department of Tokyo University. The graph indicates that the years around 1920 were the time of transition for the number of physics students (See Fig. 3.2).[141]

While the total number of university students continued to increase, the number of physics students at Tokyo University did not change much from the late 1920s to the late 1930s. Moreover, the Physics Department of Tokyo University created no chair between1923 until the end of the war. This means that those who entered after 1920 had little chance of getting a job at Tokyo University. However talented students might be, their reasonable expectation was therefore to leave the alma mater and get a job at a private university or a higher school, unless either a new imperial university would be founded and hire them, or their mentor would either retire or die. Therefore, not only were there many physics students after 1920, but they were not needed to fill vacant positions at imperial universities.

As I mentioned earlier, recent graduates of physics departments who wished to be physicists had a few possibilities: a paid assistant or a lecturer for their former mentor, a teacher at a higher school or other institutes of higher

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141. The numbers are taken from Tokyo University's catalogues (*Tokyo Teikoku Daigaku Ichiran*).

education, an unpaid assistant to a professor, and a graduate student. Here I discuss graduate education.

Graduate education in the prewar Japanese university had no structure. Graduate students were supposed to do research under the direction of an academic advisor. Graduates of the same university entered its graduate school without an entrance examination. The term of appointment was two years, which could be extended up to five years with permission of the president and the faculty council. A graduate student had to submit a report about the progress of his or her research project each year. A graduate student, who would like to receive a degree, was able to submit a dissertation after a two-year stay at a graduate school. A graduate student could attend courses offered to undergraduates with permission of the adviser. Courses specifically designed for graduate students might or might not be offered. Graduate students were required to reside near the university, but they were allowed to take other jobs if they were able to show that the job was beneficial to his research.[142] In short, graduate students could do what they liked, with minimum support from the university and its faculty.

Suzuki Akira, for example, was a graduate student in the early 1920s and remembers how it was different from what it is now. There was no obligation and no direct relevance to advanced degrees. Suzuki remembers only a few advantages of being a graduate student. First, a graduate student had a desk in the department and was able to read books and journals in the department. Second, a graduate student was allowed to enter the stack of the main library without much paperwork. In addition, in order to attend lectures in other departments, he had

142. *Tokyo Teikoku Daigaku ichiran, Taisô 8 yori Taisho 9 ni itaru* (Tokyo: Tokyo Teikoku Daigaku, 1920), 98-101.

only to ask the instructor. If one would like to do experiments, the department could make the necessary arrangements within a reasonable limit.[143]

For graduates students and other young physicists who did not have teaching obligations, the only departmental activity was to attend the colloquium. At Tokyo University, the colloquium of the physics department took place once a week from 4 to 6 p.m. First, two undergraduate students made presentations on the papers they had read, then one postgraduate, and finally one faculty member.[144] Once a month, there was an additional talk. They would eat a "lunch"[145] at a university restaurant, and a professor or someone outside the department gave a lecture.

Nakaya Ukichirô, who was a third year student in 1924, recorded the lively discussion at one of these after-supper talks. "One evening in June," Nakaya wrote, "Nagaoka presented a newly arrived book by Bohr, and talked for an hour about an outline of Bohr's theory, which was radically new at that time." As Katsuki shows, the book mentioned here was not Bohr's book, but Helge Holst and H. A. Kramer's book on Bohr's theory.[146] This book was mainly intended for

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143. Suzuki Akira, "Omoide no ki," in *Nihon no butsurigakushi*, edited by Nihon Butsrugakkai (Tokyo: Tokai Daigaku Shuppankai, 1978), 314.

144. This is based on Suzuki Akira's description in Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade*, 60-61. Nakaya Ukichirô, however, wrote that the colloquium took place after a dinner.

145. Suzuki Akira's expression. Probably a light meal provided as a lunch at the restaurant.

146. Helge Holst and H. A. Kramers, *The Atom and the Bohr Theory of Its Structure: An Elementary Presentation*, translated by R. B Lindsay and Rachel T. Lindsay (Copenhagen: Gyldendal, 1923). This can be confirmed by Terada Torahiko's diary on June 17. Since the talk after supper took place once a month, this must be what Nakaya describes. See: Katsuki Atsushi, "Ryôshirikigaku zenya no nihon," 7.

non-scientists, presenting the Bohr theory without relying on mathematics. Nagaoka, who was not averse to mathematics, chose such an elementary book for the colloquium probably because it gave a good overview of the conceptual problems that the Bohr theory faced. The authors write:

> We are inconceivably far from being able to give a description of the atomic mechanism, such as would enable us to follow, for example, an electron from place to place during its entire motion, or to consider the stationary states as links in the whole instead of isolated "gifts from above." During the transition from one stationary state to another we have no knowledge at all of the existence of the electron, indeed we do not even know whether it exists at that time or whether it perhaps is dissolved in the ether to be re-formed in a new stationary state.[147]

Probably inspired by this line of presentation, Terada Torahiko commented: "If an electron goes to the next orbit, it emits light with frequency ν and if jumps over the next orbit to go to another orbit, it emits light with frequency ν'. This is as if the electron knew which orbit it would go to, and emitted light accordingly." Sano Shizuwo, a theoretical physicist mentioned in Chapter 2, went over to the blackboard, and explained, "when an electron jumps to another orbit, it hangs around here for a while, and meanwhile it emits light." He said, "It hangs around here. It's true!" banging on the blackboard with a piece of chalk, as if to show how the electron was hanging around. Terada did not agree, saying, "According to the idea of stationary states, an electron cannot emit light on an orbit. That would contradict the fundamental concepts." Takahashi Yutaka, a young theoretical physicist, proposed another idea. "Suppose an electron departs from an orbit with a certain angle, and reaches another orbit by drawing a spiral. Then, this angle determines the orbit the electron is going to jump to, and therefore the frequency

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147. Holst and Kramers, *The Atom*, 133-34.

of the light it emits." Terada was unconvinced, saying "I cannot accept such an artificial idea."[148]

Although quantum theory found its place within it, the general tendency of the physics department colloquium did not satisfy young physicists. According to Suzuki, sometime after the earthquake the departmental colloquium divided into two parts: one for undergraduate students and the other for professors and graduates of the department. As a graduate student, Suzuki attended the latter colloquium, which began to attract a larger audience. He and other young physicists, however, found the colloquium increasingly useless. It tended to be a mere formality, without any fruitful scientific discussions. Topics were of little importance to mainstream physics. There would not be no progress, they thought, unless there could be freer and livelier discussion.[149]

Furthermore, students and young physicists felt an air of authoritarianism in the department and found it unbearable. In his interview with Katsuki, Suzuki avoided ascribing this atmosphere to anyone, particularly to Nagaoka.[150] Yet, Nagaoka was certainly the dominating figure in the physics department in the 1920s. He alone produced more than half of the publications from the department. And though he probably never intended to be authoritarian, Nagaoka, however, who was nicknamed "Thunderer" (*kaminari oyaji*), was extremely strict, outspoken, and short-tempered.[151] His harsh and critical remarks intimidated

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148. Nakaya Ukichiro, *Terada Torahiko no tsuiso*, 209-10.

149. Suzuki Akira, "Omoide no ki," 310.

150. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade*, 79.

151. As for this aspect of Nagaoka's character, there is an insightful comment by his biographer. See: Itakura Kiyonobu, *Nagaoka Hantarô* (Tokyo: Asahi Shimbunsha, 1976), 5-11.

young physicists, which suppressed freer discussion in the physics department. At the colloquia, Nagaoka always sat just in front of the presenter and dominated the place by bombarding the presenter with questions. This scared undergraduate presenters, one of whom even fainted during the presentation.[152]

Whoever was responsible, authoritarianism within the physics department disgusted Suzuki and the other young physicists in Tokyo. Suzuki explicitly mentions "rebellion against authoritarianism" (kenishugi ni taisuru hangyakushin) as one of the motivations to organize their study group *Butsurigaku Rinkôkai*.[153] For these "student radicals" in physics, forming an independent study group was a natural solution.

11. Young Physicists Began Forming Study Groups

Nitta Isamu writes in his autobiography that two years after he entered Riken (namely in 1925) "two activists (*katsudôka*) joined" and organized a study group in physics.[154] The word *katsudôka* usually refers to a leftist activist. These activists were Fujioka Yoshio and Nakaya Ukichirô, and the study group was the Physics Reading Group in Riken. Fujioka, Nakaya, Suzuki, Konkô, and others, dissatisfied with the colloquium of the physics department, organized their own colloquium, where they could talk about physics with no deference to senior professors.

Since their aim was to undertake unfettered discussion, they made sure that nothing would ruin the atmosphere of their group. When anyone wanted to join

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152. Suzuki Akira, "Omoide no ki," 309; Nitta Isamu, *Nagare no nakani*, 185.

153. Katsuki Atsushi, *Ryôshirikigaku no shokkô no nakade*, 70.

154. Nitta Isamu, *Nagare no nakani*, 186.

them, they voted to decide whether to accept that person. In fact, Suzuki confesses, they rejected some applicants.[155]

Riken provided the place, although it offered no official support. Nevertheless, many Riken affiliates naturally joined the group. Moreover, Riken, a private institution that prided its supremacy over national universities, had fermented a rebellious air. Salaries of Riken were set higher than those at imperial universities to take away better minds from these national institutions.[156] Some analogized a group of Riken with the Fortress of Mt. Liang (*Liang shan bo*) of the Chinese classical novel *Water Margin* (*Shui hu zhuan*),[157] where 108 rebellious heroes fought against the corrupt central government. This meant that this place gathered various talents from outside the establishment.[158] In particular, Terada Torahiko, the senior physicist who backed the Physics Reading Group, seemed to have pushed this analogy further. He told Fujioka or Nakaya that it would be interesting if the Riken, with its excellent minds, would plot a rebellion.[159] He also

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155. Suzuki Akira, "Omoide no ki," 310.

156. Nitta Isamu, *Nagare no nakani*, 169-70.

157. Literary, the story of water margin, one of the most well-read novels in Chinese literature. Partially based on historical facts, this novel tells about the rebellious heroes and heroines in the late Ming Dynasty. Rejected or unjustly punished by the corrupt central government, men and women of various talents gathered in a stronghold called *Liang shan bo,* where they fought and repelled the government forces. This Chinese novel has several English translations with various English titles. The most recent translation is: Naian Shi and Guanzhong Luo, *The Marshes of Mount Liang: A New Translation of the Shui Hu Zhuan or Water Margin of Shi Naian and Luo Guanzhong*, translated by John and Alex Dent-Young (Hong Kong: Chinese University Press, 1994-2001).

158. Tamaki Hidehiko and Iwaki Masao, *Nishina Yoshio* (Tokyo: Kokudosha, 1976), 123.

159. Nitta Isamu, *Nagare no nakani*, 173. Terada's expression conveyed by Nitta

called the young participants of the Physics Reading Group, "gôketsu" (heroes), an expression used for the characters in *Shui hu zhuan.*[160] The participants called themselves *akudô,* or bad boys.

In Kyoto, a few young physicists formed a group around 1927. Tamura Matsuhei, who entered Kyoto University in 1926, had already read Arnold Sommerfeld's *Atombau und Spektrallnien* when he was a third year student of the Fifth Higher School. Tamura was further encouraged by a fellow student, and began reading on quantum theory in his first year at Kyoto University.[161] After he graduated in 1927, Tamura continued his work at Kyoto University, and invited Nishida Sotohiko to study quantum mechanics with him. They thought that they first needed to know various things to understand quantum mechanics. Therefore, they started tutoring themselves with an ambitious attempt to read *Handbuch der Physik* from the beginning.[162] As Tamura himself later said, it was a "reckless" way of learning quantum mechanics.[163] This 24-volume work begins with a volume on the history of physics, then moves to a volume on physical units and their measurements. Quantum theory first appears only in the 23rd volume. It was an excellent way to absorb background knowledge (and it probably helped Tamura to become a historian of physics), but a very tedious and painful approach to quantum

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is not specific enough, but apparently Terada meant an uprising against the government.

160. Suzuki Akira, "Omoide no ki," 310.

161. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Zadankai: Nihon ni okeru soryûshiron no reimei," *Kagaku* 38 (1967): 388.

162. I assume that this was *Handbuch der Physik* by Geiger and Scheel: Hans Geiger and Karl Scheel, eds., *Handbuch der Physik* (Berlin: J. Springer, 1926-29).

163. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 389.

mechanics. Probably because of this, Nishida stopped showing up at this small study group after about five meetings, forcing Tamura to continue alone.[164]

Tamura must have felt relieved when Yukawa and Tomonaga joined him. They entered Kyoto University in 1926 and became Tamaki's advisees in 1928. Tomonaga, who "recklessly" chose to major in quantum mechanics, found that Tamaki Kajûrô, the Professor of Theoretical Physics, knew nothing about quantum mechanics. As he wrote later:

> There were however, a couple of ambitious senior students studying quantum mechanics on their own. They let me join, and gave various advises. Mr. Tamura Matsuhei and late Mr. Nishida Sotohiko were the leaders of these ambitious *modern boys*.[165]

Yukawa, having read Fritz Reiche's book on quantum theory,[166] was determined to study quantum mechanics. For his adviser, he once considered Kimura Masamichi, a spectroscopist, who knew something about quantum theory. He, however, decided not to choose him, because Kimura, being an experimentalist, would require Yukawa to do experiments, which he wanted to avoid.[167] He therefore had to choose Tamaki as his adviser. These ambitious and rebellious students had to study quantum mechanics on their own, defying Professor Tamaki.

Open-mindedly, Tamaki accepted these recalcitrant students. Yukawa, who was probably the least dissatisfied with Tamaki's advising style (or his lack of advising) among the four, associated the group, again, with the Fortress of Mt.

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164. Ibid.

165. Tomonaga Sin-itiro, "Wagashi wagatomo," 196.

166. Fritz Reiche, *The Quantum Theory* (London: Methuen, 1922).

167. Yukawa, *The Travelor*, 163.

Liang because of the variety of interests among the group members.[168] *Watger Magin* (*Shui hu Zhuan*) was his favorite reading in his childhood, having read it more often than any other novels. He later wrote that the very idea of *Lian shan bo,* where many talented "bandits" gathered and did what they liked, without title, obligation, or interference from the authority, attracted him a great deal.[169] He later reflected that such an atmosphere of Tamaki's group was the reason why he chose it. He writes:

> Professor Tamaki had little interest in the new quantum theory, and probably he was perplexed by it; but he always respected the freedom of the people in his research room. As long as one did not step beyond the boundary of theoretical physics, there was no pressure, no matter what one studied. Even if after several years one's work did not bear fruit, that person was not dismissed. Everyone studied at his own pace.[170]

This, however, does not mean that all of Tamaki's disciples were happy. Tamura Matsuhei witnessed that complaints abounded in the Tamaki group, some of which were directed toward Professor Tamaki himself. Tomonaga, much less satisfied than Yukawa, was greatly impressed by Yukawa's ability to forbear complaints.[171]

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168. Yukawa Hideki, *Tabibito: Aru butsurigakusha no kaisô* (Tokyo: Kôdansha, 1966), 233. The corresponding part in the English translation is: Yukawa, *The Travelor*, 164-64.

169. Yukawa Hideki and Ogawa Tamaki, "Shônen jidai no dokusho," in *Gakumon no sekai: taidanshû* (Tokyo: Iwanami Shoten, 1970), 242-70.

170. Yukawa, *The Travelor*, 164.

171. Tamura Matsuhei, "Wakai koro," in *Yukawa Hideki*, edited by Takeo Kuwabara, Takeshi Inoue, and Michiji Onuma (Tokyo: Nihon Hôsô Shuppan Kyôkai, 1984), 236.

12. Modern Boys

As I mentioned above, Tomonaga Sin-itiro later described young physicists in Kyoto (including himself) in the 1920s and 1930s as "modern boys." The "modern boy" and its female counterpart, the "modern girl," were dominant cultural icons in 1920s Japan, an important part of the emerging modernism in the Taishô cultures.

Along with the social, political, economical, and physical changes in the 1920s, more visible changes happened in daily cultural scenes . The 1920s witnessed the emergence of "modernism" in artistic expressions and life styles. Harry Harootunian claims that, whereas Japanese nationalistic intellectuals in the 1930s called for "overcoming modernity," by that time Japan was overcome by modernity.[172] Various forms of modernism had appeared: new fashion, such as Western-style clothes; new kind of literature, such as Yokomitsu Riichi's novels as well as detective stories and scientific fiction; new media, such as motion pictures; new music such as Jazz; new entertainment such as dance; and new sports such as baseball. At the same time, new technology was changing the material culture of everyday life: electrification (70 percent of the households used electric lighting in 1922), new transportation systems (such as trains and buses),[173] introduction of the metric system in 1924, and the inception of the radio broadcasting in 1925.

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172. Harootunian Harry, *Overcome by Modernity: History Culture, and Community in Interwar Japan* (Princeton: Princeton University Press, 2000).

173. For example, the Yamanote line, which ran through the center of Tokyo, was completed in 1925, and drastically improved the convenience of the transportation in Tokyo. Railroad then became a public transportation of everyday use in Tokyo. See: Harada Katsumasa, "Tokyo No Shigaichi Kakudai to Tetsudômô (2): Tetsudômô No Kôsei to Sono Mondaiten," in *Tokyo Kanto Daishinsai Zengo*, edited by Katsumasa Harada and Fumio Shizaki (Tokyo: Nihon Keizai Hyôronsha, 1997), 58

Along with new cultures, new types of people appeared. In many ways, "modern girls," or "moga" as people called them at that time, epitomized the Taishô youth culture. Ôya Sôichirô, a prominent journalist and *Shinjinkai* alumnus who disseminated the word "modern girl" (*modan gâru*), characterized a typical *moga* in 1929 as follows:

> Mrs. A is the prototype of "modern girl" in Japan. At least, this word, "modern girl," was coined by Mr. N, a friend of mine, to describe her . . . First of all, her face is unlike Japanese. . . . Her quick moving eyes and shapely nose make one doubt if she is really a Japanese even when she wears Japanese clothes. . . . She, of course, wears bobbed hair. Nowadays, she wears Japanese clothes, but even in Japanese clothes, she looks more Western than other women in Western clothes . . . Her makeup is very meticulous, and I have no idea how she could manage to paint her face in such details. It might be actually much simpler than it appears, but the way she makes-up, from penciling the eyebrows to manicuring the nails, is a perfect work of craftsmanship.
>
> Talking about craftsmanship, not only her makeup but her whole existence is elaborately crafted. It is as if she has painted her whole language and mind in the way she wears her makeup. It seems that she deliberately controls her facial expressions and bodily movements, as well as the frequencies of her vocal chords. She must be, therefore, very intelligent. But her intelligence is an intuitive intelligence. It was not the kind of intelligence that one could acquire through a continuous effort and thorough reflection, but rather a kind of wit that strikes sudden sparks, like toy fireworks. With her wit, she gives an impression of being caustic, and derides timid men by taking a jump on them. Her modernness becomes most apparent in a dialogue. She has no such thing as feminine modesty. She never says compliments. From the very beginning, she takes her conversant by surprise by making harsh comments to him, especially about his weaknesses, so harsh that even the cheekiest man cannot help feeling annoyed. On the one hand, she is very complex and elaborate. On the other, she can be very simple and straightforward. In appearance, she is always very sophisticated. In reality, she is very savage, vulgar, and even barbaric. . . . Being joyful, gay, sensuous, intelligent, artificial, barbaric, complex, simple, straightforward, she is certainly a typical "modern girl."[174]

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174. Ôya Sôichi, "100% moga," in *Ôya Sôichi zenshû* (Tokyo: Eichôsha, 1981), 11-13. As in the case of Mrs A, a *moga* could be a married woman. Married life, in fact, could provide more opportunities for *moga* to defy the accepted social conventions, as in the case of Naomi in Tanizaki Jun'ichirô's novel mentioned below. See: Jun'ichiro Tanizaki, *Naomi*, translated by Anthony Y. H. Chambers (New York: Knopf, 1985).

"Modern girls" resembled "flappers" in the United States. Those "flappers" with bobbed hair, the generation of young American females in the post World War I era, ignored social norms that their mothers had observed. They drank enormous amount of illegal beverage, smoked endlessly, danced overnight, and had relations with several male friends.[175] First motion pictures, then novels by Scott Fitzgerald and others, conveyed to Japan the appearances and behaviors of flappers, which modern girls in Japan eagerly emulated.

Just like flappers, modern girls were trying to subvert the male-dominant social norms of the Japanese society. As Ôya said, "the *raison d'être* of 'modern girls' was to destroy radically the conventional female ethics, male-female relationship, and life-styles."[176] They behaved in individualistic and anarchic manners and defied communal social values.[177] One example of such a "modern girl" was Fukagani Aiko, a 25-year-old woman, who shot her Italian ex-lover to death in 1925. She appeared in court with bobbed hair and Western clothes, and showed no sign of repentance. The mass media publicized her challenging attitude and behaviors in the courtroom, making Fukatani a symbol of the "modern girl," which drew both positive and negative reactions from the public. Another typical "moga" appeared as a fictional character created by Tanizaki Jun'ichirô in his novel *Naomi* published in 1924. In this novel, the main character Naomi, a Western-

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175. Michael E. Parrish, *Anxious Decades: American Prosperity and Depression, 1920-1941* (New York: W. W. Norton & Company, 1992), 147-49.

176. Ôya Sôichi, "100% Moga," 17.

177. Miriam Silverberg, "The Modern Girl as Militant," in *Recreating Japanese Women, 1600-1945*, edited by Gail Lee Bernstein (Berkeley: University of California Press, 1991), 239-66.

looking beautiful young woman, manipulated and abused her benefactor and husband, Jôji. Tanizaki depicted how this "modern girl" adopted "Western" manners and disobeyed conventional Japanese morality.[178]

Scholars of the Taishô culture pay much less attention to the "modern boy," the male counterpart of the "modern girl." They often consider "mobo" as an uninteresting appendage of "moga." However, broadly considered, the "mobo" marked the emergence of a new generation of urban male youth. Although not as fashionable as modern girls, modern boys had their distinct appearances. For example, they tended to have long hair. Humanities students, arts students and socialists preferred to have long hair, differentiating themselves from middle school students and young people in the countryside, who typically had very short hair. Long hair symbolized modernity and urban life for male youth, just as bobbed hair stood for "modern girls." It constituted their self-identity, distinguishing them from others, in particular from old or rural people. Tsuboi Shigeji, a student at Waseda University around 1920, was such a "modern boys." When he went back home to the countryside, his brother commanded him to have the hair cut short, which he adamantly refused, saying: "For me the question whether to give up my hairstyle was a serious matter, comparable to a question whether a woman should give up her constancy."[179]

Besides appearances, "modern boys" had their own inclination towards new cultural products and new literary styles. Interest in science was part of their self-identity, as one can see in a popular magazine, *Shinseinen* (New Youth). As the title suggests, *Shinseinen* was a popular magazine targeted at young males. In

178. Tanizaki, *Naomi*.

179. Tsuboi Shigeji, "Kokuban no nai gakkô," in *Wakaki hi no kiseki* (Tokyo: Gakuseishobô, c1947), 76.

the 1910s, its readership consisted of urban youth.[180] In fact, Yokomizo Seishi, once the editor-in-chief of this magazine, but also well known for his own detective stories, wrote that "shinseinen" meant "modern boy" in English.[181] In Hamada Yûsuke's expression, "*Shinseinen* in this period [1927-1937] was a magazine by modern boys and for modern boys."[182] Shinseinen offered these "modern boys" detective stories, scientific fiction, and popular accounts of science.

Shinseinen shows that scientific fiction and fantasies constituted part of the Taishô youth culture. According to Sekii Mitsuo, many works in this genre were published in *Shinseinen* in the 1910s.[183] In 1928, Sano Shôichi, an electrical engineer at the Ministry of Communications' Elestrical Testing Laboratory, began publishing popular articles on science in this magazine. In the 1930s, he started publishing his scientific fictions in this magazine under his, now much better known, pseudonym, Unno Jûza.[184] Unno thus became Japan's pioneer of scientific fiction.[185]

In quality and quantity, however, detective stories overwhelmed scientific fictions in *Shinseinen.* Detective stories were acquiring eminence in Japan in the Taishô Era as a new literary field. Prominent detective story writers, such as Edogawa Ranpo, Yumeno Kyûsaku, and Oguri Mushitarô, published many of their

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180. Karasawa Takako, "*Shinseinen* no tanjô to sono jidai," in Shinseinen dokuhon, Shinseinen Kenkyûkai (Tokyo: Sakuhinsha, 1988), 6.

181. Shinseinen Kenkyûkai, *Shinseinen dokuhon* (Tokyo: Sakuhinsha, 1988), 78.

182. Ibid., 098.

183. Sekii Mitsuo, "Kagaku bannô no romanticism," in *Shinseinen dokuhon*, edited by Shinseinen kenkyûkai (Tokyo: Seidosha, 1988), 32-35.

184. Also known as Unno Jûzô.

185. Unno Jûza, *Taiheiyô majô*, vol. 6 of *Unno Jûza zenshû* (Tokyo: San'ichi Shobô, 1989).

works on this magazine. These authors regarded detective stories as a serious literary genre, where art and science met. In a detective story, rational reasoning, or even scientific methodology, played an essential role. In their efforts to elevate this genre, authors of detective stories had to cope with the tensions between science and literature in their works. Some, in their effort to reconcile the two, recreated science into an aesthetic form, or appropriated it to adorn stories. For example, Oguri Musihtarô, a good friend of Unno Jûza, filled his 1935 Poesque story, *Murder in the House of Black Death,* with references to relativity theory.[186]

Yumeno Kyûsaku was another prominent writer of detective stories, publishing most of his stories in *Shinseinen.* His attitude toward science was more complex than Oguri's. Whereas he recognized the affinity between science and his genre, he was at the same time critical to science. In his article "Reply to Mr. Kôga Saburô,"[187] he discusses the nature of the detective story. According to him, the detective story is a heretic of arts, where "human psychology is dissected, analyzed, vitriolyzed, poisoned, atomized, and even electronized." It is a "rebellious art, of which specialty was to blaspheme the Muses." He then claims that "Such a taste and tendency coincide with the taste and tendency, or instinct of those who are scientifically oriented."

> Science has debunked all the sacred, the beautiful, and the mysterious. In particular, it has discredited the beauty and the mystery of the universe created by the God. It investigates the mystery to the bottom, and derides it claiming it being numerically no more than an effect of electrons. Science analyzes belief thoroughly, and exposes it just as a mathematical expression of an egoistic mind. ...
> Therefore, scientists, the creators of the modern civilization, were all men of detective mind, who rebelled against God and morality. Their writings

186. Oguri Mushitarô, *Kokushikan satsujin jiken*, reprint, 1935 (Tokyo: Shinchôsha, 1990).

187. Koga was another detective story writer, who actively published in *Shinseinen*.

> were, therefore, expressions of the most pragmatic detective mentality. Their chemicals and machines were nothing but criminal instruments to destroy and ridicule the God and nature.[188]

Yumeno, who detested science and the modern civilization that it presumably created, defined the mission of the detective story as an attempt to direct such a "detective" attitude of science toward the civilization and social mechanisms that science and scientific mentality produced. By doing that, he hoped, the detective story would eventually wake up the human conscience and innocence hiding behind all of the grotesque and bizarre beauty that the detective stories depicted.[189]

We have no reason to believe that the readers of *Shinseinen* shared Yumeno's agenda to turn what he conceived as "scientific attitude" against science, for which they would have needed exterior motives, such as religious belief. It is, however, more likely that those modern boys reading *Shinseinen* were exposed to the idea that science was inherently rebellious, debunking the old values, religion, and aesthetics, and that the detective story was an application of scientific mentality in literature.

"Modern girls" and their male counterpart "modern boys" rebelled against old values, paying little respect to the conventional morality and the authority of the existing social system. They accepted enthusiastically the new way of life imported from the West and indulged in new forms of the arts. Tomonaga and other young physicists, who were not modern boys in a literal sense, nevertheless shared an aspiration toward novelty, a sense of rebellion, and a revolt against authority that marked this group of young physicists as "modern boys."

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188. Yumeno Kyîsaku, "Kôga Saburô shi ni kotau," in *Ymeno Kyûsaku zenshû*, vol. 7, reprint, 1935 (Tokyo: Sanichishoboô, 1970), 369-75.

189. Ibid.

13. Study Groups and Student Radicals

As Nitta Isamu figuratively called Fujioka and Nakaya "activists,"[190] forming a study group was a standard tactic of student activists in political movements. Study groups that organized student radicals in literal sense had structural similarities to those of the young discontents in physics.

Japan saw a rise of student activism in the 1920s. Already in the 1910s, there were student political groups that advocated democratization of Japan. For example, *Shinjinkai* was founded in 1918. In the early 1920s, student radicals at many schools (universities, higher schools, and trade schools), organized study groups for the "social sciences," very often called *Shakai kagaku kenkyûkai* (Social Sciences Study Club), or "shaken." These study groups offered reading seminars in the "social sciences," which consisted of Marxist-Leninst literature. The weekly schedule of the study groups of the "Shaken" at Kyoto University in 1924 shows the standard readings of these study groups:[191]

Monday: Lenin, *Staat und Revolution*[192]

Tuesday: Engels, *Grundsaetze des Kommunismus*.[193]

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190. See Section 10; Nitta Isamu, *Nagare no nakani*, 186.

191. Kikukawa Tadao, *Gakusei shakaiundô shi*, reprint, 1931 (Tokyo: Kaikôsha, 1946), 226.

192. Vladimir Ilich Lenin, *Staat und Revolution: die Lehre des Marxismus vom Staat und die Aufgaben des Proletariats in der Revolution* (Berlin-Wilmersdorf: Verlag die Aktion (Franz Pfemfert), 1918).

193. Friedrich Engels, *Grundsätze des Kommunismus: eine gemeinverständliche Darlegung von Friedrich Engels.* (Berlin: Buchlandlung Vorwärts P. Singer, 1914).

Engels, *Development of socialism from Utopian to Scientific*[194]

Wednesday: Marx u Engels, *Das Kommunistische manifest.*[195]

Thursday: Bucharin, *Das A. B. C. des Kommunismus.*[196]

Friday: Borchardt, *People's Marx. Value, Price & Profit*.[197]

Saturday: Bucharin, *Theorie des historischen Materialismus*[198]

These were standard readings in a "shaken" of many schools, including the largest and the most academic "shaken" of Tokyo University. In 1923, Shinjinkai established the Social Science Study Club as a member organization of the Student Association (*Gakuyûkai*). The Student Association was an umbrella organization that included various athletic and non-athletic extracurricular clubs of the university, and it was then undergoing a reform led by Shinjinkai activists. The membership of Tokyo University's "Shaken" reached a few hundred,[199] thus

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194. Friedrich Engels, *Development of Socialism from Utopia to Science*, translated by Daniel de Leon (New York: New York Labor News Co.).

195. Karl Marx and Friedrich Engels, *Das kommunistische Manifest: mit den Vorreden von Karl Marx und Friedrich Engels und einer Einleitungvon Rosa Luxemburg* (Wien: Verlag der Arbeiter-Buchhandlung, 1926). It is of course not clear which edition they used.

196. Nikolai Ivanovich Bukharin, *Das ABC des Kommunismus: Populäre Erläuterung des Programms der Kommunistischen Partei Russlands (Bolschewiki): mit Illustrationen von Wladimir W. Majakowskij und einer Einführung von Boris Meissner*, reprint, 1920, Manesse Bibliothek der Weltgeschichte (Zürich: Manesse, 1985).

197. Julian Borchardt, ed., *The People's Marx: Abridged Popular Edition of the Three Volumes of "Capital"* (International Bookshop, Ltd, 1921).

198. Nikolai Ivanovich Bucharin, *Theorie des historischen Materialismus: gemeinverständliches Lehrbuch des Marxistischen Soziologie*, Frida Rubiner (Hamburg: Verlag des Kommunistischen Internationale, 1922).

forming a university inside a university. The topics studied at this club included: law, politics, literature, agriculture, social medicine, engineering, economics, and philosophy. Disgusted by the university lectures of professors who as always read their lecture notes in a singsong manner, students activists chose and invited lecturers from inside and outside the university. Few participants were actually activists; most were just serious students disappointed by the university courses, and interested in the newest theories in the social sciences, which happened to be Marxism. Both tacitly and explicitly, the "Shaken" criticized the low quality of education at Tokyo University, taking a confrontational stance. Kikuchi Tadao, a Shinjinkai activist, wrote in 1931 that the conservative factions of the university hated the Shaken so much that they were determined to destroy this organization. After a few of their attempts failed, conservative professors dismantled the Gakuyûkai itself.[200] According to Kikuchi, "It was because the 'Shaken' had such a rebellious nature."[201]

In addition to the study groups, Shinjinkai activists were involved in translation of Marxist classics. In particular, there are two important multivolume achievements. One was the 10 volume *Writings of Lenin* (Rênin chosakushû),[202]

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199. Henry Smith estimates that the membership of the Social Science Study Club reached three hundred in its apex. See: Smith, *Japan's First Student Radicals*, 147, note 39.

200. Kikuchi's perception was not accurate, and right-wing students seem to have played a more important role in the demise of the Gakuyûkai than conservative faculties. The Gakuyûkai was dissolved in 1928. The immediate cause was the withdrawal of athletic clubs from the Gakuyûkai, which was triggered by the right-wing student organization Shichiseikai (Seven Lives Society), who were discontent with the Shinjinkai dominated Gakuyûkai. See: Smith, *Japan's First Student Radicals*, 156-61.

201. Kikukawa Tadao, *Gakusei shakaiundô shi*, 194-95.

202. *Rênin zenshû* (Tokyo: Hakuyôsha, 1925-27).

edited and translated by Shinjikai members. The other was the 27 volume *Collected Works of Marx and Engels* (Marukusu Engerusu zenshû),[203] which was translated by Shinjinkai's allumni, such as Yamamoto Umashi and Sakisaka Itsurô.[204]

The literal student radicals in the 1920s thus reacted to the poor university education with rebellion, sought after a new kind of social sciences, organized study groups, and engaged in translation of the canonical texts. Their activities were, therefore, parallel to those of the young physicists whom I metaphorically call the "student radicals" in science.

14. Understanding Quantum Physics

The participants of the Physics Reading Group gathered to read recently published papers in physics, many of which were on quantum mechanics. It was highly contingent, but not completely accidental that these ambitious physicists chose quantum mechanics. Since their motivation was to revolt against the physics establishment and authority, they chose new subjects for their readings. 1925 and 1926 happened to be the time the foundational works on quantum mechanics appeared. At the University of Tokyo, although Nagaoka was reading papers on quantum mechanics, no one was researching it, and there was no course on quantum mechanics until 1928.

The physicists in the Physics Reading Group read Heisenberg, Schrödinger, Dirac, de Broglie and other founders of quantum mechanics. They wrote Japanese digests of these papers, which were about one-third of their original length and published them as volumes for Iwamami Shoton, one of Japan's leading academic

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203. *Marukusu Engerusu zenshû* (Tokyo: Kaizôsha, 1928-34).

204. Smith, *Japan's First Student Radicals*, 134.

publishers. More than half of the papers in the first volume dealt with topics on quantum mechanics.[205]

After Doi's sketch of the early quantum theory, Shiba Kamekichi offered a shortened translation of Louis de Brolie's long paper, "Recherches sur la théorie des quanta," (originally) published in 1924, in which de Broglie systematically presented his notion of matter wave.[206] Kiuchi Masazô and Suzuki Akira picked up the second and third reports of Erwin Schrödinger's "Quantisierung als Eigenwertproblem," which contain the essential part of Schrödinger's wave mechanics.[207] Fujioka Yoshio took Heisenberg's "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," the very paper that laid the foundation of quantum mechanics.[208] Konkô Masamichi abridged and translated Max Born and Pascual Jordan's first explicit formulation of matrix mechanics.[209] And, again, Fujioka presented P. A. M. Dirac's q-number formulation of quantum mechanics, combining his two papers: "The Fundamental Equations of Quantum Mechanics," and "Quantum Mechanics and a Preliminary Investigation of the Hydrogen Atom."[210]

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205. Butsurigaku Rinkôkai Dôjin, *Butsurigaku bunkenshô 1* (Tokyo: Iwamami Shoten, 1927).

206. de Broglie, "Recherches sur la théorie des quanta."

207. Erwin Schrödinger, "Quantisierung Als Eigenwertproblem, Zweite Mitteilung," *Annalen der Physik* 79 (1926): 489-527; Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Dritte Mitteilung," *Annalen der Physik* 80 (1926): 437-90.

208. Heisenberg, "Über quantentheoretische Umdeutung."

209. Max Born and Pascual Jordan, "Zur Quantenmechanik," *Zeitschrift für Physik* 34 (1925): 858-88.

210. Paul Maurice Adrian Dirac, "The Fundamental Equations of Quantum

In those abridged translations, the young physicists added relevant scientific and historical background, summarized lengthy arguments, omitted materials that did not interest them, combined two papers into one if necessary, and corrected mistakes in the original papers.

For example, to his translation of Heisenberg's "matrix mechanics" paper, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," Fujioka Yoshio gave his own title, "Foundation of New Quantum Mechanics,"[211] and added an introduction to explain the prehistory of this seminal paper, particularly in regards to the correspondence principle and quantum conditions. Furthermore, he corrected a mistake in this chapter. In preparation for his discussion of the non-harmonic oscillator, Heisenberg reformulated the quantum condition within his scheme. Starting from Bohr's quantum condition, he inserted a Fourier expansion of the coordinate, and differentiated it by the principal quantum number. The result was equation 16 on p. 886, which coincided with Kramers' dispersion relation. Heisenberg, however, erred in one of the signs in this equation, which should be plus instead of minus.[212] In his digest, Fujioka corrected Heisenberg's mistake, using the correct minus sign.[213]

More importantly, Fujioka projected his conception of a break between classical and quantum mechanics in a more explicit manner than Heisenberg

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Mechanics," *Proceedings of the Royal Society of London, Series A* 109 (1925): 642-53; Paul Maurice Adrian Dirac, "Quantum Mechanics and a Preliminary Investigation of the Hydrogen Atom," *Proceedings of the Royal Society of London, Series A* 110 (1926): 561-79.

211. In Japanese, "Shin ryôshirikigaku no kiso."

212. Heisenberg, "Über Quantentheoretische Umdeutung," 886.

213. Fujioka Yoshio, "Shin Ryôshirikigaku No Kiso," in *Butsurigaku Bunken Shô*, vol. 1, Butsurigaku Rinkôkai Dôjin (Tokyo: Iwanami Shoten, 1927), 116.

himself. To support his move to restrict the physical quantities to the only observable ones, Heisenberg claimed that the hope that so-far unobservable quantities would be some day accessible was justifiable only when the rules of early quantum theory were internally consistent and applicable in a certain well-defined domain of quantum-theoretical problems. Experiments, however, showed that those rules did not work in some cases. Heisenberg mentioned, for example, the case of an atom with multiple electrons.[214]

On the other hand, Fujioka gave a different justification for Heisenberg's positivistic move. According to Fujioka, the reason the rules of early quantum theory did not work was "normally considered to be the fact that it was impossible to determine the motion of electrons in a stationary state, namely it was impossible to solve problems of classical electromagnetism." Fujioka, then, claimed that since quantum theory denied classical electromagnetism, it was inconsistent to use classical electromagnetism in atomic theory, and to be unable to complete it because of the problems caused by classical electromagnetism. "Rather," Fujioka argues, "quantum theoretical atomism should be completely independent of classical theory even in the treatment of the simplest problem."[215] Although both of their arguments do not appear adequate, it is clear that Fujioka made Heisenberg's theory a more radical break from classical theory, a clearer departure from the past, than Heisenberg himself presented.

In Kyoto, young physicists' efforts were less coordinated. Yukawa and Tomonaga started their work on quantum mechanics with Max Born's *Probleme der Quantenmechanik,*[216] which Yukawa read in 1926,[217] and Tomonaga, in

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214. Heisenberg, "Über Quantentheoretische Umdeutung," 879.

215. Fujioka Yoshio, "Shin ryôshirikigaku no kiso," 107.

1928.[218] This book was a publication of Born's lectures at MIT from November 1925 to January 1926.[219] It was a very up-to date set of lectures on the current status of quantum mechanics. Starting with the difficulties asscoaited with the old quantum theory, it presented the contents of Heisenberg's first paper on matrix mechanics, Born and Jordan's formulation of Heisenberg's theory, a more systematic formulation and some new developments of this theory in the so-called, *Dreimänner Arbeit*, and a treatment of the aperiodic system by operators, which Born and Norbert Wiener were developing at MIT. The last two papers were not in print when the lectures were delivered.

Written before Schrödinger's wave mechanics, Born thought that the discreteness implied by various quantum numbers, was the essential character of quantum mechanics, and began this book with an audacious claim that physicists were near the final formulation of the indivisible, the ideal sought after since Democritus.[220] Yukawa considered that Born was claiming "Space-time might be discrete, everything might be discontinuous," and was attracted and "agitated" by the very radicalness of these ideas.[221] He, however, was greatly frustrated and

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216. Max Born, *Probleme der Atomdynamik* (Berlin: Verlag von Julius Springer, 1926).

217. Yukawa Hideki, *Tabibito*, 220. The translators of this book erroneously write the title of Born's book as "Mechanics of the Atom": Yukawa, *The Travelor*, 154-55.

218. For example, Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 390.

219. Max Born, *Problems of Atomic Dynamics: Two Series of Lectures on: I. The Structure of the Atom (20 Lectures), II. The Lattice Theory of Rigid Bodies (10 Lectures),* (Cambridge: Massachusettes Institute of Technology, 1926), ix.

220. Ibid., 1-3.

221. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 390.

angered by Paul Dirac's earlier papers on q-number,[222] which he could not understand. He, then, found Schrödinger's wave mechanics papers much easier to understand and turned to the continuous *Weltanschauung* of wave mechanics.

Similarly, Tomonaga turned to wave mechanics soon. He did not understand Dirac's papers, either, and one of "various suggestions" he received from Tamura Matsuhei in his third year at the university was that he should start with wave mechanics rather than matrix mechanics because linear algebra would be too difficult for him.[223] He was recommended Schrödinger's book, *Abhandlugen der Wellenmechanik,*[224] a collection of Schrödinger's original papers on wave mechanics.[225]

Both in Tokyo and Kyoto, young physicists' choices to study quantum mechanics were contingent in the sense that they perceived certain intrinsic characters of quantum mechanics that induced them to study it. Originally, young physicists in Tokyo had no intention to study quantum mechanics (Indeed, the second volume of their publication did not contain any papers on quantum mechanics). They happened to form their study group in 1926, when quantum mechanics papers had just appeared. What attracted them was the novelty of quantum mechanics. This was also the case in Kyoto to some extent, although Tomonaga and Yukawa saw "mysteriousness" in quantum mechanics that attracted them.

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222. Dirac, "Fundamental Equations"; Dirac, "Quantum Mechanics and a Preliminary Investigation."

223. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 390.

224. Erwin Schrödinger, *Abhandlungen zur Wellenmechanik* (Leipzig: J. A. Barth, 1927).

225. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 390.

As it turned out, however, besides its novelty, quantum mechanics offered these young physicists something different from classical mechanics or electromagnetism. Problems in classical physics and electromagnetism were in theory solvable through calculation, often lengthy and dry manipulation of equations. The difficulty was not really physics, but mathematics. Quantum mechanics required more than calculations, however. Young physicists had to understand physical principles, different from classical mechanics. They had to learn new physical concepts, such as wave-particle duality, spin, q-number, and the wave function.

As I discussed in the previous chapter, the appreciation of advanced mathematics and meticulous calculation, what I call the "culture of calculating," dominated the previous generation of theoretical physics in Japan. Theoretical physics in this culture required advanced mathematics and exceptional calculational skills for increasingly complicated problems in hydrodynamics, electromagnetism, and mechanics, using the same physical principles of classical mechanics and electromagnetic theory.

Yamanouchi Takahiko, a student of Terezawa Kwan-iti, was trained in such a tradition of theoretical physics, although he was about the same age as Suzuki and Tomonaga. Both extremely talented and well-trained in mathematics, he had mastered mathematical approaches to physics by perusing Courant and Hilbert's *Methods of Mathematical Physics,*[226] before he began reading the foundational papers of quantum mechanics. He had no problem understanding those papers in terms of mathematics. He understood Heisenberg's seminal paper as a natural extension of the correspondence principle, which he knew through

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226. Richard Courant and David Hilbert, *Methoden der Mathematischen Physik*, Die Grundlehren der Mathematische Wissenschaften in Einzeldarstellungen (Berlin: Springer, 1924).

Nagaoka's course on quantum theory. He could almost notice that Heisenberg's calculations were those of matrices, since he knew matrices through the course of the famous mathematician Takagi Teiji at Tokyo University. Although Schrödinger's papers on wave mechanics impressed Yamanouchi with their mathematical neatness, they were not exciting to him. Having mastered the Courant-Hilbert volumes, the problem of eigenvalues was too familiar and too easy.[227] Only Herman Weyl's *Quantum Mechanics and Group Theory* attracted him.[228] In 1932, Yamanouchi translated into Japanese this obtuse book , which repelled even mathematically savvy quantum physicists such as Schrödinger.[229] In short, Yamanouchi, able and loyal heir of the mathematical tradition of Japanese theoretical physics, was too talented to realize the radical significance of quantum mechanics.

For younger physicists, the contrast between the newly emerging theoretical physics and the "Culture of Calculating" must have been even more acute. Nagamiya Takeo was a slightly younger physicists in the Terazawa school, who graduated from the physics department in 1933 and joined Terazawa's group at the Department of Dynamics in the College of Engineering as a research associate. He wrote that theoretical physics in Japan began to develop about 1933. "We had to experience a 'struggle' to escape from the spell of classical theoretical

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227. Nishijima Kazuhiko, Yamaguchi Yoshio, and Yamanouchi Takahiko Tomonaga Sin-itiro, "Zadankai ryôshirikigaku no shôgeki to taiken," in *Ryôshirikigaku: Tanjô kara 60-nen* (Tokyo: Saiensusha, 1984), 11-12.

228. Herman Weyl, *Gruppentheorie und Quantenmechanik* (Leipzig: S. Hirzel, 1928).

229. Hermann Weyl, *Gunron to ryôshi rikigaku*, translated by Yamanouchi Takahiko (Tokyo: Shôkabô, 1932).

physics or applied mathematics and to create theoretical physics in the new age."[230] He probably failed to escape. As a research associate of the Dynamics Department, Nagamiya busied himself with calculations about the hydrogen molecule. "During my three years as a research associate, I learned applied mathematics, dynamics, and the attitude to do science." To explain the desirable attitude of a scientist, he mentioned Yamanouchi's comment on Nagamiya's presentation at a conference during this period, where Nagamiya presented the results of his calculations. Yamanouchi said that Nagamiya's was the only significant presentation at the conference. Nagamiya considered this comment to imply what scientific research should be like: Similar to his own calculations on hydrogen molecule, scientific research should be an indisputable and laborious work that would make a little advancement. Nagamiya considered that trying to produce such research should be scientists' attitude.[231]

The young physicists in this chapter apparently opposed such a tradition. Terada Torahiko, who masterminded those younger physicists in Tokyo, made it explicit in his diary in the entry of March 1926 the month when the first meeting of the Physics Reading Group took place: "Today's dead pedagogy is out of date. Hydrodynamics is no longer a study on the motion of water. It just provides practice problems of mathematics,"[232] which, as Katsuki claims,[233] might came from Terada's contact with the "student radicals" in science. Similarly, in Kyoto,

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230. Nagamiya Takeo, "Senpai kara uketsuida gakumon no nayami," in *Waga shi waga tomo*, edited by Hagiwara Yûsuke (Tokyo: Misuzu Shobô, 1967), 104.

231. Ibid., 112.

232. Terada Torahiko, *Nikki 3*, vol. 13 of *Terada Torahiko zenshû bungakuhen* (Tokyo: Iwanami Shoten, 1951), 336.

233. Katsuki Atsushi, *Ryôshirikigaku No Shokkô No Nakade*.

Professor Tamaki invited Tamura to study hydrodynamics (which was Tamaki's specialty) when he was a graduate student, but Tamura adamantly refused, saying that hydrodynamics was something that people should do in the college of engineering, not in the college of science.[234] Neither did Yukawa like calculating. Later he joked that Heisenberg's *Principles of Quantum Physics* was a good book because it contained few equations in the text, most equations being in the appendix.[235] Certainly, these young Japanese physicists felt a strong sympathy to Heisenberg, whose mathematical and calculations skills were not outstanding. Later, partially defending himself, Heisenberg expressed a skepticism toward rigorous mathematical approaches, claiming that "dirty mathematics" might be more useful to achive a scientific break through, because one would be forced to link the theory to experiment when using non-rigorous "dirty mathematics."[236]

It was, therefore, not the case that cultural rebellion and certain intrinsic characteristics of quantum mechanics compelled young physicists to study this physical theory. Rather, they discovered it accidentally, induced by cultural circumstances and the historical contingency of the emergence of quantum mechanics. Quantum mechanics, however, enabled them to see in it what they wanted.

15. Conclusion

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234. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 389.

235. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Reimei," 394. As Heisenberg's book indicates, Yukawa was exaggerating. There are still many equations in the text. The fact that this book made such a strong impression on him supports my point even more eloquently.

236. Werner Heisenberg, "Theory, Criticism and a Philosophy," in *From a Life of Physics*, Hans A. Bethe, et al. (Singapore: World Scientific, 1989), 44.

Quantum mechanics found a favorable niche in a part of Japanese culture in the 1920s. Quantum mechanics would not have traveled automatically from Europe to Japan only because it was proven correct or it was the latest development in physics. For this relocation to take place, quantum mechanics had to find an accommodating culture, of which it could be a part.

Those young physicists, such as Tomonaga or Suzuki, who initiated quantum mechanics research in Japan were not political radicals in a literal sense. Nor were they barbaric higher school students or modern boys. Yet, these young physicists had a close contact with those types, shared some of their cultural resources, and, to some degree, espoused the same values. In this sense, the young physicists shared with other contemporary youth the "culture of rebellion," where the conventional values were challenged, the authority of the establishment was diminished, and novelty and the break from the tradition were appreciated.

In this culture of rebellion of young Japanese physicists, quantum mechanics fit well. Quantum mechanics was, above all, new. Moreover, it challenged the old style of physics. Not only did it break from classical physics, but working on quantum mechanics required a different kind of research style from the dominant style of theoretical physics in Japan, or what I call the "culture of calculating."

Thus, quantum mechanics acquired a local meaning in the culture of rebellion of the young physicists in late 1920s Japan. Studying quantum mechanics was a tacit act of rebellion against the authoritative physicists, an act of defiance to the old professors who could not understand it, and a leaping board from the conventional style of Japanese theoretical physics to a new theoretical physics.

Rebellion only, however, did not prove constructive. Most of these young physicists fell short of producing creative works in the field of quantum physics.

Most of the young physicists in the Physics Reading Group did not become a research physicists in theoretical physics. Many of them became experimentalists, and not all of them worked on quantum mechanical phenomena. The establishment of a new research tradition of theoretical physics required more than a break from the conventional style of physics. For this, the rebellious young physicists had to wait for an able leader and organizer.

Table 3.1 Participants of *Butsurigaku rinkôkai*

Founding Members

Doi Uzumi

Konkô Masamitsu

Shiba Kamekichi

Suzuki Akira

Fujioka Yoshio

Nakaya Ukichirô

Senior Participants

Terada Torahiko

Nishikawa Shôji

Others

Fukuda Mitsuharu

Kiuchi Masazô

Sasaki Jirô

Nitta Isamu

Kikuchi Seishi

Tsuboi Chûji

Tomiyama Kotarô

Suga Tarô

Table 3.2 Table of Contents of *Butrusigaku Bunkenshô,* vol. 1.

1. "Outline of the early quantum theory" by Doi Uzumi.
2. Louis de Broglie, "Recherches sur la théorie des quanta," *Annale de physique*, 31, 1925 22, translated by Shiba Kamekichi.
3. Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Zweite Mitteilung," *Annalen der Physik,* 79, 1926: 489, translated by Kiuchi Masazô.
4. Erwin Schrödinger, "Quantisierung als Eigenwertproblem, Dritte Mitteilung," *Annalen der Physik,* 80, 1926: 437, translated by Suzuki Akira.
5. Werner Heisenberg, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," *Zeitschrift für Physik,* 33, 1925: 879, translated by Fujioka Yoshio.
6. Max Born and Pascual Jordan, "Zur Quantenmechanik," *Zeitschrift für Physik,* 34, 1925: 858, translated by Konkô Masamichi.
7. P. A. M. Dirac, "The Fundamental Equations of Quantum Mechanics," *Proceedings of Royal Society,* A 109, 1925: 642; and P. A. M. Dirac, "Quantum Mechanics and a Preliminary Investigation of the Hydrogen Atom," *Proceedings of Royal Society,* A 110, 1926: 561, translated by Fujioka Yoshio.
8. "A Part of a Paper on Nuclear Structure Conjectured from Radioactivity" by Kikuchi Seishi.
9. F. Paschen, "Serienenden und molekulare Felder," *Sitzungsberichte (Preuss.),* 16, 1926: 135, translated by Fukuda Mitsuharu.
10. R. W. Wood, "Self-Reversal of the Red Hydrogen Line," *Philosophical Magazine,* 2, 1926: 876, translated by Nakaya Ukichirô.
11. "On Langmuir's Theory of Mono-Molecular Layer" by Nakaya Ukichirô.
12. "X-ray and Long-Chain Organic Compounds" by Nitta Isamu.
13. "On X-ray Scattering Power of the Atom in Crystal," by Tsuboi Chûji.

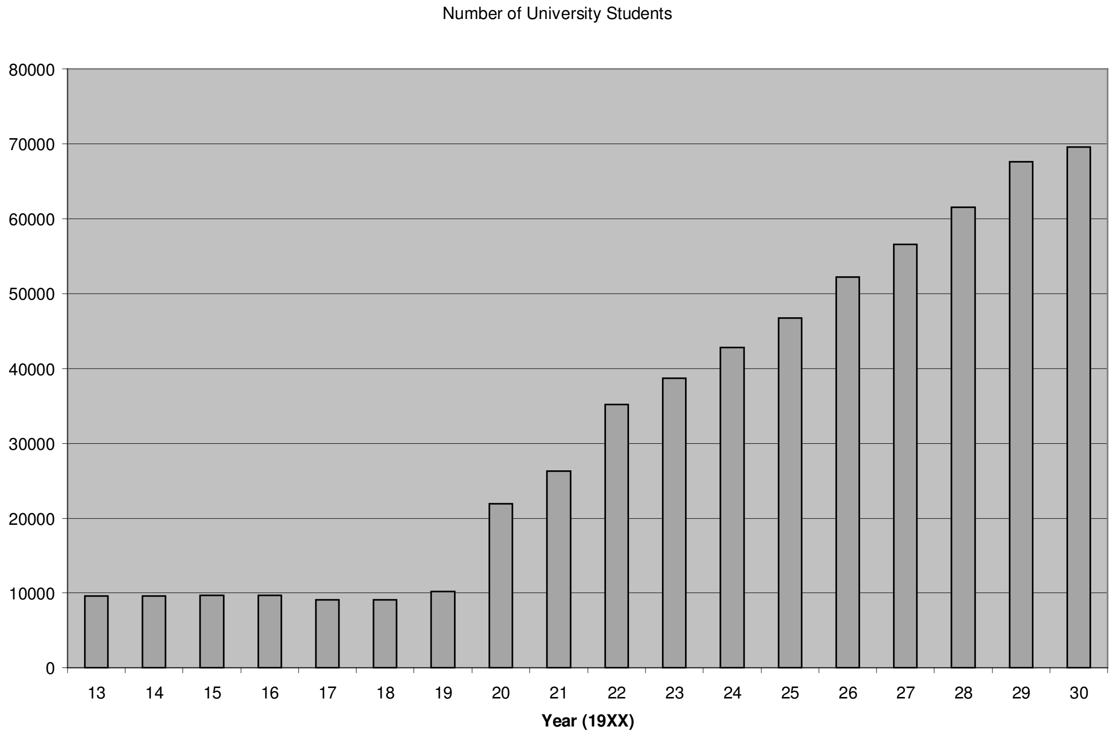

Fig. 3.1 Number of University Students

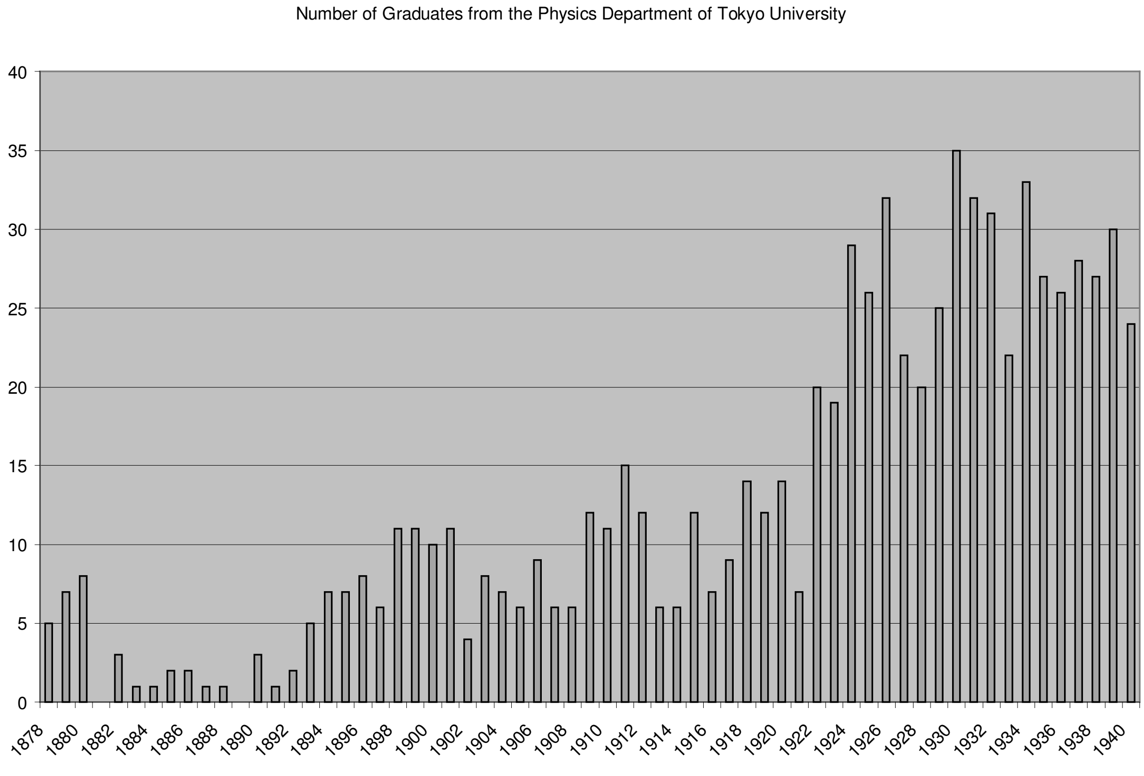

Fig. 3.2 Number of Graduates from the Physics Department of Tokyo University

Chapter 4
Superposing Dynamos and Electrons:
Electrical Engineering and Quantum Physics in Nishina Yoshio

1. Engineering and Physics

In the late 1920s, while young physicists in Tokyo and Kyoto were struggling to master quantum mechanics, quantum physics research Europe was moving toward a new stage, along with new developments. Some physicists were insterested in using the current scheme of quantum mechanics in physics and related subjects, such as solid-body physics and chemistry. Other physicists worked on the theory of quantum mechanics, trying to remove its inner inconsistencies and, in particular, to make it compatible with Einstein's relativity theory. P. A. M. Dirac's relativistic theory of the electron in 1928[1] was one of the earliest such attempts and would eventually lead to quantum field theory.[2]

Whereas, in the developments of early quantum theory and the construction of quantum mechanics, Japanese physicists had no presence except for Ishiwara Jun, who, as mentioned in Chapter 2, did some work on the quantum conditions, in this new stage of quantum physics research, two Japanese physicists in Europe accomplished quantum theoretical works that achieved international fame. One was Nishina Yoshio, who, with Oskar Klein, applied Dirac's theory of the electron to the scattering of an electron by X-rays, and derived a formula for

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1. Paul Adrian Maurice Dirac, "The Quantum Theory of Electron," *Proceedings of the Royal Society of London, Series A* 117 (1928): 610-24.
2. For Dirac's theory of the electron, see: Helge Kragh, "The Genesis of Dirac's Relativistic Theory of Electrons," *Archives for the History of Exact Sciences* 24 (1981): 31-67; or Helge Kragh, *Dirac: A Scientific Biography* (Cambridge: Cambridge University Press, 1990), Chapter 3.

this phenomenon, which was named after Klein and himself.[3] This was one of the earliest applications of Dirac's theory, and constituted important evidence for its validity. The other was Sugiura Yoshikatsu, who applied the method that Walter Heitler and Fritz London developed in their work on the hydrogen molecule. Heitler and London found that attraction between two hydrogen atoms can be accounted by "exchange force," a mysterious attraction resulting from Pauli's exclusion principle.[4] Sugiura Yashikatsu, who was staying in Europe, first in Copenhagen and then in Göttingen, had been working on applications of quantum mechanics on relatively complex systems, such as the helium and lithium atoms.[5] When Born showed the work by Heitler and London, he was working on the collision of two atoms. Since Heitler and London had not carried out some of calculations, Sugiura reformulated Heitler and London's somewhat primitive theory into a quantum-mechanical perturbation theory[6] and carried out calculations

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3. Oskar Klein and Yoshio Nishina, "Über die Streuung von Strahlung durch freie Elektronen nach der neuen relativistischen Quantendynamik von Dirac," *Zeitschrift für Physik* 52 (1929): 853-68.

4. Walter Heitler and Fritz London, "Wechselwirkung neutraler Atome und homöpolare Bindung nach der Quantenmechanik," *Zeitschrift für Physik* 44 (1927): 455-72; For a historical account, see for example: Kostas Gavroglu and Ana Simoes, "The Americans, the Germans, and the Beginnings of Quantum Chemistry: The Confluence of Diverging Traditions," *Historical Studies in Physical and Biological Sciences* 25 (1994): 61-65. For a biography of London: Kostas Gavroglou, *Fritz London: A Scientific Biography* (Cambridge: Cambridge University Press, 1995).

5. Yoshikatsu Sugiura, "Über die numerische Bestimmung der Mittelwerte zwischen Ortho- und Paratermen von He und Li+ bei Berücksichtigung des Polarisationsgliedes in der quantenmechanischen Störungstheorie," *Zeitschrift für Physik* 44 (1927): 190-206.

6. Perturbation theory is a method to calculate an approximate solution to a differential equation. It starts with an appropriate zeroth order approximation, and using the original equation, calculates the first order correction term to the

for various properties of the hydrogen molecule. Although the Heitler-London theory was a relatively straightforward application of quantum mechanics by physicist, it was a first step toward quantum chemistry.[7]

Suguira, a mathematical adept who represented what I call the "culture of calculating," would waste his later years as an assistant to Nagaoka Hantarô, in his boss's fruitless attempts to transmutate mercury into gold,[8] and would soon disappear from Japan's scientific scene. On the other hand, Nishina became a leading figure of Japan's atomic physics from the 1930s until his death in 1951. Indeed, the second ("student rebellion") phase, ended around 1929, giving way to the third stage of Japanese quantum mechanics in this work, the "Copenhagen" phase. In this stage, which I discuss closely in the next chapter, Nishina Yoshio played the central role as organizer of the newly emerging group of physicists working on atomic physics.

Unlike the majority of Japanese physicists, Nishina was not initially trained

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solution, and derives the first order approximation. Then, it starts with the first order approximation to calculate the second order approximation. Repeating this, if conditions meet, the perturbation method leads to a better and better approximation. In actual cases, physicists have developed more efficient ways to calculate correction terms. Perturbation theory in quantum mechanics was first formulated in Göttingen by Max Born, Werner Heisenberg, and Pascual Jordan in their so-called *Dreimänner Arbeit*: Max Born, Werner Heisenberg, and Pascual Jordan, "Zur Guantenmechanik II," *Zeitschrift für Physik* 35 (1925-06): 585-90. Being in Göttingen, Sugiura was thoroughly familiar with this, using it in his previous paper cited above.

7. The Heitler-London method is generally considered a precursor of the Slater-Pauling method. For the differences between the work of the German physicists and of American quantum chemists, see: Gavroglu and Simoes, "Beginning of Quantum Chemistry."

8. Itakura Kiyonobu, Kimura Tôsaku, and Yagi Eri, *Nagaoka Hantarô den* (Tokyo: Asahi Shimbunsha, 1973), 473-507.

as a physicist but as an electrical engineer.[9] He graduated from the Department of Electrical Engineering of Tokyo University in July 1918. Although physics students enjoyed more advanced mathematical training, as described in Chapter 2, the savior of Japan's atomic physics did not come from there, not from the College of Science, but from among the ranks of engineers. Nor was it a separate incident. The only group that would rival Nishina's at Riken was the department of physics at Osaka University, which thrived under the leadership of Yagi Hidetsugu, a distinguished electrical engineer, who chaired this department.[10]

In this chapter, I claim that the engineering education that Nishina received in his undergraduate years contained certain elements that Nishina could turn to his advantage when he began studying quantum mechanics and worked on his most important theoretical work, the Klein-Nishina formula. Whereas I do not claim that Nishina's earlier training in electrical engineering in any way led inevitably to the Klein-Nishina formula, I do claim it to be no accident that Japan's first successful theoretical physicist in the 1920s was someone from electrical engineering. The electrical engineering education that Nishina received emphasized theory construction, the graphical understanding of physical phenomena, and the maintenance of close ties to experiments. A research culture that included such characteristics, I argue, was more suited for a time when a radical theoretical change was occurring along with the emergence of quantum theory.

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9. Another Japanese physicist initially trained in engineering that I am aware of is Kakinuma Usaku. Kakinuma graduated from the department of electrical engineering in 1914, and his thesis, like Nishina's, was on the three phase system: Usaku Kakinuma, "Three Phase Generators and Induction Motor Under Unsymmetrical Three Phase System," Senior Thesis (Tokyo: University of Tokyo, 1914). As other graduates from this department, Kakinuma wrote his thesis in English.

10. As for the group at Osaka University, see Chapter 5.

The most striking example of the ties between electrical engineering and quantum physics in Nishina's work was the principle of superposition. This concept was central to the school of electrical engineering in which Nishina was trained, to his undergraduate thesis, to Dirac's formulation of quantum mechanics which Nishina favored, and to the work that Nishina did with Oskar Klein. Electrical engineering cultures helped Nishina acquire skills to deal with these problems.

This chapter indicates one of the cultural resources in Japan that played a role in the introduction of quantum mechanics. Along with the cultures of calculating and rebellion, discussed in Chapters 2 and 3, a particular research culture of engineering, in which Nishina made himself an electrical engineer, contributed, in this case positively, to the introduction of quantum mechanics.

This study also addresses a broader theme, namely how a scientist can belong to different cultures, such as scientific and engineering cultures, and how engineering and science are related. Nishina seems to have experienced no communication breakdown between different disciplines. It appears immensely inappropriate to consider different disciplines as different "paradigms" and assume "incommensurability" between them. Peter Galison shows how the theoretical physicist Julian Schwinger, when he worked with electrical engineers at the Radiation Laboratory, utilized the idea of equivalent circuits in the collaboration to design the wave guide.[11] Schwinger, then, made his experience there in his work on renormalization theory.[12] Schwinger, the physicist, communicated with electrical engineers in the "trading zone" of military research at the Rad Lab. In Nishina's case, Nishina was himself both an electrical engineer and theoretical

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11. Peter L. Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: The University of Chicago Press, 1997), 821-27.

12. Ibid., 826; Julian Schwinger, *Tomonaga Sin-Itiro: A Memoria. Two Shakers of Physics* (Tokyo: Nishina Memorial Foundation, 1980).

physicist. Nishina was among those "boundary persons" between engineering and theoretical physics, along with Albert Einstein,Henri Poincaré, and P. A. M. Dirac.[13]

2. The Department of Electrical Engineering at Tokyo University

When Nishina entered the Department of Electrical Engineering in September 1914, he could be proud of himself. As I mentioned in Chapter 2, one can count the College of Engineering among Japan's most prestigious institutions of higher education. Until the 1910s, graduates of this school had very good chances of getting an excellent job, possibly in the central government or the military. Unlike those who chose to go to the College of Science, whose typical career paths would seldom swerve from teaching communities in secondary and higher education, ambitious young men gathered in the College of Engineering, aspiring to join the cohort of engineers building the technological backbones of the modernizing state.

Yet, Nishina might not have been completely happy. Having decided at the last minute that he wanted to go to the Department of Civil Engineering, he submitted a plea to switch departments, which the University rejected.[14]

Nevertheless, Nishina's achievements in his undergraduate years do not show any sign of misgivings. He was always among the top students in the

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13. On Einstein and electrical engineering, see: Lewis Pyenson, "Audacious Enterprise: The Einsteins and Electrotechnology in Late Nineteenth-Century Munich," *Historical Studies in the Physical Sciences* 12 (1982): 373-92; or Lewis Pyenson, *The Young Einstein: The Advent of Relativity* (Bristol: Hilger, 1985). On Einstein and Poincaré in relation to engineering, see: Peter L. Galison, *Einstein's Clocks, Poincaré's Maps* (Forthcoming). On Dirac and engineering, see: Peter L. Galison, "The Suppressed Drawing: Paul Dirac's Hidden Geometry," *Representation* 72 (2000): 145-66.

14. For the reason why Nishina wanted to change to civil engineering, see Chapter

department, except for the year 1914-15 when Nishina's recurring pleurisy prevented him from taking the final exam in June, which resulted in his failure to advance to the second year.[15] In 1915-1916, he repeated his first year, and was in the second place among 43 students with 92.4 on a 100 point scale, while the top student, Noguchi Takashige (an eminent electronics engineer who later joined Riken), obtained 92.6.[16] The next year, beating Noguchi, Nishina gained first place among 31 students. He graduated as the best of the Department of Electrical Engineering's 22 graduating students,[17] as one of several students of the university

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15. In his comprehensive chronology of Nishina, Ezawa Hiroshi writes that Nishina was ill from 1915 to 1916, and that he therefore had to stay in the first year. Nishina's letter on June 7, 1915, however, seems to show that Nishina was then in poor health, because of which his doctor recommended a medical leave. The end of year examination was immanent, Nishina was wondering what to do. The university catalogue indicates that Nishina was registered for the first year in the year of 1915-1916. Nishina's letter to his mother and brother in July 8, 1916, shows that Nishina was then staying at his brother Yasuo's place in Takayama, and that someone let him know his grade. This means Nishina attended classes and sat for the examination in the year of 1915-1916. It is, therefore, reasonable to conclude that Nishina had to repeat the first year in the year 1915-1916 because he took a medical leave in June 1915 and did not take the end of year examination, not that Nishina took a medical leave for the whole academic year of 1915-1916. See: Ezawa Hiroshi and Takeuchi Hajime, "Nishina Yoshio nempu," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shoƀô, 1991), 273-300; Nishina Yoshio, A letter to Nishina Teisaku, June 7, 1915 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagaku Shinkô Nishina Zaidan, 1993), 123-28; Nishina Yoshio, A letter to Nishina Tsune and Nishina Teisaku, June 8, 1916 in *Nishina Yoshio hakase shokanshû: Shônenjidai hen* (Satoshô: Kagaku Shinkô Nishina Zaidan, 1993), 135-37.

16. Nishina Yoshio, A letter to Nishina Tsune and Nishina Teisaku, June 8, 1916, 135 .The university catalogue in year 1916-1917 lists the students' names according to their grades in the previous year. *Tokyo Teikoku Daigaku Ichiran Taisho 5-nen yori 6-nen ni itaru* (Tokyo: Tokyo Teikokudaigaku, 1916), 44.

17. Incidentally, this number shows the high attrition rate of the program.

honored by a silver watch that the emperor awarded in person. This naturally made Nishina feel extremely proud of himself. As the top student, he was selected as the representative of all the graduating students of the College, although, unable to attend the commencement rehearsal, he had to yield the honor to the student in second place.[18] By any measure, Nishina was an exceptionally good student of electrical engineering.

The three-year program of the Electrical Engineering Department included theoretical subjects, but many fewer than the Department of Physics. There were naturally more experimental subjects than the theoretical physics track in the Physics Department. Nonetheless, the program encompassed much more than rules-of-thumb practical knowledge and skills. The first year focused on fundamental skills and knowledge necessary to electrical engineering. A little less than half the class time was devoted to lectures.The principal subjects included electromagnetism, mathematics, dynamics, and thermodynamics. In the second year, more practical subjects came into the curriculum, and lecture courses related to power networks occupied the largest portion of the instruction. Such courses included the design of electric plants, power transmission and distribution, electrical lighting, design of generators, dynamos, and converters. Although not given as much time, alternating current theory and electric railroad were taught in the second year. There was little formal instruction in the third year, which students would typically use to write their theses.

Lecture-style instruction took less than half of class time. In the first year, drawing and experiment occupied 23% and 30% of the total class time, which

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18. Nishina Yoshio, A letter to Nishina Masamichi, July 10, 1918 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagaku Shinkô Nishina Zaidan, 1993), 145. Nishina probably had to go home to discuss the marriage of his younger brother Masamichi. See Chapter 6.

averaged forty hours per week.[19] Drawing was obviously crucially important for future engineers. They learned not only projective geometry, but also how to draft actual designs of electrical engineering products. The Department took drawing training very seriously. Students were required to bind and submit their works to the Department, whose library would preserve their *études* of drawings permanently along with their theses.

Emphasis on drawing, so typical in engineering, contrasted with the calculation-intensive culture of theoretical physics at the time. As we have seen in Chapter 2, developing mathematical skills was the main focus of education in the physics department, in particular, for first-year studetns. Mathematics in this case was not projective geometry, but calculus, algebra, differential equations, and special functions, where calculation skills were more important than a graphical understanding of three-dimensional objects. Acquiring drawing skills was not an easy process, and theoretical physics students could afford to lack drawing skills, as long as they could calculate well. But an engineer who could not draw would be quite useless. Engineering students had to develop a high standard of drawing skills and a graphical understanding of three-dimensional space. In other words, as Nishina's teacher Hô would have put it, they had to learn to grasp things in terms of "mental pictures."

The Department of Electrical Engineering had its own laboratory, but experiments were for pedagogical purposes only. The laboratory was not well-equipped. It had various measuring devices, such as galvanometers, and various kinds of generators and cells. In addition, it had motors, transformers, a wireless

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19. The percentages here are calculated by simply adding the class time per week in term. There were three terms in one academic year, each approximately three months. See: *Tokyo Teikoku Daigaku Ichiran Taisho 6-nen yori 7-nen ni itaru* (Tokyo: Tokyo Teikoku Daigaku, 1917), 194-97.

telegraph, and a telephone.[20] The equipment was suitable for familiarizing students with measuring devices and to teach them the basics of electromagnetism, but not enough to conduct original research.[21]

The frequency of examinations at the College of Engineering bespeaks its pedagogical stance. Unlike most other colleges, including the College of Science and the College of Law, which had a single examination period each year (the College of Medicine had two), the College of Engineering imposed an examination at the end of each of the three terms. Engineering students were thus forced to learn to study constantly, while science students studied whatever they liked (or spent time on other activities) when the examination was not imminent.[22]

Partly as part of their education and partly to have fun, students in the Electrical Engineering Department often took field trips to various electrical engineering or other technological installations in the country. In Nishina's case, he took one five-day trip in his second year, visiting technological sites north of Tokyo. The trip started with Niitsu City in Niigata Prefecture, the home of Japan's largest oil field. The next destination was the mountainous Yokokawa region in Gunma Prefecture, where an electric railroad and a power plant had been constructed. To make the many tunnels in the undulatory landscape of this area more bearable for passengers, the electrification of the railroad along this local line took place in 1911, earlier than most other lines. Nishina probably had a chance to

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20. *Tokyo Teikoku Daigaku Ichiran Taisho 3-nen yori 4-nen ni itaru* (Tokyo: Tokyo Teikokudaigaku, 1914), 217.

21. Asami Yoshihiro, "Taishô jidai no jisshû," in *Sho senesi no omokakge (dai nishû): Tôdai Denki Kôgakka no ayumi*, edited by Tokyo daigaku Denki Denshi Kôgakka Dôsôkai (Tokyo: Tokyo daigaku Denki Denshi Kôgakka Dôsôkai, 1983), 15-20.

22. See the annual catalogue of the University of Tokyo, *Tokyo Teikoku Daigaku ichiran.*

see the embodiment of what he had learned in the classroom. Nishina's next five days was in the Kinugawa River area, in Tochigi Prefecture. First, he visited Ashio, known for a large copper mine run by Furukawa Mining company and its environmental problems, as well as a famous riot in 1907.[23] Whereas the Ashio Mine was a favorite spot for Tokyo University's engineering students to stay and conduct their practical training, Nishina made only a brief visit to see the mine's hydraulic power plant. The next day, he went to Hosoo near Nikko, visiting another power plant of Furukawa Mining, but passing by the famous mausoleum of the early Tokugawa shoguns. He ended his tour by visiting another major power plant, Kinugawa Power Plant, on his seventh day before he returned to Tokyo.[24]

In the second and third years, students were required to do "practical training "(*jicchi jisshû*). The experience of practical training differed among students, its specifics being decided in consultation with the academic adviser. It is not clear what Nishina did for the second year's practical training. The above trip might be considered his practical training for that year. In his third year, he commuted to the Testing Department of Shibaura Engineering Works from January 15, 1919, working everyday from 7 a.m. to 5 p.m. and probably collecting experimental data for his thesis.[25] He tested the induction motor under asymmetrical supply voltages and examined how the asymmetrical load affected

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23. Kazuo Nimura, *The Ashio Riot of 1907: A Social History of Mining in Japan*, edited by Andrew Gordon, translated by Terry Boardman and Andrew Gordon (Durham: Duke University Press, 1997).

24. Nishina Yoshio, A letter to Nishina Tsuneko and Nishina Teisaku, September 9, 1917, Kagaku Shinkô Nishina Kaikan (Satoshô).

25. Nishina Yoshio, A letter to Nishina Tsuneko and Nishina Teisaku, 18 January 1918, Kagaku Shinkô Nishina Kaikan (Satoshô).

the mortor's performances.[26] Students were supposed to submit a report on what they did.[27] It is not clear how long Nishina worked there. It might be a month, as another student's case shows,[28] or several months.[29] Since the laboratory of the Department was not well-equipped, it was important for students to go to electric companies to see and use the newest electrical machines and laboratory equipment, and sometimes to collect data for their theses.[30]

The thesis was a graduation requirement in the Electrical Engineering Department. Hand-written in English and about 150 pages in length, the theses indicate the degree of students' immersion into electrical engineering subjects, although, containing little original research, they were more like a good review essays.[31] I discuss Nishina's thesis at length in a later section. Because of the poor

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26. Yoshio Nishina, "Effects of Unbalanced Single-Phase Loads on Poly-Phase Machinery and Phase Balancing," graduation thesis (University of Tokyo, 1918), Preface.

27. Reports were bound and preserved with the theses. See: Nishina Yoshio, "Jisshû Hôkoku," Shiryô Bangô 907, Tokyô Daigaku, Denki Kôgakuka (Tokyo, 1918).

28. Asami Yoshihiro, "Taishô jidai no jisshû"; Shimazu Yasujirô, "Gakusei no koro no omoide," in *Sho senesi no omokakge (dai nishû): Tôdai Danki Kôgakka no ayumi*, edited by Tokyo daigaku Denki Denshi Kôgakka Dôsôkai (Tokyo: Tokyo daigaku Denki Denshi Kôgakka Dôsôkai, 1983), 46.

29. The experience probably varied among students. Shibusawa Motji, who graduated in 1900, spent eleven months in his practical training. See: Shibusawa Motoji, *Gojûnen no kaiko* (Tokyo: Shibusawa Sensei Chosho Shuppan Jigyôkai, 1953), 198.

30. Asami Yoshihiro, "Taishô jidai no jisshû."

31. It is not clear why writing in English was a requirement. Possibly, it was a tradition since foreign teachers taught Japanese students at the College of Engineering.

laboratory equipment, the theses tended to be more theoretical and experimental, as was the case with Nishina.[32]

As an undergraduate, therefore, Nishina received rigorous training in electrical engineering. The training was highly structured, with little room for choice. Students spent an extensive amount of time in experiment and drawing. On the other hand, compared to the physics department, relatively little time was pent on mathematics. Rather than algebraic manipulation of equations, Nishina was trained to deal with drawings and actual machines.

3. Hô Hidetarô and His Textbooks

To understand what kind of engineering education Nishina received at the University of Tokyo, it is essential to look at Nishina's mentor during his undergraduate years, Hô Hidetarô. In this section, I examine Hô's research and teaching style and show two of their characteristics: Hô's emphasis on graphical or pictorial understanding of electrical phenomena and his theoretical approach to electrical engineeering. By "theoretical," I mean his tendency to derive fairly general theoretical results from fundamental principles, rather than solving problems in particular cases using rules of thumb. It was what Edwin Layton called an "engineering science," an autonomous body of knowledge and skill based on experience and on the Maxwellian theory of electromagnetism.[33]

The tension between physics and electrical engineering is well represented by Charles Proteus Steinmetz, who himself made the transition from mathematics to electrical engineering. Trained in scence, he was able to use advanced

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32. Asami Yoshihiro, "Taishô jidai no jisshû," 20.

33. Edwin T. Layton, "Mirror Image Twins: The Communitis of Science and Technology in Nineteenth Century America," *Technology and Culture* 12 (1971): 562-80.

mathematics and knew how to theorize. Having worked as an engineer, he acquired essential engineering skills, such as the graphic representation of machinery, and became familiar with actual machines. He differed from the kind of engineers, such as Thomas Edison, who relied more on their experience, skills, and pseudo-empirical rules of thumb than on electromagnetic theories, and from electrical theorists, for whom the problems of electrical engineering were direct applications of Maxwellian theory. While practitioners of electrical engineering, even the best ones like Nikola Tesla would be satisfied with constructing working machines, Steinmetz sought a general theory of electrical machines, like, in his biographer's expression, "'pure' physicists at the time."[34] Whereas a Maxwellian theorist, such as Michael Pupin chided Steinmetz for modifying Maxwell's theory (claiming that "attempts of ordinary mortals to do better than Maxwell did must be discouraged"), Steinmetz was trying to construct a middle-level theory, which would in no way replace Maxwellian theory but departed from the latter so as to better fit actual machines. Engineers valued theories, not because they were universal, but because they were practical and could help them conceive a new design for machines.[35]

His famed theory on the use of complex numbers in alternating current theory illustrates this point.[36] Using a highly mathematical entity such as an imaginary number, whose physical reality is dubious, might be considered contrary to the pragmatism of engineers. Yet, it evolved from graphic representations of

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34. Ronald R. Kline, *Steinmetz: Engineer and Socialist* (Baltimore: The Johns Hopkins University Press, 1992), 106, 116.

35. Ibid., 110-12.

36. Charles Proteus Steinmetz, "Complex Quantities and Their Use in Electrical Engineering," in *Proceedings of the International Electrical Congress* (New York, 1893), 37-53.

alternating current theory, which Steinmetz himself had worked on previously. Whereas physicists would use differential equations to analyze alternating current circuits, electrical engineers found that, as far as they needed to deal with the steady state condition of the circuits, they could represent the circuit with rotating vectors, and determine the necessary quantities by manipulating a graph.[37] Steinmetz's use of complex numbers was a clever translation of these graphic representations of rotating vectors.

Nishina's electrical engineering teacher Hô Hidetarô was Steinmetz's principal follower in Japan. Nor only did he introduce Steinmetz's alternating current theory into Japan, he shared the quality that differentiated Steinmetz from other electrical engineers or physicists: the ability to construct a middle-level theory and tendency toward graphic and intuitive understandings of electrical phenomena. Hô was born in 1872 in the city of Sakai in today's Osaka Prefecture, in a family of the confectionery shop called "Suruga-ya."[38] His younger sister, Akiko, married the writer Yosano Tekkan and became the best-known poetess in modern Japan.[39] Hidetarô, however, seems to have had little to do with his famous

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37. Kline, *Steinmetz*, 38-39.

38. Ôyama Matsujirô, "Hô sensei no kyôju buri," in *Shosensei no omokakge (dai ichi-shû): Tôdai Denki kôgakuka no oitachi*, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed, 1959), 127.

39. For more onYosaka Akiko's early life: Janine Beichman, "Yosano Akiko: The Early Years," *Japan Quarterly* 37 (1990): 37-54. See also: Laurel Rasplica Rodd, "Yosano Akiko and the Taisho debate over the new woman," in *Recreating Japanese women, 1600-1945*, edited by Gail Lee Bernstein (Berkeley: University of California Press, 1991), 175-98. For a recent study on her poetry: Noriko Takeda, *A Flowering Word: The Modernist Expression in Stephane Mallarmé, T. S. Eliot, and Yosano Akiko* (New York: Peter Lang, 2000). There is an English translation of her chef-d'œuvre, *Tangled Hair*: Akiko Yosano, *Tangled Hair:Selected Tanka from Midaregami* (Lafayette: Purdue University Press,

literary sister.[40] Hidetarô graduated from the Department of Electrical Engineering in 1895 and became an assistant professor at his alma mater the following year.

In Nishina's undergraduate years, Hô occupied the leading position in the Electrical Engineering Department. In his forties, Hô was the youngest of three full professors of the department. Another professor Asano Ôsuke was renowned for his research on wireless telegraphy, but he had a weaker presence in the department because he had a joint appointment in the Ministry of Communications and only lectured the course on telegraphy and telephone. The other professor, Yamakawa Gitarô, was hardly as competent as Hô. Yamakawa received a doctoral degree on the dean's recommendation, not from his dissertation, and did not do any notable work. Students found Yamakawa's lectures mediocre and unimpressive.[41] Both Asano and Yamakawa would retire in Nishina's time.[42] Seniority notwithstanding, the vigorous and competent Hô dominated the department.

All the young faculty members of the department in the 1910s, Nishi Takeshi, Kujirai Tsunezaburô, Shibusawa Motoji, and Ôyama Matsujirô, graduated from the Electrical Engineering Department and had studied electrical

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1971).

40. Akiko was known and criticized as anti-patriotic for a poem in which she expressed her feelings for her younger brother Chûzaburô, who was conscripted and sent to the Russo-Japanese war. In her poem, Akiko asked his brother "not to die," even though Japanese soldiers were expected to die for their country. Hidetarô, on the other hand, edited and published an anthology of heroic stories in the Russo-Japanese war. See: Hô Hidetarô, *Taisen yokyô* (Tokyo: Hakubunkan, 1917).

41. Yasukawa Daigorô, "Sho sensei no omoide," in *Shosensei no omokakge (dai ichi-shû): Tôdai Denki kôgakuka no oitachi*, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed), 100.

42. Asano retired in 1918, Yamakawa in 1923.

engineering under Hô's tutelage. Nishi became a lecturer in the department when he graduated in 1912, with Hô's support,[43] and he was an assistant professor in Nishina's time. Kujirai was also an assistant professor, who became a lecturer when he graduated in 1907 and had been overseas from 1912 to 1915.[44] Shibusawa was appointed as a lecturer in 1918, shortly before Nishina graduated. Although his principal teacher was Asano, Hô joined the faculty when Shibusawa was an undergraduate, impressing Shibusawa and his classmates with enthusiasm and the high standard of his lectures.[45] He had earned a doctorate from the Electrical Engineering Department in 1911; Hô was the referee for his dissertation.[46] Shibusawa recalls that he was appointed to the Electrical Engineering Department thanks to Hô's recommendation.[47] Ôyama Matsujirô, who joined the department

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43. Arranging the jobs of graduating students was one of the important functions of the professors in prewar Japan. When Nishi was going to graduate, Hô asked Kajii Tsuyoshi what kind of job would be adequate for the graduating students. Kajii was also graduating, but, since he was already determined to have a job in the Ministery of Post and Telecommunication, Hô thought that Kajii was able to make a fair judgment. He told Hô that Nishi would succeed in any job. Nishi, consequently, had a position in the department. See: Kajii Tsuyoshi, "Hô Hidetarô sensei no omoide," in *Shosensei no omokakge (dai ichi-shû): Tôdai Denki kôgakuka no oitachi*, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed, 1959), 95.

44. K. R. Iseki, *"Kogaku Hakushi" (Dr. of Engineering)*, vol. V of *Who's Who in "Hakushi" in Great Japan: A Biographical Dictionary of Representative Scholars in Various Branches of Learning and Holders of the Highest Academic Degree "Hakushi"* (Tokyo: Hattensha, 1930), 260.

45. Shibusawa Motoji, "Kaiko (sono ichi)," in *Shosensei no omokakge (dai ichi-shû): Tôdai Denki kôgakuka no oitachi*, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed, 1959), 44.

46. Shibusawa Motoji, *Kaiko*, 177.

47. Shibusawa Motoji, "Kaiko (sono ni)," in *Shosensei no omokakge (dai ichi-*

a year after Nishina's graduation, was an advisee of Hô's and succeeded him after the retirement.[48] Both politically and intellectually, Hô was the most powerful professor of the Electrical Engineering Department around the time when Nishina was there.

Students found Hô's courses impressive. They felt that Hô's lecture on alternating current theory was better than foreign textbooks, such as Alexander Russell's *A Treatise on the Theory of Alternating Currents*.[49] Students had to work hard to digest Hô's demanding lectures. They were inspired and awed by Hô's scholarly demeanor during his lectures.[50] Whereas students hardly remember what Yamakawa taught, Hô and his lectures, in particular those on alternating current theory and transition phenomena, left students with deep impressions,[51] and Nishina was one such student.[52] According to one of his colleagues, Hô prepared his lectures very carefully, revising his lecture notes every year, a practice not common among Japanese professors, as we have seen in Chapter 3. Students saw in Hô's lectures and textbooks a unique way of grasping electromagnetic

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shû): Tôdai Denki kôgakuka no oitachi, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed, 1959), 130.

48. Ôyama Matsujirô, "Hô Sensei No Kyôju Buri."

49. Baba Kumeo, "Mukashi no sensei no omoide," in *Shosensei no omokakge (dai ichi-shû): Tôdai Denki kôgakuka no oitachi*, edited by Tokyô Daigaku Denki Kôgakuka Dôsôkai (Tokyo: Tokyô Daigaku Denki Kôgakuka Dôsôkai, ed, 1959), 90; Russel Alexander, *A Treatise on the Theory of Alternating Currents* (Cambridge: University Press, 1904-06).

50. Kajii Tsuyoshi, "Hô Hidetarô sensei no omoide," 92.

51. Yasukawa Daigorô, "Sho sensei no omoide," 101.

52. Nishina Yoshio, "Watashi wa nani wo yondaka," in *Genshiryoku to watashi*, reprint, 1946 (Tokyo: Gakufû Shoten, 1950), 226.

phenomena and called it "the Hô-style."[53] Although students did not articulate what "the Hô-style" was, from Hô's textbooks, which were originally Hô's lectures at the University of Tokyo, we can surmise that "the Hô-style" was a combination of a theoretical approach to electromagnetic phenomena and emphasis on graphic understanding of the phenomena (see below). As one of Hô's advisees, Nishina must have learned electromagnetic theory in his first year, and alternating current theory in his second year.

Other than lectures at the university, Nishina learned through Hô's textbooks. In his later years, Nishina remembered four books that inspired him during his undergraduate years.[54] *The Mathematical Theory of Electricity and Magnetism* by James Jeans,[55] *Theory and Calculation of Alternating Current Phenomena* by Charles Proteus Steinmetz;[56] *Wechselstromtechnik* by Engelbert Arnold;[57] Kôryûriron (Alternating Current Theory) by Hô Hidetarô.[58]

Hô's book was the first volume of his series, the "Course of Electrical Engineering Theory," first published in 1912, In the volume, *Kôryûriron* (Alternating Current Theory), Hô, with his incongruously archaic style and language, introduced Steinmetz's newest formulation of alternating current theory into Japan.

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53. Ôyama Matsujirô, "Hô sensei no kyôju buri," 120-22.

54. Nishina Yoshio, "Nani wo yondaka," 226.

55. James H. Jeans, *Mathematical Theory of Electricity and Magnetism*, 2nd (Cambridge: Cambridge University Press, 1908).

56. Charles Proteus Steinmetz, *Theory and Calculation of Alternating Current Phenomena*, 5th (New York: McGraw Hill, 1916).

57. Engelbert Arnold, *Wechselstromtechnik* (Berlin: Springer, 1905-12).

58. Hô Hidetarô, *Koryûriron* (Tokyo: Maruzen, 1912).

In Hô's time, it might have been appropriate to show modesty (false or genuine) in the preface of a book. In his preface, Hô apologized for writing this book. He wrote that he knew how careless he was and that his writing a book would make him a laughingstock of future generations. The only reason he had written the book was to correct the errors and mistakes he had made during his lectures.

Of more interest to us is the acknowledgment in the preface, where the author stated his relation to Steinmetz.

> This book is mostly influenced by Mr. Steinmetz's book. It is, therefore, not surprising that   each part of this book tends to follow Mr. S[teinmetz's] method. So it can be said to be an introductions to his book.[59]

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Theoretical analysis of transition phenomena in the electric circuit was one of Steinmetz's (and therefore Hô's) specialties. "Transition phenomenon" refers to what happens before an electric circuit reaches its steady state, for example just after a switch is turned on. As I mentioned above, once the circuit reaches a steady state, voltages and currents in the circuit are governed by relatively simple algebraic relations. Before this happens, voltages and currents change dynamically with time, and their relations are governed by fundamental equations of electrical circuits, such as the relations between current and voltage in an inductance or in a capacitance, which are differential, not algebraic, equations. Transition phenomena, therefore, require more sophisticated theoretical treatments than solving stationary electrical circuits. They require the solution of differential equations, often using approximation. In this sense, solving transition phenomena resembled solving problems in physics proper. In particular, some materials dealt

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59. Ibid., 1.

with by Hô in his volumes on transition phenomena closely resembled scattering problems.

In the third volume of the course on alternating current theory, Hô discussed transition phenomena in electric circuits, such as oscillation and surge. A large portion of the book discusses the propagation of various forms of waves in electric circuits. In particular, he discusses in a few chapters, the effects of impedance on traveling waves.[60]

To illustrate what kind of physical phenomena Hô treated in his textbook, let me summarize one example. When electric current travels along an ideal wire (whose resistance and inductance can be ignored), nothing happens. Hô constructed a theory that predicts what happens when there are various kinds of electromagnetic "barriers" along its way. Here, as an example, I take the case of electric current in a sinusoidal (wave-like) form, with a coil acting as "barrier."[61]

Suppose there is a wire of which inductance and capacity per length are C_1 and L_1, and there is a coil at point *b*, whose inductance is *L*. The coil is infinitesimally short and can be treated as a point.[62] There are currents of incoming, reflecting, and penetrating waves at point *b*. Let's define functions $f_1(t)$, $f_2(t)$, and $f_3(t)$ as follows:

$f_1(t)$: Current of the incoming wave

$f_2(t)$: Current of the reflecting wave

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60. Hô Hidetarô, *Hadô shindô oyobi hirai*, reprint, 1915, Hô shi kôryû kôgaku riron kaitei (Tokyo: Maruzen, 1923).

61. Ibid., 288-92.

62. Hô considers the case where capacitance and inductance are different on the both sides of the wire. For the sake of brevity, I simplified the problem.

$f_3(t)$: Current of the penetrating wave

One can calculate the voltages of the waves by multiplying the current by $\sqrt{L_1/C_1}$. Because of the continuity,

$$f_1(t) - f_2(t) = f_3(t)$$

By the definition of inductance,

$$\sqrt{\frac{L_1}{C_1}} f_1(t) + \sqrt{\frac{L_1}{C_1}} f_2(t) - \sqrt{\frac{L_1}{C_1}} f_3(t) = L\frac{df_3(t)}{dt}$$

By solving this, we have:

$$f_2(t) = e^{-nt} n \int e^{nt} f_1(t)dt + Ae^{-nt},$$

$$f_3(t) = f_1(t) - e^{-nt} n \int e^{nt} f_1(t)dt - Ae^{-nt},$$

$$(n = \frac{2}{L}\sqrt{\frac{L_1}{C_1}})$$

Hô applied these formulae to several forms of the incoming wave. For example, if the incoming wave is a half wavelength of a sinusoidal wave with a certain angular frequency ω ,[63]

$$f_1(t) = I_1 \sin \omega t \left(0 \leq t \leq \frac{\pi}{\omega} \right)$$

Then the solutions are:

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63. Hô Hidetarô, *Hadô*, 294-98.

$$f_2(t) = I_1\sqrt{\frac{\omega^2}{n^2+\omega^2}}\sin(\omega t+\phi) - \frac{n\omega I_1}{n^2+\omega^2}e^{-nt}\left(0 \le t \le \frac{\pi}{\omega}\right)$$

$$f_3(t) = \frac{nI_1}{\sqrt{n^2+\omega^2}}\sin(\omega t-\phi) + \frac{n\omega I_1}{n^2+\omega^2}e^{-nt}\left(0 \le t \le \frac{\pi}{\omega}\right)$$

$$f_3(t) = -f_3(t) = \frac{n\omega I_1}{n^2+\omega^2}\left(1+e^{-n\left(t-\frac{\pi}{\omega}\right)}\right)\left(\frac{\pi}{\omega} < t\right)$$

$$\phi = \arctan\frac{\omega}{n}, n = \frac{2}{L}\sqrt{\frac{L_1}{C_1}}$$

For this result, Hô drew the results in diagrams in Fig. 4.1.

A problem like the above can be considered as a one-dimensional scattering problem: a wave collides with a particle, making a certain interaction with it. In a sense, Hô solved it to the first order (the assumption that the coil is infinitely small is equivalent to substituting the actual curve with a flat line within that length, namely taking the first order approximation). It would be absurd to see a direct connection between such works and the problem that Nishina would deal with later in the Compton scattering. It indicates, however, the degree of affinity between the problems in physics and the kind of problems that Hô dealt with and taught at the electrical engineering department.

A more direct link between alternating current theory and quantum physics was the notion of linearity in both theories. In his textbook on alternating current theory, after discussing of notations and fundamental notions, Hô started the main part of his textbook on alternating current theory with a discussion of the principle of superposition. Suppose there are three configurations: A, B, and C. They are same except:

Configuration A: There is a voltage source E_1 at point A, but none at B.

Configuration B: There is a voltage source E_2 at point B, but none at A.

Configuration C: There is a voltage source E_1 at point A, and E_2 at B.

Then one knows the solution to the Configuration C, where there are sources at both point A and B, by adding up the solutions to Configurations A and B.[64]

Although Hô explained and proved this principle algebraically, using Kirchhoff's laws, he stressed that understanding the principle in terms of the algebraic expressions would not be enough. He recommended trying to grasp the situation as a "clear mental picture."[65]

The principle of superposition would prove to be essential for Hô's fame in Japan. In 1922, in his attempt to apply this principle to the problem of power lines, he rediscovered what is now known as Thévenin's theorem, a cornerstone of circuit theory, which every electrical engineering student learns today.[66] The theorem renders the calculation of complicated electrical circuits much easier than applying the Kirchhoff's laws directly to electrical circuits. Thévenin's theorem resembles what Layton called engineering science. While the validity of this theorem lies in its practicality, it is a middle-level theory, derived rigorously through theoretical considerations from the fundamental principles (Kirchhoff's laws). This theorem had been derived repeatedly and sometimes independently by several scientists and engineers, including Herman von Helmholtz, Léon Charles Thévenin, Hans Ferdinand Mayer, and Edward Lawry Norton. Although there are some different formulations, it is essentially a way to substitute a part of complex circuit with a simpler equivalent circuit consisting of a certain voltage source and a resistance. In Thévenin's expression:

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64. Hô Hidetarô, *Koryûriron*, 67-68.

65. Ibid., 68.

> Assuming any system of linear conductors connected in such a manner that to the extremities of each one of them there is connected at least one other, a system having some electromotive forces, $E_1, E_2, \ldots, E_n,$ no matter how distributing, we consider two points A and A' belonging to the system and having actually the potentials V and V'. If the points A and A' are connected by a wire ABA', which has a resistance r, with no electromotive forces, the potentials of points A and A' assume different values of V and V', but the current I flowing through this wire is given by the equation
>
> $$I = \frac{V - V'}{R - r}$$
>
> In which R represents the resistance of the original system, this resistance being measured between the points A and A', which are considered to be electrodes.[67]

The theorem is derived from the principle of superposition and Ohm's law, and the proof can be stated simply. I reformulate here Thévenin's proof without changing it much. Let's define the following four configurations:

1. Configuration I is defined as the original system where A and A' are not connected.

2. Configuration I' is defined as the one where A and A' are connected, and there is a voltage source of V-V' at point B. The voltage source is connected in the opposite direction to A and A', so that there is no current between them.

3. Configuration II is defined as the system having the same resistance as Configuration I' but no voltage source except the one at B in the opposite direction to the one in Configuration I'.

4. Configuration III is the system where A and A' are connected by a wire of the resistance r.

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66. Tokyo Daigaku hyakunenshi henshû iinkai, ed., *Bukyokushi 3*, Tokyo Daigaku hyakunenshi (Tokyo: University of Tokyo, 1987), 330.

Since there is no current between *A* and *A′* in Configuration I', Configuration I' gives the same voltages and currents in each point as in Configuration I. According to the principle of superposition, Configuration III can be obtained by adding Configuration I' to Configuration II. Since there is no current at *B,* the current at *B* in Configuration III comes only from Configuration II, which is what the theorem states.

Thévenin's theorem and proof might appear unintuitive when stated in texts, but they become extremely clear when we visualize them, or, following Hô's recommendation, use "mental images." For the proof of the theorem, see Fig. 4.2.

The superposition of Configuration I' and Configuration II gives Configuration III. Therefore, when one wants to know the current between *A* and *A′* in Configuration II, one can calculate it from the much more simplified circuit of Configuration II.

Although Thévenin did not realize it, this theorem was immediately generalized to alternating current theory, and could be used to calculate circuits with coils and condensers once one knew Steinmetz's alternating current theory. One only needs to substitute the resistance with the complex impedance. Hô might have noticed this earlier than Mayer and Norton did (their works appeared in 1926).[68]

This theorem was not well known until the late 1920s, and its importance and utility were not widely recognized. Thévenin himself was surprised to know

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67. Charles Suchet, "Léon Charles Thévenin (1857-1926)," *Electrical Engineering* 68 (1949): 843-44.

68. Don H. Johnson, "Origins of the Equivalent Circuit Concept," Submitted to *Proceedings of IEEE,* 2001 (2001), Http://cmc.rice.edu/docs/docs/Joh2001Aug1Originsoft.pdf.

shortly before his death in 1926 that his theorem was by then known all over the world.[69]

Hô reached a form of this theorem without knowing that others had already found it. In his paper on power transmission in 1922, Hô devised a way to calculate the effects of an accidental grounding of a transmission line, by ingeniously using the principle of superposition. The result was same as Thévenin's theorem, except that Hô discussed an alternating current circuit instead of a direct current circuit, and grounding instead of shortening. The proof was equivalent to the one presented above. Ho considered the transmission line grounded by a wire with resistance *R*, as in Fig. 4.3a. Suppose the voltage at point *a* is given by:

$$v_a = V_m \sin(\omega t - \theta_0),$$

where, V_m, ω, θ_0 are the voltage's amplitude, angular frequency, and intial phase. Then there will be no current through *R* if there is an electromotive force with the same strength but in the opposite direction as in Fig. 4.3b. If there is an electromotive force with the same strength but in the opposite direction at the same point as in Fig. 4.3c, then those two electromotive forces cancel each other and the result should be same as Fig. 4.3a. Since Fig. 4.3c can be obtained by superposing Fig. 4.3b and Fig 4.3d, the current through *R* can be calculated by Fig. 4.3d.[70]

Although this was a special case of the theorem presented above, as we have seen, Hô's proof was the same as the one for the general case. Because of this work, the theorem is called the Hô-Thévenin theorem in Japan, and Hô's name is firmly attached to this theorem. Whether Hô is entitled to be one of the

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69. Suchet, "Thévenin," 844.

70. Hô Hidetarô, "Sôdensen no secchi to chôjô no ri," *Denki Gakkai Zasshi* 42 (1922): 193-94.

discoverers of Thévenin's theorem is not the issue here. What interests us is the fact that the principle of superposition was so central to Hô's work.

Hô's series of textbooks on alternating current theory, therefore, contained theoretical treatments of physical phenomena, some dealing with the behaviors of waves. The idea of superposition played a central role in his textbook and his research. More generally, Hô's textbook also stressed that readers should understand electromagnetic phenomena and theories, such as the principle of superposition, through "mental pictures" not just through algebraic symbols as we have seen above.[71] Visualization was essential to Hô's description of Thévenin's theorem and its proof in alternating current theory. Hô's approach to visualizing physical phenomenae left a deep impression on some of his students,[72] including Nishina himself, who, in his words, learned "how to grasp the physical meanings of things" from Hô[73] Hô's alternating current theory did not differ much from "theoretical physics" in the sense that it was a theoretical treatment of physical phenomena. It, did however, differ from Japan's theoretical physics, as we have seen in Chapter 2, in its strong emphasis on visualization.

4. Nishina Yoshio's Thesis

Nishina Yoshio wrote his thesis with Hô Hidetarô, and his thesis was very much in agreement with Hô's interests. It was a theoretical investigation of alternating current generators, motors, and transformers, in the three-phase

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71. Hô Hidetarô, *Koryûriron*, 68.

72. Yamaki Naomi, "Sho sensei no kôgi buri," in *Sho sensei no omokage (dai nishû): Tôdai Denki Kôgakuka no ayumi*, edited by Tokyo Daigaku Denki Denshi Kôgakuka Dôsôkai (Tokyo: Tokyo Daigaku Denki Denshi Kôgakuka Dôsôkai, 1983), 97-98.

73. Nishina Yoshio, "Nani wo yondaka," 226.

system, focusing on how unbalanced loads would affect the system. It relied heavily on Hô's and Steinmetz's works.[74]

Nishina started the thesis with definitions of concepts. In an N-phase system, if the voltage is equal in all branches, and the phase difference between the branches is one Nth, the system is called symmetrical. If not, it is asymmetrical. If the sum of power in all N branches is constant, it is called balanced; If not, unbalanced. A symmetrical system, for example, can be unbalanced when loaded unequally.[75]

According to Nishina, the problem of unbalance in the three phase system was of very practical value. Nishina thought that, as the centralization of electrical power supply continued, the three-phase system would be the most efficient system to generating and transmitting electric power. On the other hand, since the introduction of the single-phase commutator motor, there were demands for a single-phase electrical power supplies. If a single-phase load was supplied with electricity directly from the three phase system, the voltage would become unbalanced. Hence there would be the problem of the unbalanced load.[76]

With such a motivation in mind, Nishina proceeded to the main part of his theses, which discussed how unbalanced loads would affect a few kinds of alternating current devices, such as an alternator, a motor, or a rotary transformer. In the case of the alternator, for example, Nishina examined what would happen when loads were connected unbalancedly to a three-phase alternator (namely,

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74. It is even likely that the theme itself was partially given by Hô, considering the fact that Kakinuma's subject in his thesis was also very close to Nishina's. Both of them worked on the three-phase system. Nishina focused on unbalanced systems, Kakinuma asymmetrical systems.

75. Nishina, "Unbalanced Single-Phase Loads," 1.

76. Ibid., 3.

loads were connected to only one or two of the three phases). By treating the problem theoretically, Nishina argued that there would be some unfavorable effects. Terminal voltage would become "unsymmetrical" both in phase and magnitude. It would increase both iron and copper loss,[77] reducing the efficiency and producing more heat. The unbalanced load would also cause odd higher harmonics, which would result in an "uncomfortable" humming noise.

In analyzing the unbalanced system, Nishina applied a reasoning similar to Hô's "principle of superposition." In his discussion of the unbalanced three-phase system, he claimed that an unbalanced three-phase system could be considered a superposition of two balanced three-phase systems circulating in both directions, or in his words:"An unbalanced polyphase system can be resolved into two balanced components of opposite phase rotations, one positive and the other negative."[78] Nishina was citing R. E. Gilman and Charles LeGeyt Fotescue, who originally "discovered" and "proved" this theorem. In his thesis, Nishina reproduced their proof.

The proof goes as follows. Define ε as:

ε=exp(2πj/n)

where j is the imaginary unit and n is the number of the phase. $E_1, E_{2,} .., E_{n,}$ and $E'_1, E'_2, \ldots, E'_n$, are terminal voltages of two symmetrical n-phase systems, rotating in opposite directions. Since the factor of ε rotates the phase of a complex number by the degree of 2π/n, these terminal voltages of the symmetrical n-phase systems can be written as:

77. Copper loss is the loss caused by the resistance of the conducting wire (which is often a copper line). Iron loss is the loss resulting from the iron core of the coil.

78. Nishina, "Unbalanced Single-Phase Loads," 20.

$$E_1 = E_1$$
$$E_2 = \varepsilon E_1$$
$$E_3 = \varepsilon^2 E_1$$
$$\dots$$
$$E_n = \varepsilon^{n-1} E_1$$
$$E_1' = E_1'$$
$$E_2' = \varepsilon^{-1} E_1'$$
$$E_3' = \varepsilon^{-2} E_1'$$
$$\dots$$
$$E_n' = \varepsilon^{-n+1} E_1'$$

The theorem above states that for any n phase system, of which terminal voltages are V_1, V_2, ... , V_n, there are E_1, E'_1, where,

$$V_1 = E_1 + E_1'$$
$$V_2 = E_2 + E_2'$$
$$\dots$$
$$V_n = E_b + E_n'$$

Nishina's proof goes as follows. If the above equations are multiplied with $\varepsilon^n, \varepsilon^{n-1}, \dots, \varepsilon^1$:

$$\varepsilon^n V_1 = \varepsilon^n E_1 + \varepsilon^n E_1'$$
$$\varepsilon^{n-1} V_2 = \varepsilon^{n-1} E_2 + \varepsilon^{n-1} E_2' = \varepsilon^n E_1 + \varepsilon^{n-2} E_1'$$
$$\dots$$
$$\varepsilon V_n = \varepsilon E_n + \varepsilon E_n' = \varepsilon^n E_1 + \varepsilon^{-n+2} E_1'$$

If we sum up each side of the equations, by considering:

$$\varepsilon^n + \varepsilon^{n-2} + \dots + \varepsilon^{-n+4} + \varepsilon^{-n+2} = \frac{\varepsilon^n - \varepsilon^{-n}}{1 - \varepsilon^{-2}} = \frac{1-1}{1-\varepsilon^{-2}} = 0$$

the result will be:

$$\varepsilon^n V_1 + \varepsilon^{n-1} V_2 + \dots + \varepsilon V_n = n \varepsilon^n E_1$$

By calculating the sum the second term on the right hand side vanishes.

Therefore,

$$E_1 = \frac{V_1 + \varepsilon^{-1} V_2 + \dots + \varepsilon^{-(n-1)} V_n}{n}$$

E'_1 can be derived similarly.

Although the proof itself was not Nishina's own, this indicates Nishina's familiarity with the idea of analyzing the physical system by decomposing it into superpository components. The most interesting aspect of this proof is, however, the fact that it was wrong. The formulae for E_1 and E_1' that Nishina derived are necessary conditions for the original equation, and it is not guaranteed that the derived form of E_1 and $E_{1'}$ and others satisfy the equations. They in fact do not satisfy the equations in general, which one can confirm by simple substitution. A mathematically savvy student, such as those in the physics and mathematics departments, would not have made such a mistake. Since there are n equations and only two variables, this set of equations in general has no answer. Nishina as an electrical engineering student was well-versed in theory, to the extent that he could push theoretical reasoning and draw some results, but not enough to avoid such mistakes.

Considering the grade that Nishina received, apparently no one noticed this mistake, and that was not without reason. Although this theorem constituted the basis of many of Nishina's analyses, in the actual situation of a three-phase system, this error did not turn out to be catastrophic. Nishina could have decomposed an arbitrary unbalanced three-phase system into three, not two, symmetrical systems, two rotating in the opposite directions, and one not rotating at all. Nishina used the reverse component to show the production of higher harmonics and other undesirable effects. These qualitative conclusions did not change significantly whether or not one took the stationary component into consideration. In short, Nishina's arguments in his thesis were mathematically inaccurate but physically correct.

Although it was a theoretical treatment of a polyphase circuit, Nishina's thesis also incorporated experimental data that Nishina himself collected. In

Chapter IV of his thesis, for example, Nishina showed how the balancing action of a generator occurred in synchronous motors under unbalanced terminal voltage with the experimental data that he himself collected at the Shibaura Engineering Works. Since the practical training was part of the departmental curricula, it is very likely that the department, in particular his advisor Hô, encouraged Nishina to collect experimental data, lest Nishina's work would be purely theoretical.

Nishina's thesis shows his commitment to Hô's tradition of theoretical electrical engineering and his close ties to Steinmetz's tradition. It shows Nishina's ability in theoretical reasoning— and its limits. The work was theoretical in the sense that Nishina was deriving fairly general characteristics of the three-phase system. The thesis certainly reveals Nishina's relative mathematical weakness compared to the mathematical wizards at the Physics Department. At the same time, however, it demonstrates Nishina's ability to draw physically correct conclusions. It, of course, differed from a treatise in the contemporary style of theoretical physics, in its close ties to actual machinery and its frequent use of drawings.

5. Nishina Yoshio and the Klein-Nishina Formula

Nishina seemed to have made a very good impression on the people at the Shibaura Engineering Works, who offered him a job in April, three months before Nishina's graduation. Nishina, however, decided to turn down the offer, and began to pursue a career oas a scientist (See Chapter 6). Nishina entered the graduate school of engineering of Tokyo University and at the same time became a research student (kenkyûsei) of Riken. Nishina's act seemed to have angered Hô. Because of Nishina's rejection of the job offer, Hô lost face, and his future students might have had difficulties getting jobs in the Shibaura Engineering Works. In any case, although he remained at the College of Engineering, Nishina had to change his adviser to Kujirai, who was also his boss at Riken.[79]

During his postgraduate years, Nishina shifted his focus from engineering to physics. Officially, Nishina belonged to the graduate school of the College of Engineering, and his research topic concerned the electric furnace, but the unstructured education at the graduate school gave him ample opportunities to pursue his interests in other areas. Nishina studied physics and mathematics, with Nagaoka as his principal teacher. Other teachers included Terada Torahiko, and Sano Shizuwo.[80] Although not much is known about Nishina in this period, it is very likely that Nishina was at this point immersed in the style of theoretical physics discussed in Chapter 2, the "Culture of Calculating," learning some mathematics and becoming accustomed to intensive calculation.

In hindsight, it appears almost accidental that Nishina was able to play such an important role in Japanese physics, but the crucial turning point is obvious: He had a chance to study abroad.

In the course of importing, adopting and appropriating Western science and technology, Japan's government and academic institutions used various techniques to facilitate this process. One of them was to send students to Europe and America. To study abroad was called *ryûgaku*, literally "to stay and to study." In 1922, *ryûgaku* was not as common as it had been. Partly because Japanese universities became good enough to train scientists and engineers for most purposes. Still, a few of the most excellent students, who were destined to become professors at an imperial university or group leaders at Riken, were dispatched to

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79. Nishina Yoshio, "Nani wo yondaka," 227.

80. Ibid.

Europe or to the United States, and stayed one or several years.[81]

Kikuchi Taiji was one of those bright students. In fact, he was a most promising and promised one. As a son of Baron Kikuchi Dairoku, a former president of Tokyo University and ex-Minister of Education (see Chapters 2 and 5), Kikuchi Taiji had many useful connections in Japan's academic world. Among his relatives was Nagaoka Hantarô, the leader of the Japanese physics community. Moreover, he was not only well-connected but also gifted enough to graduate from the Department of Physics in first place.[82] Riken hired him and sent him to Cambridge, England, to work under Ernest Rutherford. He, unfortunately, died there, presumably due to radiation sickness. At the news of Kikuchi Taiji's untimely death, Nagaoka shouted at his own son, "why did Taiji die and a man like you survive?"[83] Quite unexpectedly, money to support a student abroad become available. An obvious solution was to choose another student to send abroad. Riken chose Nishina Yoshio, a 30-year-old research student in the Kujirai group.

It is not clear why Riken chose Nishina. Since Kikuchi was a physicist, someone in physics was an obvious choice. Nishina, who graduated from the competitive College of Engineering with excellent achievements, was expected to have a brighter future, even more than a good student from the less competitive

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81. On studying abroad and its significance in Japan, see also: James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition* (New Haven: Yale University Press, 1989), 68ff.

82. As I mentioned before, students names were listed according to their grades in his time (Kikuchi Taiji graduated in 1917). See, for example, Tokyo Daigaku, *Tokyo Daigaku sotsygôsei shimeiroku* (Tokyo: Tokyo Daigaku, 1950), 554. Alternatively, see *Tokyo Teikoku Daigaku Ichiran Taisho 6-nen yori 7-nen ni itaru*.

83. Nagaoka Haruo, "On'yônaru bishô," in *Tsukiai: Yukawa hakase kanreki kinen bunshû*, edited by Tanigawa Yasutaka (Tokyo: Kôdansha, 1968), 212.

College of Science. Nagaoka must have backed him strongly; otherwise, considering his influence, Nishina could never have a chance. Okouchi, the Director, who specialized in weapons engineering, was unlikely to have any objection.

Nishina left Japan on April 5, 1921, and, like Kikuchi, stayed at the Cavendish Laboratory for about a year.[84] There, Nishina conducted experimental work on the recoil electron from X-ray scattering. In a year, he moved to Göttingen and spent six months learning from David Hilbert and Max Born. In early 1923, Nishina went to Copenhagen to work with Niels Bohr. His initial focus was experimental physics, especially X-ray spectroscopy.[85] Circa early 1927, however, Nishina's interest shifted to theory. In late 1927, he moved to Hamburg with I. I. Rabi to study quantum mechanics from Wolfgang Pauli, and there completed his first work in theoretical physics with Rabi.[86] He returned to

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84. One reason Nishina went to Cavendish might be his foreign language background. English was his first foreign language, and in his higher school years, he had been a member of the school's English Speaking Society. During his stay in Europe, he learned German, to the extend he could attend Pauli's seminar in Hamburg. He tried to learn French by staying in Paris for a few months, but one letter indicates that his attempt was not successful.

85. Nishina's works on X-ray spectroscopy in this period include: Dirk Coster and Sven Werner, "Röntgenspektroskopie über die Absorptionsspektren in der L-Serie der Elemente La (57) bis HF(72)," *Zeitschrift für Physik* 18 (1923): 207-11; Yoshio Nishina, "L-Absorption Spectra of the Elements from Sn(50) to W(74) and Their Relation to the Atomic Constitution," *Philosophical Magazine* 49 (1925): 521-37; Dirk Coster and Yoshio Nishina, "On the Quantitative Chemical Analysis by Means of X-Ray Spectrum," *The Chemical News* 136 (1925): 149-52; Shin'ichi Aoyama, Kenjirô Kimura, and Yoshio Nishina, "Die Abhängigkeit der Röntgenabsorptionsspektren von der chemischen Bindung," *Zeitschrift für Physik* 44 (1927): 810-33.

86. Yoshio Nishina and I. I. Rabi, "Der wahre Absorpotionskoeffizient der Rôntgenstrahlen nach der Quantentheorie," *Verhandlung der Deutschen Physikalischen Geselschaft* 9 (1928): 6-9.

Copenhagen in March 1928, where he worked with Oskar Klein on the relativistic treatment of the Compton effect.[87]

The Compton effect occupies a central place in the history of the wave-particle duality of light.[88] Although the great Isaac Newton considered light to be particles, the 19th century French wave theorists triumphed over proponents of the particle theory of light. Moreover, Maxwell's electromagnetic theory appeared to give a definitive and final confirmation to the wave theory of light. The wave of electromagnetic fields governned by Maxwell's equations accounted for all the properties of light—or, it appeared so, until, in 1905, a young Swiss patent clerk proposed a theory ("very revolutionary" even by his standard[89]) that claimed light to be particles.[90] Among physicists, the light quanta theory of the patent clerk Albert Einstein was harder to swallow than his relativity theory. Whereas relativity theory could encompass Newtonian mechanics as a case where speeds in question are far smaller than the speed of light, light quanta theory appeared to be in irreconciliable contradiction with numerous triumphs of nineteenth century physics. Certainly, light quanta theory explained a single phenomenon called the photoelectric effect, a physical phenomenon where a metal illuminated with light

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87. For Nishina's chronology, see: Ezawa Hiroshi and Takeuchi Hajime, "Nempu".

88. For a history of experimental studies on wave and particle theories of light, see: Bruce R. Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism* (Cambridge: Cambridge University Press, 1983). For the place of the Compton effect, see, pp. 283-286.

89. In a letter from Albert Einstein to Conrad Habicht in the spring of 1905. Quoted in Carl Seelig, *Albert Einstein: A Documentary Biography*, translated by Mervyn Savill (London: Staples Press Limited, 1956), 74-75.

90. Albert Einstein, "Über einen Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt," *Annalen der Physik* 17 (1905): 185-93.

ejects electrons.[91] But what about other numerous light-related phenomena, such as diffraction and inteference, that apparently show the wave-like nature of light? Most physicists, therefore, did not take Einstein seriously as far as light quanta was concerned.[92] This changed when the American experimentalist Arthur H. Compton proposed an interpretation of the mysterious shift in wavelength of scattered X-rays in 1922.[93] When a light atom (such as the carbon atom) is illuminated by an X-ray, the wavelength of the scattered X-ray is longer than the original, and the difference depends on the direction of the outgoing X-ray. In a paper written in December 1922, Compton explained this phenomenon using the light quanta theory, treating this phenomenon as a collision of two particles. When a moving particle collides with a stationary one, the moving particle transfers some of its energy and momentum to the other, and the more squarely they collide, the more energy is transferred. Since, according to Einstein's formula a particle with smaller energy has a longer wavelength, the scattered X-ray has a longer wavelength. The more the scattered X-ray deviates from the original course, the longer its wavelength becomes. After many twists and turns, Compton found that such an interpretation explained his and others' experiments on X-ray scattering of the electron. In a mathematical expression, his results for the angular distribution

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91. For the photoelectric effect, see: R. Bruce Wheaton, "Philipp Lenard and the Photoelectric Effect, 1889-1911," *Historical Studies in Physical Sciences* 9 (1978): 299-323.

92. As for Einstein's light quanta theory and physicists' reactions to it, see: Martin J. Klein, "Einstein's First Paper on Quanta," *The Natural Philosopher* 2 (1963): 59-86; Martin J. Klein, "Einstein and the Wave Particle Duality," *The Natural Philosopher* 3 (1964): 3-49; Wheaton, *The Tiger and the Shark*, 109.

93. Arthur H. Compton, "A Quantum Theory of the Scattering of X-Rays by Light Elements," *Physical Review* 21 (1923): 482-502. As for the history of the Compton effect, see: Roger Stuewer, *The Compton Effect: Turning Point in Physics* (New York: Science History Publications, 1975).

of the frequency and number (intensity) of the scattered light-quanta took the following form:[94]

$$\frac{\nu_\theta}{\nu_0} = \frac{1}{1+2\alpha\sin^2(\theta/2)},$$
$$I(\theta,\alpha) = \frac{Ne^4}{m^2c^4}\left\{\frac{1+\cos^2\theta+2\alpha(1+\alpha)(1-\cos\theta)^2}{2[1+\alpha(1-\cos\theta)]^5}\right\},$$
$$\alpha = h\nu_0/mc^2$$

Here, I is the intensity per angle, ν_0, the original frequency, ν_θ, the frequency of the outgoing radiation, θ, the angle of the outgoing radiation, N, the number of the incoming photons, m, the mass of the electron, h, Planck's constant, and α, a dimensionless quantity defined above (not the fine structure constant).

The Compton effect constituted one of the most convincing experimental supports for light quanta theory, as Arnold Sommerfeld said, it "sounded the death-knell" of wave theory.[95] It therefore became one of the major battlefields for those who adamantly opposed it. Objectors included Niels Bohr, who remained skeptical of Einstein's theory. The strife continued until as late as 1924. Bohr, along with his Dutch collaborator Hendrik Anthony Kramers,[96] appropriated the idea of "virtual radiation field," suggested by the young American scientist John Slater, then visiting Copenhagen,[97] proposed the so-called Bohr-Kramers-Slater

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94. Quoted in Stuewer, *Compton Effect*, 226, 230.

95. Quoted in Wheaton, *The Tiger and the Shark*, 286.

96. For Kramers' biography, see: Max Dresden, *H. A. Kramers: Between Tradition and Revolution* (New York: Springer, 1987).

97. On Slater's young years, see: Silvan S. Schweber, "The Young John Clarke Slater and the Development of Quantum Chemistry," *Historical Studies in the Physical and Biological Sciences* 20 (1990): 339-406.

theory.[98] According to this theory, whereas atoms made transitions discontinuously, radiation remained continuous. This theory, however, paid a high price, namely causality. Since one became continuous and the other discontinuous, they could only be related statistically.[99] A couple of experiments published in early 1925 by Geiger and Bothe, as well as by Compton and Simon, however, provided evidence in favor of light quanta theory.[100] In this "first phase of Einstein-Bohr dialogue,"[101] thus, Einstein prevailed.

After the emergence of quantum mechanics, it was natural that the Compton effect drew the attention of quantum physicists, in particular those in Copenhagen who wanted to check the validity of the new theory. P. A. M. Dirac and Walter Gordon carried out quantum mechanical treatments of Compton scattering in different ways.[102] Since Klein and Nishina followed Gordon's strategy, here I focus only on his paper.

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98. Niels Bohr, Hendrik A. Kramers, and John C. Slater, "The Quantum Theory of Radiation," *Philosophical Magazine* 47 (1924): 785-802.

99. For historical accounts of the Bohr-Kramers-Slater theory, see, for example: Martin J. Klein, "The First Phase of the Bohr-Einstein Dialogue," *Historical Studies in the Physical Sciences* 2 (1970): 1-39; John Hendry, "Bohr-Kramers-Slater: A Virtual Theory of Virtual Oscillators and Its Role in the History of Quantum Mechanics," *Centaurus* 25 (1981): 189-221; or John Hendry, *The Creation of Quantum Mechanics and the Bohr Pauli Dialogue* (Dordrecht: D. Reidel, 1984).

100. Walter Geiger and Hans Bothe, "Über das Wesen des Comptoneffekts," *Zeitschrift für Physik* 32 (1925): 639-63; Arthur H. Compton and A. W. Simon, "Directed Quanta of Scattered Xrays," *Physical Review* 26 (1925): 289-99; Arthur H. Compton and A. W. Simon, "Measurements of [Beta]-Rays Associated with Scattered x-Rays," *Physical Review* 25 (1925): 306-13.

101. Klein, "Bohr-Einstein."

102. Paul Adrian Maurice Dirac, "Relativity Quantum Mechanics with an Application to Compton Scattering," *Proceedings of the Royal Society of London,*

Walter Gordon was a young German physicist born in 1893, who obtained his doctorate at the University of Berlin in 1921. He was based in Berlin until 1929, when he was appointed as a *Privatdozent* of the University of Hamburg.[103] In his 1926 paper, in a way reminiscent of the early years of quantum theory, Gordon proceeded by comparing classical and quantum mechanical calculations. He had a relatively simple picture behind his calculation. The incoming radiation disturbs and gives motion to the electron, making an electromagnetic interaction with it. So, Gordon first calculated how the incoming radiation would interact with the electron both in classical mechanics and quantum mechanics. When moving, the electron, a charged particle, emits radiation, which Gordon calculated with a classical electromagnetic formula and considered as the outgoing X-ray observed in the experiment.

In mathematical expression, what Gordon did can be written as follows. He assumed that the incoming radiation was a monochromatic plane wave, setting its (four-)vector potential Φ_α as:

$$\Phi_\alpha = a_\alpha \cos\varphi, a_4 = ia_0$$

$$\varphi = \frac{2\pi\nu}{c}\left(\sum n_k x_k - ct\right)$$

where c is the speed of light, n_k the vector that give the direction of the radiation, ν, the frequency of the wave, a_α the amplitude of the wave, and α is the suffix for

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Series A 111 (1926): 405-23; Walter Gordon, "Der Comptoneffekt nach der Schrödingerschen Theorie," *Zeitschrift für Physik* 40 (1926): 117-33.

103. Walter Gordon's life has not received its due attention, and a touching biographical note by his colleague Oskar Klein is all I have about it. According to Klein, Gordon advanced to an associate professor at the University of Hamburg, but, because of his Jewish origin, he lost the job in 1933. He emigrated to Sweden, and became a member of the Institute of Mathematical Physics, but he could never obtain a regular professership. He died young, in adversity, in 1940. See: Oskar

a four vector taking the value of 1 through 4 (alternatively 0 through 3), whereas *k* is the suffix for a three vector, taking the value of 1 through 3. The first task was to solve the equations of motion of the electron. In the classical calculation of the electron's motion, he used the relativistic Hamilton-Jacobi equation:

$$\sum\left(\frac{\partial W}{\partial x_\alpha}-\frac{e}{c}\Phi_\alpha\right)^2+m^2c^2=0$$

where, *W* is action of the system, *m,* the mass of the electron, and *e,* its charge. For the quantum mechanical treatment, Gordon chose to use the Klein-Gordon equation:[104]

$$\left\{\sum\left(\frac{h}{2\pi i}\frac{\partial}{\partial x_\alpha}-\frac{e}{c}\Phi_\alpha\right)^2+m^2c^2\right\}\psi=0$$

where Ψ is the wave function. In the presence of the above-mentioned radiation, these equations can be solved to the first order:

$$W=px+\frac{pb}{pl}\sin\varphi,\psi=e^{\frac{2\pi i}{h}w}$$

where $b_\alpha = (e/c)a_\alpha$, $l_k = 2(\pi\nu/c)nk$, $l_0 = i2(\pi\nu/c)$, *px, pb, pl* are all inner products of four vectors, *p, x, b, l*, defined above. In classical mechanics, where the electron can be considered as a point mass, the electromagnetic wave resulting from its motion is easily calculated. In particular, the frequency of the wave is trivially the same as the frequency of the moving electron.[105] The quantum

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Klein, "Gordon, Walter," in *Dictionary of Scientific Biography*, vol. 5, Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1972), 473-4.

104. The Klein-Gordon equation is a relativistic version of the quantum mechanical wave equation. On the historical background of this equation, see: Helge Kragh, "Equation with Many Fathers. The Klein-Gordon Equations in 1926," *American Journal of Physics* 52 (1984): 1024-33.

105. Gordon, "Der Comptoneffekt nach der Schrödingerschen Theorie," 125.

mechanical treatment required a more complicated procedure since the electron needed to be considered not as a point mass but as a spatially distributed wave. From the solutions of the equation, Gordon wrote up the general form of the solution as an arbitrary superposition of them:

$$\psi = \int z(p)C(p)e^{\frac{2\pi i}{h}W}dp, dp = dp_1dp_2dp_3$$

where $z(p)$ and $C(p)$ are certain functions of p, to be determined (I omit how Gordon determined them). Gordon assumed that electric current in quantum mechanics should take the following form:

$$s_\alpha = \frac{1}{i}\left(\overline{\psi}\frac{\partial\psi}{\partial x_\alpha} - \psi\frac{\partial\overline{\psi}}{\partial\psi} - \frac{4\pi i}{h}\frac{e}{c}\Phi_\alpha\psi\overline{\psi}\right).$$

Then he plugged in the current into the classical electromagnetic formula of the retarded potential at a certain point,

$$\Phi_\alpha = \frac{1}{c}\int\frac{[s_\alpha]}{R}dx, dx = dx_1dx_2dx_3$$

which gave the electromagnetic field caused by the current. Here, R is the spatial distance between the volume element dx of the integral and the point in question and the bracket [] indicates that t in S_α should be substituted by $(t-R/c)$. Then, Gordon calculated the frequency and intensity of the induced radiation.[106] The result, according to Gordon, agreed with the one obtained by Dirac in the above-mentioned paper:[107]

$$I = \frac{e^4}{m^2c^4r^2}I_0\frac{\sin^2\phi}{(1+\alpha(1-\cos\theta))^3}$$

where ϕ is the angle between the electric field and the observed direction, θ, between the direction of the incoming radiation and the observed direction, I_0, the

106. Ibid., 133.

107. Dirac, "Compton Scattering," 422.

intensity of the incoming radiation, and *r*, the distance between the point of scattering and the point of observation. It was approximately identical to the formula obtained by Compton above.

In February 1928, P. A. M. Dirac's relativistic theory of electron appeared in the *Proceedings of the Royal Society.*[108] The original fundamental equations in quantum mechanics, such as the Schrödinger equations, not being covariant, do not satisfy the requirements of special relativity theory. Klein and Gordon proposed the above-mentioned the Klein-Gordon equation, a covariant quantum mechanical equation, which was, however, second order in the time derivative, and gave anomalous solutions, in particular solutions with a negative energy. Dirac succeeded to make a quantum mechanical equation, linear in space-time and covariant, which is the famous Dirac equation:

$$\left[p_0 + \frac{e}{c}A_0 + \rho_1\left(\boldsymbol{\sigma}, \mathbf{p} + \frac{e}{c}\mathbf{A}\right) + \rho_3 mc\right]\phi = 0$$

Here (**a**, **b**) is the inner product of the (three-)vectors **a** and **b**. *Ao* and **A** are components of the vector potential, *m,* the mass of the electron, *e,* its charge, *c,* the speed of light, and ϕ, the wave function. The operators σ_r and ρ_s are defined as satisfying the following relations:

$$\begin{aligned}
&\sigma_r^2 = 1, \sigma_r\sigma_s + \sigma_s\sigma_r = 0 (r \neq s)\\
&\rho_r^2 = 1, \rho_r\rho_s + \rho_s\rho_r = 0 (r \neq s)\\
&\rho_r\sigma_t = \sigma_t\rho_r.
\end{aligned}$$

These are called Dirac matrices and can be represented by four-by-four matrices:

108. Dirac, "The Quantum Theory of Electron."

$$\sigma_1 = \left\{\begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}\right\}, \sigma_2 = \left\{\begin{bmatrix} 0 & -i & 0 & 0 \\ i & 0 & 0 & 0 \\ 0 & 0 & 0 & -i \\ 0 & 0 & i & 0 \end{bmatrix}\right\}, \sigma_3 = \left\{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\right\},$$

$$\rho_1 = \left\{\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}\right\}, \rho_2 = \left\{\begin{bmatrix} 0 & 0 & -i & 0 \\ 0 & 0 & 0 & -i \\ i & 0 & 0 & 1 \\ 0 & i & 0 & 0 \end{bmatrix}\right\}, \rho_3 = \left\{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}\right\}.$$

The most remarkable feature of Dirac's theory was its natural derivation of the spin of the electron, which had been previously added to the theory in an *ad hoc* way. In this formulation, σ_r are operators of the electron's spin, and the expected value of the spin is now given by $u(\mathfrak{p})\boldsymbol{\sigma}v(\mathfrak{p})$, where $u(\mathfrak{p})$ and $v(\mathfrak{p})$ are time independent parts of the wave functions.[109]

Sometime during the winter of 1927 and 1928, Dirac sent a draft of his theory to Copenhagen, which shocked physicists at Bohr's institute, among others Oskar Klein. Oskar Klein was a Swedish physicis born in 1896, the son of Sweden's first rabbi.[110] As we have seen, he had been working on the relativistic reformulation of quantum mechanics, being one of the "many fathers" of the Klein-Gordon equation.[111] He had also been working on the Compton effect in quantum mechanics, although Gordon published the result before Klein. He was

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109. Ibid., 610.

110. For Klein's biography, see: Karl von Meyenn and Marino Baig, "Klein, Oskar Benjamin," in *Supplement II*, vol. 17 of *Dictionary of Scientific Biography*, edited by Frederic L. Holmes (New York: Charls Scribner's Sons, 1990), 480-84.

111. Kragh, "Klein-Gordon Equations."

one of Bohr's closest collaborators and gained the coveted position of lecturer at Bohr's institute, succeeding Kramers and Heisenberg. Dirac's theory of electrons came as an "amazing surprise" to Klein. Bohr sent Klein to Cambridge in January 1928 so that Klein could learn the new theory from Dirac. Klein became preoccupied by this theory, abandoning his work on general relativity for a while.[112]

Nishina was then in Hamburg. Having heard of Dirac's new theory or read a copy sent to someone in Hamburg, Nishina wrote to Dirac on February 10, 1928, to congratulate him on the success of the new theory. He also asked for a separate copy of his paper, and stated his wish to go and stay in Cambridge in the next term to spend a month or two "learning" from Dirac.[113] Nishina wrote to Dirac again on February 25 to tell Dirac that Nishina would "calculate Compton effect according to your new theory," again asking for a copy of Dirac's "theory of the electron" paper. Having learned that Dirac would be in Leiden not in Cambridge, Nishina proposed to visit him in Leiden.[114]

In the spring of 1928, Nishina returned to Copenhagen, where he met Gordon, who returned to Bohr's institute. Oskar Klein also had come back to Copenhagen from Cambridge. Nishina, as I mentioned, had been working on experiments related to X-rays and Compton effects and was looking for a chance to turn to theory. Klein had been working on a quantum mechanical treatment of

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112. Oskar Klein, "From My Life of Physics," in *From a Life of Physics (Singapore: World Scientific, 1989)*, Hans. A Bethe, et al. (Singapore: World Scientific, 1989), 82.

113. Yoshio Nishina, A letter to P. A. M. Dirac, February 10, 1928, Churchill College (Cambridge).

114. Yoshio Nishina, A letter to P. A. M. Dirac, February 25, 1928, Churchill College (Cambridge).

the Compton effect, although Gordon had done it before him. One day, Gordon, Klein, and Nishina chatted at the institute, and Gordon suggested the problem of applying Dirac's relativstic treatment to the Compton effect would be best suited for Nishina. Klein was thinking of working on this problem himself, but immediately agreed to work with Nishina.[115]

There is already a very detailed study by Yazaki Yuji about the Klein-Nishina work, which examines the process of their work. Closely studying archival sources left by Nishina in Riken, Yazaki shows that not only the meticulous calculation but also the physical interpretation of solutions to the Dirac equation was essential in the Klein-Nishina work. It was a time when physicists were not yet sure what the four components of Dirac's wave functions meant. In particular, Klein and Nishina had to grope for a counterpart to orthogonality in Dirac's theory. In ordinary quantum mechanics, orthogonality is straightforwardly defined: when the inner product of two wave functions (usually the integration of their product over the entire space) is zero, these functions are orthogonal. Orthogonality is the basis of many quantum mechanical calculations, such as the calculation of average values (since quantum mechanics is a fundamentally probabilistic theory, we can calculate only average for the experimentally observable quantities). In order to carry out the same calculations in Dirac's theory, Klein and Nishina had to find the counterpart of orthogonality in Dirac's theory, which they did through physical guess work, rather than mathematical axiomatization.[116] Since Yazaki's study is not known outside Japan, and it is in our

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115. Oskar Klein, "Kenkyû no hibi," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi, translated by Koizumi Kenkichirô (Tokyo: Misuzu Shobô, 1991), 94.

116. Yazaki Yûji, "Klein-Nishina kôshiki dônyû no katei," *Kagakushi Kenkyû* 31 (1992): 81-91, 129-37.

interest to see what Klein and Nishina actually did, here I discuss Klein and Nishina's work, without worrying about redundancy.

The strategy of the Klein and Nishina paper was simple. They followed the same procedure as Gordon did in the above-mentioned paper. They calculated the motion of the electron by solving Dirac's equations in the presence of radiation and then derived the radiation resulting from the motion of the electron by using the formula for retarded potential.

As Yazaki points out, however, there were physical or interpretive problems. In ordinary quantum mechanics, the degeneracy resulting from spin causes no problem because spin does not appear in the equations. But Dirac's equations give two solutions corresponding to two spin states. The equation itself contains spin, so does the expression of the outgoing radiation. How to calculate the average value in such a case was a problem. The authors answered this question by taking a superposition of two spin states.[117]

In a preparation, the authors derived a solution to the equation for the "free electron," namely the electron under no outside interaction. The equations for time-independent wave functions for the free electron are:[118]

$$u(\mathfrak{p})\{E/c + \rho_1(\sigma\mathfrak{p}) + \rho_3 mc\} = 0$$
$$\{E/c + \rho_1(\sigma\mathfrak{p}) + \rho_3 mc\}v(\mathfrak{p}) = 0.$$

In order to solve these equations, the authors first considered the solution to stationary electrons, u^* and v^*.

$$u(\mathfrak{p}) = u^*(\mathfrak{p})S(\mathfrak{p}), v(\mathfrak{p}) = S^{-1}(\mathfrak{p})v^*(\mathfrak{p})$$

where S represents the Lorentz transformation:

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117. Ibid., 129.

118. Note that in the notation of this paper symbols in German script and symbols in gothic fonts are spatial vectors, and u and v have four components (the category of quantity soon named as "spinor").

$$S = \alpha + i\beta\rho_2(\sigma\mathfrak{p})$$
$$\alpha = \sqrt{\frac{m^* + m}{2m^*}}, \beta = \sqrt{\frac{m^* - m}{2m^*\mathfrak{p}^2}}, m^* = \sqrt{c^2 + \frac{\mathfrak{p}^2}{c}}$$

By plugging in the above expressions of wave functions, one gets the following equations:

$$u^*(1+\rho_3) = 0, (1+\rho_3)v^* = 0$$

These are naturally the same as those that one gets by setting $\mathfrak{p}$=0 in the Dirac equations for free electrons. With the representation of the Dirac matrices given above (except Klein and Nishina used the opposite signs for $\boldsymbol{\rho}$), these can be solved. There are two independent solutions:

$$u_1^*(\mathfrak{p}) = a_1 e^{i\sigma_1(\gamma)}, u_2^*(\mathfrak{p}) = a_2 e^{i\sigma_2(\gamma)},$$
$$v_1^*(\mathfrak{p}) = a_1 e^{-i\sigma_1(\gamma)}, v_2^*(\mathfrak{p}) = a_2 e^{-i\sigma_2(\gamma)},$$
$$a_1^2 = a_2^2 = (2\pi\hbar)^{-3}$$

where the normalization condition is set as:

$$u(\mathfrak{p})v(\mathfrak{p}) = (2\pi\hbar)^{-3}$$

I rewrite the above solutions in more explicit forms.[119] For *u**:

$$\begin{pmatrix} a_1 e^{i\sigma_1(\gamma)} \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ a_2 e^{i\sigma_2(\gamma)} \\ 0 \\ 0 \end{pmatrix}$$

and *v**:

$$\begin{pmatrix} a_1 e^{-i\sigma_1(\gamma)} \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ a_2 e^{-i\sigma_2(\gamma)} \\ 0 \\ 0 \end{pmatrix}$$

As in the case of Gordon, the first step is to solve the motion of the electron with incoming radiation. As Gordon did, Klein and Nishina set the incoming radiation as a plain monochromatic wave:

$$\mathfrak{A} = \mathfrak{a} e^{i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)} + \bar{\mathfrak{a}} e^{-i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)}$$

Using the solutions to the free electrons, the authors assumed that the solutions would take the following forms:

$$\varphi(\mathfrak{p}) = \varphi_0(\mathfrak{p})\left\{1 + f(\mathfrak{p}) e^{i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)} + \bar{f}(\mathfrak{p}) e^{-i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)}\right\},$$

$$\psi(\mathfrak{p}) = \left\{1 + g(\mathfrak{p}) e^{i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)} + \bar{g}(\mathfrak{p}) e^{-i\nu\left(t - \frac{(\mathfrak{n}\mathfrak{r})}{c}\right)}\right\}\psi_0(\mathfrak{p}).$$

where, $f(\mathfrak{p})$, $\bar{f}(\mathfrak{p})$, $g(\mathfrak{p})$, $\bar{g}(\mathfrak{p})$ are all mutually independent functions to be decided to satisfy the equations. They were solved up to the first order as:

$$f(\mathfrak{p}) = \frac{e}{2h\nu(E/c - (\mathfrak{n}\mathfrak{p}))}\{2(\mathfrak{a}\mathfrak{p}) + h(\boldsymbol{\sigma}\boldsymbol{\eta}) - ih\rho_1(\boldsymbol{\sigma}\boldsymbol{\varepsilon})\},$$

$$\bar{f}(\mathfrak{p}) = -\frac{e}{2h\nu(E/c - (\mathfrak{n}\mathfrak{p}))}\{2(\mathfrak{a}\mathfrak{p}) + h(\boldsymbol{\sigma}\bar{\boldsymbol{\eta}}) - ih\rho_1(\boldsymbol{\sigma}\bar{\boldsymbol{\varepsilon}})\},$$

$$g(\mathfrak{p}) = -\frac{e}{2h\nu(E/c - (\mathfrak{n}\mathfrak{p}))}\{2(\mathfrak{a}\mathfrak{p}) + h(\boldsymbol{\sigma}\boldsymbol{\eta}) + ih\rho_1(\boldsymbol{\sigma}\boldsymbol{\varepsilon})\},$$

$$\bar{g}(\mathfrak{p}) = \frac{e}{2h\nu(E/c - (\mathfrak{n}\mathfrak{p}))}\{2(\mathfrak{a}\mathfrak{p}) + h(\boldsymbol{\sigma}\bar{\boldsymbol{\eta}}) + ih\rho_1(\boldsymbol{\sigma}\bar{\boldsymbol{\varepsilon}})\},$$

where,

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119. These are based on: Klein and Nishina, "Streuung," 858.

$$\varepsilon = -\frac{i\nu}{c}\mathfrak{a}, \quad \bar{\varepsilon} = -\frac{i\nu}{c}\bar{\mathfrak{a}},$$
$$\eta = -\frac{i\nu}{c}[\mathfrak{n}\mathfrak{a}], \quad \eta = \frac{i\nu}{c}[\mathfrak{n}\bar{\mathfrak{a}}]$$

Here, $\mathfrak{n}$ is the unit vector in the direction of the incoming radiation (and $\mathfrak{n}'$, which appears later, is of the outgoing). The authors wrote down the general solutions as superpositions of the above solutions over momentum:[120]

$$\Phi = \int \varphi(\mathfrak{p})d\mathfrak{p}, \Psi = \int \psi(\mathfrak{p})d\mathfrak{p}$$

The next step was to calculate current. Following Dirac,[121] Klein and Nishina defined the electric density and current density as:

$$\rho = -\varphi\psi, \mathfrak{J} = ce\Phi\rho_1\sigma\Psi$$

In spite of the authors' misleading notation, ρ on the left-hand side of the first equation is not a Dirac matrix introduced above, but electric density.

By plugging in these into the expression of the current:

$$\mathfrak{J} = \mathfrak{J}_0 + ce\iint d\mathfrak{p}d\mathfrak{p}'\left\{u(\mathfrak{p})[\rho_1\sigma g(\mathfrak{p}') + f(\mathfrak{p})\rho_1\sigma]v(\mathfrak{p}')e^{\frac{i}{h}\left[(E+h\nu-E')t-\left(\mathfrak{r}+\mathfrak{n}\frac{h\nu}{c}\right)\right]}\right\} + c.c.$$
$$\mathfrak{J}_0 = ce\Phi_0\rho_1\sigma\Psi_0, \Phi_0 = \int \varphi_0(\mathfrak{p})d\mathfrak{p}, \Psi_0 = \int \psi_0(\mathfrak{p})d\mathfrak{p}.$$

where *"c. c."* is the complex conjugate of the preceding term.[122]

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120. Klein and Nishina, "Streuung," 860.

121. Paul Adrian Maurice Dirac, "The Quantum Theory of Electron, Part II," *Proceedings of the Royal Society of London, Series A* 118 (1928): 354.

122. Klein and Nishina, "Streuung," 861.

The next step is to derive the outgoing radiation using the electric current obtained above. By the formula of the retarded potential, the resulting radiation $\mathfrak{A}'$ became:

$$\mathfrak{A}' = \frac{c}{r}\iint dpdp'\left\{e^{\frac{i}{h}(E+h\nu-E')}\int d\mathfrak{r}u(\mathfrak{p})\left[\rho_1\sigma g(\mathfrak{p}')+f(\mathfrak{p})\rho_1\sigma\right]v(\mathfrak{p}')e^{-\frac{i}{h}\left[\mathfrak{p}-\mathfrak{p}'+\mathfrak{n}\frac{h\nu}{c}-\mathfrak{n}'\frac{E+h\nu-E'}{c}\right]\mathfrak{r}}+c.c.\right\}.$$

Having a few variables replaced,

$$\mathfrak{P} = \mathfrak{p}+\mathfrak{n}\frac{h\nu}{c}-\mathfrak{n}\frac{E+h\nu}{c}, \mathfrak{P}' = \mathfrak{p}'+\frac{E'}{c}\mathfrak{n}'.$$

and divided by the necessary Jacobians Δ, Δ',

$$\mathfrak{A}' = \frac{(2\pi h)^3}{r}\int\frac{d\mathfrak{P}}{\Delta\Delta'}\left\{e^{i\nu'\left(t-\frac{r}{c}\right)}u(\mathfrak{p})\left[\rho_1\sigma g(\mathfrak{p}')+f(\mathfrak{p})\rho_1\sigma\right]v(\mathfrak{p}')+c.c.\right\}.$$

Here, again, "c. c." means the complex conjugate of the preceding term. By the definition of the vector potential, magnetic field is:

$$\mathfrak{H}(\mathfrak{p},\mathfrak{p}') = rot\ \mathfrak{A}(\mathfrak{p},\mathfrak{p}')$$

To make the calculation manageable, the authors calculate when the electron is original stationary, and call the vector potential and the magnetic field $\mathfrak{A}_0$ and $\mathfrak{H}_0$.

Then,[123]

$$\mathfrak{H}_0 = \frac{(2\pi h)^3c^2\nu'}{2mc^2r\left(\nu-\nu'+\frac{2mc^2}{h}\right)}\sqrt{\frac{E'\nu'}{mc^2\nu}}\left\{d\left(\frac{1}{\nu}(\mathfrak{n}'\varepsilon)(\nu'-\nu)[\mathfrak{n}'\mathfrak{n}]-\nu'\left(\frac{1}{\nu}+\frac{1}{\nu'}\right)^2\frac{mc^2}{h}[\mathfrak{n}'\varepsilon]\right)\right.$$
$$-i\left[\left(\frac{1}{\nu'}-\frac{1}{\nu}\right)\left((\mathfrak{S},\mathfrak{n}\nu'-\mathfrak{n}'\nu')((\mathfrak{n}'\varepsilon)\mathfrak{n}-(\mathfrak{n}\mathfrak{n}')\varepsilon)+\left(\nu-\nu'+\frac{2mc^2}{h}\right)((\mathfrak{S}\mathfrak{n}')\varepsilon-(\mathfrak{n}'\varepsilon)\mathfrak{S})\right)\right.$$
$$\left.\left.+\frac{2}{\nu}(\varepsilon\mathfrak{n}')((\mathfrak{n}\nu-\mathfrak{n}'\nu')+(\nu'-(\mathfrak{n}\mathfrak{n}')\nu)\mathfrak{S})-\left(\frac{1}{\nu}-\frac{1}{\nu'}\right)((\mathfrak{n}[\varepsilon\mathfrak{S}])\nu[\mathfrak{n}'\mathfrak{n}]+\nu'(\mathfrak{n}'[\mathfrak{n}\varepsilon])[\mathfrak{n}'\varepsilon])\right]\right\}e^{i\nu\left(t-\frac{r}{c}\right)}+c.c.$$

where

$$\mathfrak{s} = u(\mathrm{p})\sigma v(\mathrm{p}'),\ \bar{\mathfrak{s}} = u(\mathrm{p}')\sigma v(\mathrm{p}),$$
$$\mathrm{d} = u(\mathrm{p})v(\mathrm{p}'),\ \bar{\mathrm{d}} = u(\mathrm{p}')v(\mathrm{p})$$

To calculate the intensity of the radiation, Klein and Nishina needed the average value of the square of the magnetic field. A problem arose here. It was not clear in Dirac's theory how to calculate average values when there were two solutions. In order to proceed, Klein and Nishina employed the following consideration. They assumed that the final state should contain both of the independent solutions with the same weight. In other words, it should be a superposition of the two independent solutions. They further assumed that those solutions should be multiplied with phase factors and an average should be made over the phases.[124]

Klein and Nishina were probably unaware, but this procedure amounts to a statistical average (not quantum mechanics) with equal weights. In mathematical symbols, they carried out the following calculation:

$$\iint \left(\langle +|e^{-i\delta_1} + \langle -|e^{-i\delta_2}\right)\mathfrak{S}\left(|+\rangle e^{i\delta_1} + |-\rangle e^{i\delta_2}\right)\frac{d\delta_1}{2\pi}\frac{d\delta_2}{2\pi}$$
$$= \iint \left(\langle +|\mathfrak{S}|+\rangle + \langle -|\mathfrak{S}|-\rangle + \langle -|\mathfrak{S}|+\rangle e^{i\delta_1 - i\delta_2} + \langle +|\mathfrak{S}|-\rangle e^{i\delta_2 - i\delta_1}\right)\frac{d\delta_1}{2\pi}\frac{d\delta_2}{2\pi}$$
$$= \langle +|\mathfrak{S}|+\rangle + \langle -|\mathfrak{S}|-\rangle + 0 + 0$$

The authors adhered to superposing two states and writing down a pure quantum state, rather than a mixed state as in quantum statistics.

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123. Ibid., 864.

124. Ibid., 865-66.

The principal difficulties that Klein and Nishina faced was how to choose two independent states. One plausible solution was to choose two independent spin states, such as up and down along the *z*-axis, which were two orthogonal states in ordinary quantum mechanics. Unfortunately, however, spin was not Lorentz invariant, not preserved by the Lorentz transformation. Chosen by this way, two states might be independent in one frame of reference, dependent in another. As we have seen, Klein and Nishina avoided this difficulty by using Lorentz transformation, and choosing two independent states with spin up and down when they were stationary.[125]

Klein and Nishina, therefore, put the solutions for the final states as follows:

$$u(\mathfrak{p}) = u^{*}(\mathfrak{p})S(\mathfrak{p}), v(\mathfrak{p}) = S^{-1}(\mathfrak{p})v^{*}(\mathfrak{p})$$

$$u^{*}(\mathfrak{p}) = (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} e^{i\sigma(\mathfrak{r})} \\ 0 \\ 0 \\ 0 \end{pmatrix} + (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} 0 \\ e^{i\sigma(\mathfrak{r})} \\ 0 \\ 0 \end{pmatrix} = (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} e^{i\sigma(\mathfrak{r})} \\ e^{i\sigma(\mathfrak{r})} \\ 0 \\ 0 \end{pmatrix},$$

$$v^{*}(\mathfrak{p}) = (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} e^{-i\sigma(\mathfrak{r})} \\ 0 \\ 0 \\ 0 \end{pmatrix} + (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} 0 \\ e^{-i\sigma(\mathfrak{r})} \\ 0 \\ 0 \end{pmatrix} = (2\pi\hbar)^{-\frac{3}{2}}\begin{pmatrix} e^{-i\sigma(\mathfrak{r})} \\ e^{-i\sigma(\mathfrak{r})} \\ 0 \\ 0 \end{pmatrix}.$$

Then, the authors applied the above procedure to calculate the average values. In this process, however, they created a discrepancy. Because Klein and

Nishina simply superposed the two states, the new absolute value of the wave functions became, as in Equation (52):[126]

$$u(\mathrm{p}')v(\mathrm{p}') = u^*(\mathrm{p}')v^*(\mathrm{p}') = 2(2\pi h)^{-3}$$

which differed from what they set as the normalization condition in Equation (20):[127]

$$u(\mathrm{p})v(\mathrm{p}) = (2\pi h)^{-3}$$

By adhering to the idea of superposing quantum states and constructing a pure quantum state of the solution to the equations, the authors unintentionally contradicted themselves.

The other necessary value was the average values of $u(\mathrm{p})\sigma v(\mathrm{p})$. This term should vanish, considering its physical meaning (the expectation value of spin), which could be demonstrated by plugging in the values of each vector component.[128]

These values allowed Klein and Nishina to calculate each term that appeared when they multiplied the magnetic field with itself and took its average (I omit the details). The result was

$$\overline{\mathfrak{H}}_0^2 = \frac{e^4}{m^2c^4r^2}\left(\frac{\nu'}{\nu}\right)^3\left\{\left(\frac{\nu}{\nu'}+\frac{\nu'}{\nu}\right)\varepsilon^2 - 2(\mathfrak{n}'\varepsilon)^2\right\}.$$

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125. Klein and Nishina, "Streuung," 858. Yazaki discusses this issue closely. See: Yazaki Yûji, "Klein-Nishina kôshiki," 129-32.

126. Klein and Nishina, "Streuung," 866.

127. Ibid., 858.

128. Ibid., 866.

($\boldsymbol{\varepsilon}$ is the incoming electric field) and to compare with Gordon's result, the intensity was:

$$\bar{I} = I_0 \frac{e^4}{m^2 c^4 r^2} \frac{\sin^2 \vartheta}{(1+\alpha(1-\cos\Theta))^3}\left(1+\alpha^2 \frac{(1-\cos\Theta)^2}{2\sin^2\vartheta(1+\alpha(1-\cos\Theta))}\right).$$

where Θ was the angle between the observed direction and the direction of the incoming radiation, θ the angle between the observed direction and the direction of the electric field. Their result differed from the one Gordon derived from his quantum mechanical treatment of the Compton effect by the additional term of α squared in parenthesis.[129]

One obvious feature of the Klein-Nishina paper is its calculation-intensiveness. Some of the above calculations must have been very tedious and laborious. In this sense, this work by Nishina and Klein was in line with the calculation intensive tradition of the "Culture of Calculating." This tendency was further intensified in Nishina's single-authored paper that appeared soon after the Klein-Nishina paper.[130] This was probably why Gordon thought this work would be suited for Nishina, whose extreme diligence was known among Copenhageners.[131]

The work by Klein and Nishina was, however, more than just a series of lengthy calculations. Being the first application of the Dirac theory to an actual scattering problem, it gave a theoretical result from Dirac's theory that differed from the result obtained by non-relativistic quantum mechanics and would be

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129. Ibid., 867.

130. Yoshio Nishina, "Die Polarization der Comptonstreuung nach der Diracschen Theorie des Elektrons," *Zeitschrift für Physik* 52 (1929): 869-77.

131. See Chapter 5.

compared with actual experimental results. Moreover, as we have seen, the application was not straightforward, involving physical interpretation of the Dirac equations and their solutions. Although highly calculational, the Klein and Nishina paper was in fact an attempt to connect Dirac's mathematical theory to the physical reality, a work beyond applied mathematics.

At the same time, the crucial physical consideration of this work involved applying the quantum mechanical notion of superposition. The central physical problem that faced Klein and Nishina was how to choose two independent states to be superposed as the final state of the electron.

The principle of superposition is intimately embedded in quantum mechanics, in particular in Dirac's formulation of it. Therefore, tt might be no coincidence that P. A. M. Dirac, possibly the most prominent theoretical physicists of the era initially trained as an electrical engineer, started his textbook with the principle of superposition.[132] In Dirac's textbook, the principle of superposition was closely tied to physical interpretation of quantum mechanics. Dirac's formulation of the quantum-mechanical superposition was, however, rather unintuitive and operational, not even algebraic:

> *We say that a state A may be formed by a superposition of states B and C when, if any observation is made on the system in state A leading to any result, there is a finite probability for the same result being obtained when the same observation is made on the system in one (at least) of the two states B and C* [Dirac's emphasis].[133]

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132. Paul Adrien Maurice Dirac, *The Principles of Quantum Mechanics* (Oxford: Clarendon Press, 1930). Later, under Nishina's direction, his disciples translate this textbook into Japanese. See Chapter 5.

133. Dirac, *Quantum Mechanics*, 15-16.

In this formulation, superposition differed markedly from its traditional conception (such as superposition of two waves). This does not mean that Dirac did not have a "mental picture" of superposition in the ordinary sense here. More probably, as with his projective geometry, visualization of superposition is suppressed here.[134] Indeed, as I explain in the next chapter of his textbook, the reader finds that Dirac reformulated the superposition of states in terms of the linear combination of what he calls ψ-symbols.[135]

Using his definition of superposition, Dirac formulated the principle of superposition in quantum mechanics as follows:

> The Principle of Superposition says that any two states B and C may be superposed in accordance with this definition to form a state A and indeed an infinite number of the different states A may be formed by superposing B and C in different ways.[136]

Dirac's principle of superposition does not hold in electrical circuit theory, because, in the latter case, there is only one way to superpose two circuits, and not all circuits can be superposed with each other. Nevertheless, both quantum mechanics and electric circuit theory exploit the linearity of the subject matter. They share the idea of considering physical states as a linear superposition of other states, and analyzing them as such.

When Nishina went back to Japan, it was Dirac's textbook (along with Heisenberg's *Physical Principles*[137]), not John von Neumann's *Mathematische*

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134. Galison, "Dirac’s Hidden Geometry."

135. Dirac, *Quantum Mechanics*, 18.

136. Ibid., 16.

137. Werner Heisenberg, *Physical Principels of Quantum Theory* (Chicago: University of Chicago Press, 1930).

Grundlagen der Quantenmechanik,[138] not Herman Weyl's *Gruppentheorie und Quantenmechanik,*[139] and not Max Born's *Probleme der Atomdynamik*[140] that he chose to translate into Japanese with his disciples.

6. Conclusion: Electrical Engineering and Quantum Mechanics

Nishina Yoshio, therefore, started his career as an electrical engineer, who completed his training with excellent achievements. As a student of Hô Hidetarô, Nishina specialized in alternating current theory, and was drilled to grasp the "physical meanings" of things. In particular, he became familiar with the principle of superposition in the alternating current circuit, with which his mentor would produce his most important work and acquire lasting fame in Japan as a "co-discoverer" of the Hô-Thévenin theorem. Nishina himself used the idea of superposition in his graduation thesis. About ten years later, when Nishina started learning quantum mechanics, he was not totally unprepared for a theoretical subject. In particular, the principle of superposition in quantum mechanics, although not completely identical to the one in electrical engineering, was familiar to him. In his most important theoretical work with Oskar Klein, Nishina used the idea of superposing quantum states, and interpreting its physical meaning was essential in their work.

There were obvious disadvantages for someone originally trained as an electrical engineer to turn to physics. Nishina's career as a physicist started slowly.

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138. John von Neumann, *Mathematische Grundlagen der Quantenmechanik* (Berlin: J. Springer, 1932).

139. Herman Weyl, *Gruppentheorie und Quantenmechanik* (Berlin: S Hirzel, 1928).

140. Max Born, *Probleme der Atomdynamik* (Berlin: Verlag von Julius Springer, 1926).

After having graduated, he had to relearn physics in graduate school, which took two years. Combined with leaves of absence caused by his illness, the training took him a long time. He was already 31 years old when he travelled to Europe. Nishina was 37 when he started working as a theoretical physicist.

In Nishina's case, however, the engineering background was far from useless. Unlike theoretical physics students, whose training emphasized mathematics and calculation, Nishina, as an engineering student, was trained to deal with physical images, when drafting designs of electromagnetic machinery, while familiarizing himself with theoretical considerations through alternating current theory. Rather than applying first principles to particular problems, which theoretical physicists in the "culture of calculating" often did, the Hô-Steinmetz tradition emphasized the construction of middle-evel theories, such as the Hô-Thévenin theorem. As symbolized by the notion of superposition, the conceptual training in electromagnetism proved relevant, if not directly applicable, to learning and practicing quantum mechanics. As we have seen in Chapter 2, the apparent dualism of theory and practice collapses here. In understanding quantum mechanics, electrical engineering, which might be considered much more practical than theoretical physics, could in fact be more useful in some aspects than a form of theoretical physics.

Electrical engineering itself shaped part of Nishina's scientific style. In addition to the actual use of power electrical engineering in the construction of cyclotrons, the pragmatic attitudes of engineers, which we can find even in the most theoretical engineer such as Steinmetz, is unmistakable in Nishina's attitude toward science. Nishina was, for example, interested, but did not participate in Bohr's philosophizing of quantum mechanics. Nishina's approach to physics was much more pragmatic than Bohr, as was evident in their different attitudes toward

Yukawa's meson theory.[141] This pragmatism was probably rooted in the electrical engineer in Nishina.

Neither did Nishina subscribe to highly mathematical approach. For example, as mentioned above, he did not follow John von Neumann's axiomatic approach to quantum mechanics. As we have seen in Chapter 3, some theoretical physicists in Japan, such as Yamanouchi Takahiko, were more attracted by such mathematical approaches.

Another important aspect of this story is Nishina's experience moving across disciplinary boundaries. While most Japanese scientists were trained in one specialty, Nishina was trained in two, a luxury not affored to many in a developing country like prewar Japan. This ability to cross boundaries proved essential when Nishina organized an interdisciplinary research group, as we will see in the following chapters.

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141. See Chapter 5.

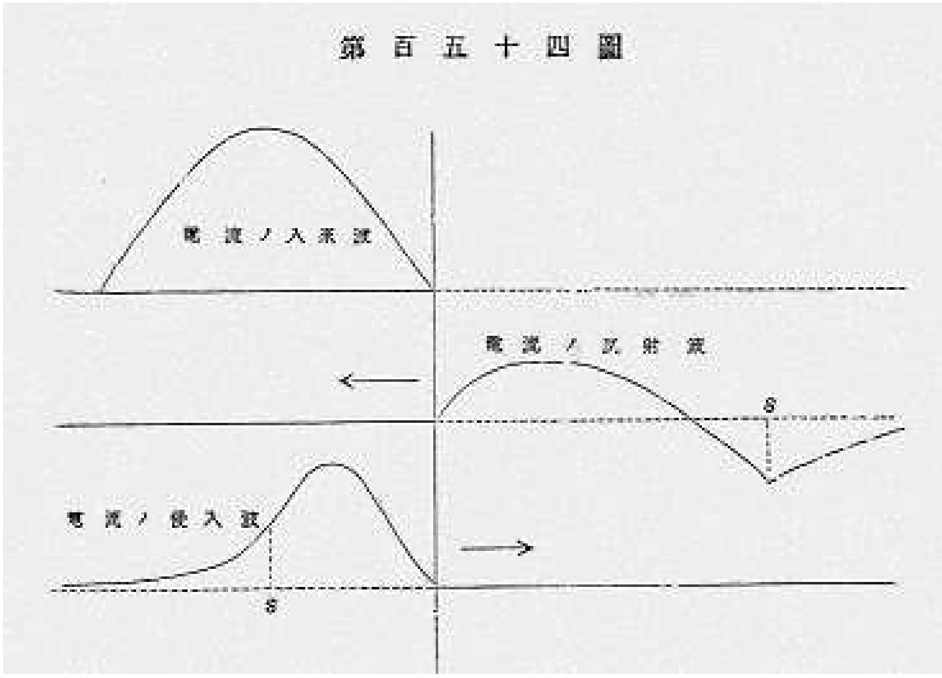


Fig. 4.1 Ho's diagram of a Transition Phenomenon

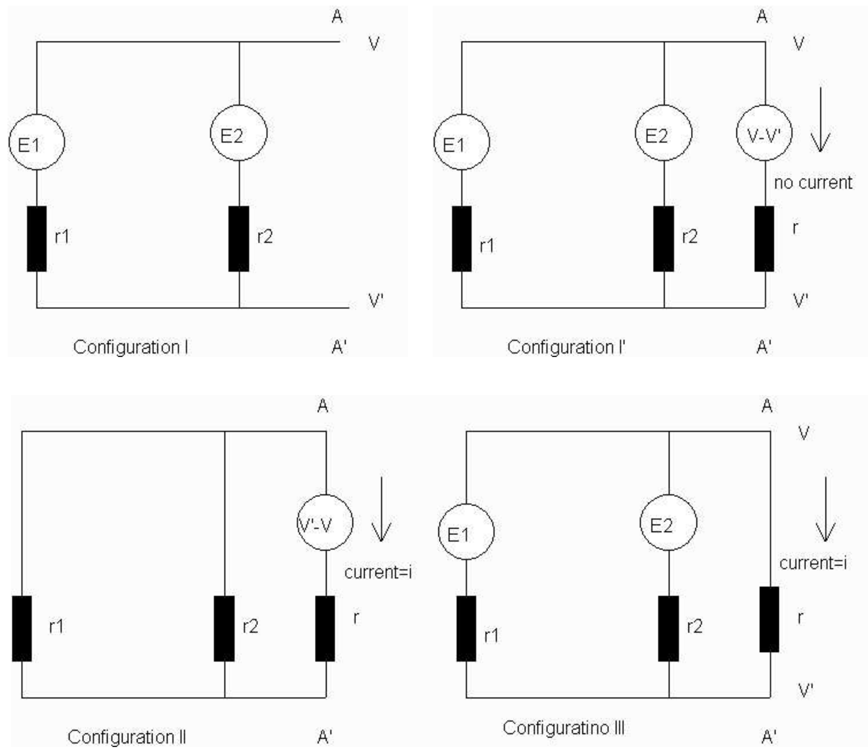
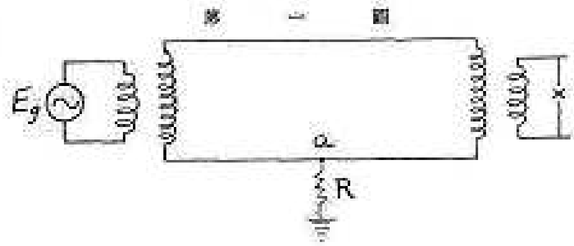
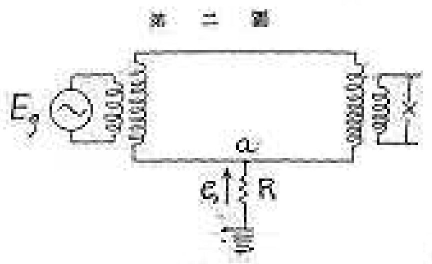


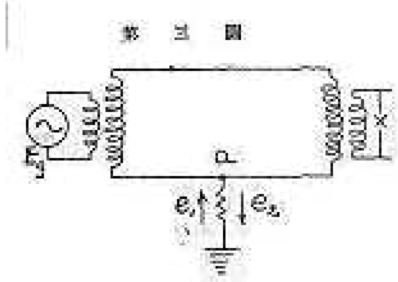
Fig. 4.2 Thévenin's Theorem: Proof



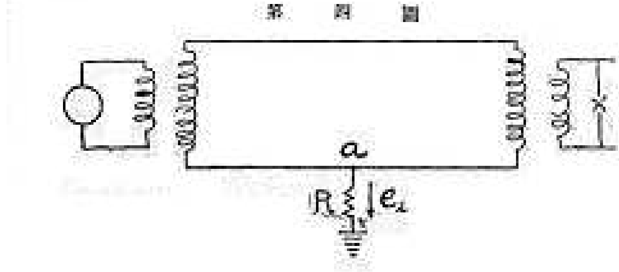
[Fig. 4.3a]



[Fig. 4.3b]



[Fig. 4.3c]



[fig. 4.3d]

Fig 4.3 Thévenin's Theorem by Hô

Chapter 5
The *Geist* in the Institute:
The Production of Quantum Physicists in 1930s Japan

1. The Metaphor of Spirit

Erwin von Baelz was a German physician who taught medicine in Japan since 1876, and played an essential role in the introduction of Western medicine there. At a party on November 22, 1901, in honor of his twenty five year jubilee in Japan, he gave an address to an audience consisting mostly of professors of Tokyo University and bureaucrats of the Ministry of Education (including the Minister Baron Kikuchi Dairoku). In his speech, Baelz shared with the guests the following observations on the situation of science in Japan at the turn of the century:

> It seems to me that in Japan erroneous conceptions about the origin and nature of western science are widely prevalent. It is regarded as a machine which can turn out so much work every year, and therefore as a machine which can without further ado be transported from the West to any other part of the world there to continue its labours. This is a great mistake. . . . It [the road of science] has been the highway of the human spirit, and the great names are written on its milestones: one of the early milestones such names as Pythagoras, Aristotle, Hippocrates, and Archimedes; and on the recent milestones such names as Faraday, Darwin, Helmholtz, Virchow, Pasteur, Roentgen. The spirit of these is the spirit that will sustain us Europeans until the end of the world. . . . . From all the lands of the West there have come to you teachers eager to *implant this spirit* in the Land of the Rising Sun and to enable you of Japan to make it your own. . . . But many in Japan were content to take over from these Westerners the latest acquisitions, instead of studying the spirit which made the acquisitions possible.[1] (emphasis is mine)

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1. Toku Baelz, ed., *Awakening Japan: The Diary of a German Doctor: Erwin Baelz*, Eden Paul and Ceder Paul (New York: The Viking Press, 1932), 149-50.

Some historians of science quote this passage to characterize the superficiality of the introduction of Western science into Japan.[2] Japan only imported science as a form of technology, forgetting its intellectual roots, or its "spirit," such as Christianity. Others argue that the so-called "Western science" itself had made a radical transformation in the 19th century, and Japan simply adopted this new breed of science, inseparably tied to technology and inevitably institutionalized by the state.[3] Rather than arguing over this issue, this chapter examines the validity of this metaphor of the "spirit" as the essential entity that conveys scientific knowledge and skills in the case of the introduction of quantum mechanics into Japan.

The metaphor of the "spirit" that allegedly constitutes the basis of scientific developments is indeed a familiar one to the historians of modern physics. Werner Heisenberg, one of the founders of quantum mechanics wrote in the preface of his influential early textbook of quantum mechanics, *Physical Principles of Quantum Theory*:

> The purpose of the book seems to me to be fulfilled if it contributes somewhat to the diffusion of that *Kopenhagener Geist der Quantentheorie,* if I may so express myself, which has directed the entire development of modern atomic physics.[4]

In Japan, the introduction of quantum mechanics, or, if we adopt Heisenberg's expression, the diffusion of the "Kopenhagener Geist," began in the

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2. See: Masao Watanabe, "Science Across the Pacific : American-Japanese Scientific and Cultural Contacts in the Late Nineteenth Century," *Japanese Studies in the History of Science*, no. 9 (1970): 115-36.

3. For example: Hirosige Tetu, *Kagaku no shakaishi: Kindai Nihon no kagaku taisei* (Tokyo: Chûôkôronsha, 1973).

late 1920s, as we have seen in Chapter 3. If we could talk about the "missionaries of the Copenhagen spirit," as John Heilbron did,[5] the principal "missionary" of the Copenhagen spirit to Japan would be Nishina Yoshio. As we have seen in Chapter 4, while in Copenhagen he produced one of the earliest contribution to quantum mechanics made by the Japanese. After his return to Japan in late 1928, he directed a group of young scientists and developed a school of atomic physicists in Tokyo. Nishina's efforts appear to have been successful. Japan began to have a fairly strong tradition of theoretical physicists since the 1930s, with the rise of able theoretical physicists, including, among others, Tomonaga, Yukawa, Sakata Shôichi, Kobayashi Minoru, Tamaki Hidehiko, Taketani Mituo, Umeda Kwai.

Echoing Heisenberg and other alumni of the Copenhagen school of physics, Japanese physicists described Nishina's efforts to bring quantum mechanics into Japan as introducing and disseminating the "Copenhagen spirit" there.[6] For Japanese physicists, the "Copenhagen spirit" was a workable guiding principle, which contained the methodology, knowledge, and research skills of quantum mechanics. They thought that this spirit was transferred, not through books and journals, but by human mediation. Reading printed, mostly technical, some philosophical, materials would not be enough to incarnate such a spirit. In this sense, Japanese physicists were aware of the aspect of knowledge that can only be transferable through personal contact.

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4. Werner Heisenberg, *Physical Principles of Quantum Theory* (Chicago: The University of Chicago Press, 1930), Preface.

5. John Heilbron, "Earliest Missionaries of the Copenhagen Spirit," in *Science in Reflection*, vol. 110 of *Boston Studies in the Philosophy of Science*, Edna Ullmann-Margalit (Dordrect, Boston: Kluwer Academic Publishers, 1988), 201-33.

6. I write the examples in Section 4.

Thus, the "Copenhagen spirit" was not unlike the tacit knowledge, the notion, for instance, employed by Harry Collins in his discussion on the transmission of experimental skills. Collins considered experimental ability as a "skill-like knowledge, which travels best (or only) through accomplished practitioners." It cannot be "fully explicated or absolutely established." It is "invisible in its passage and in those who possessed it."[7] If, as Japanese physicists perceived, the "Copenhagen spirit" was something like tacit knowledge, the vehicle to transmit the "theoretical skills" of quantum mechanics, then it would be the solution to the pedagogy of theoretical skills. The transplantation of the "Copenhagen spirit" might be the key for the apparently rapid growth of theoretical physics in Japan since the 1930s. It might be therefore the secret recipe to produce theoretical physicists.

Two questions then occur:

1. What was the "Copenhagen spirit" that was allegedly brought to Japan and instrumental to produce theoretical works in quantum mechanics?

2. Did it really facilitate dissemination of theoretical skills and production of quantum theorists in Japan? If it did, to what extent?

To answer the first question, I will analyze the accounts about how physicists at Bohr's institute conducted theoretical physics, and, by doing so, try to capture what the "Copenhagen Spirit" was. Avoiding an essentialist approach, I will not try to determine what the "Copenhagen spirit" *really* was. Rather, I first try to understand the way physics was conducted at Bohr's institute. By examining reminiscences of the Copenhagen physicists, I structure my description according to the values that governed physicists at this institute. In other words, I start by

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7. Harry M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage Publications, 1985), 103-4.

asking what was considered important and desirable, and how or why it was considered so. Next, I move on to show how these values materialized in the ways physics was generally conducted or meant to be conducted at the institute, and various small incidents in this group of scientists. If the "Copenhagen spirit" had any effect on the way the Copenhagen physicists behaved, the characteristics of their scientific practices should reflect the "Copenhagen spirit," whatever the "Copenhagen" spirit was.

Then, I will apply the same analysis to the groups of Japanese physicists that were allegedly governed by the "Copenhagen spirit," and examine similarities and differences between Bohr's group and the groups of Japanese physicists. I analyze Nishina's theoretical group in Japan, and, as an example of the alleged "dissemination of the Copenhagen spirit," the theoretical physics group at Osaka University in the 1930s. I conclude the paper by discussing the validity of the spirit metaphor in the case of quantum mechanics.

These analyses will illuminate to what extent the metaphor of "spirit" fails to account for the historical process in question. Instead of talking about transplantation of the "spirit," I propose to see the dissemination of quantum mechanics as a "resonance." A similar but not identical phenomenon of scientific practices followed another, not because the original set of practices was transported in its totality, but because a certain social and cultural conditions allowed such phenomenon to occur, and because some human or material mediations triggered such a resonance of scientific practices.

The story of this chapter constitutes the central piece of the introduction of quantum mechanics into Japan. In this "Copenhagen phase," ranging roughly from 1931 to 1940, a scientific culture of Japan's atomic physics was established, in which theoretical physics flourished.

2. Nishina in Copenhagen

While working at Cambridge, Nishina Yoshio had had a chance to talk to Bohr and listen to his talk when Bohr visited there in 1922. Bohr, apparently, was somewhat obscure in his talk, which Nishina took as a challenge. He later told the Japanese chemist Kimura Kenjirô that "Bohr's talk was murky, and it was hard to grasp what he meant. This made me think that I should definitely work with this person sometime."[8] In his letter to Bohr on March 25, 1923, Nishina conveyed his wish to work at Bohr's institute.[9] Bohr, who, accordingly to Heisenberg, never answered letters,[10] replied to Nishina rather quickly, granting permission for him to work at his institute.[11] Two weeks later, Nishina arrived in Copenhagen.

In his letter to Bohr on March 25, Nishina had written that he would like to study Bohr's theory of atomic constitution, but would be willing to help others in experimentation and calculation. He did not intend to stay more than several months because his institute would not allow him to "stay for more than "two terms."[12] "Several months" turned out to be seven and a half years, which made

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8. Kimura Kenjirô, "Kopenhâgen no Nishina hakase," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hroshi (Tokyo: Misuzu Shobô, 1991), 35.

9. Yoshio Nishina, A letter to Niels Bohr, March 25, 1923 in *Y. Nishina's Letters to N. Bohr, G. Hevesy, and Others*, vol. 21, NKZ Publication (Tokyo: Nishina KInen Zaidan, 1985), 1.

10. Stefan Rozental, *Niels Bohr: Memoirs of a Working Relationship* (Copenhagen: Christian Eilers, 1998), 12.

11. Bohr's letter to Nishina, dated March 29. Koizumi Kenkichirô, "Yôroppa ryûgaku jidai no Nishina Yoshio: Rironbutsurigaku no sendatsu no kiseki," *Shizen*, November 1976, 67.

12. Nishina, A letter to Niels Bohr, March 25, 1923.

his concerned relatives think: "Perhaps, he got a girlfriend there."[13]

In Copenhagen, Nishina first lived with Kondô Kinsuke, a Japanese biochemist working with S. P. L. Sørensen at Carlsberg Laboratory, on the second floor a boarding house of some Mr. Jacobsen at Ceresvej 3, near the Frederiksberg Station. When Kondô left Copenhagen, Nishina moved to Gustav Adolf Gade 12.[14]

As mentioned in the previous chapter, for the first four years of his stay at Bohr's institute, Nishina worked on experimental subjects. He started working with Dirk Coster, and then, George Hevesy, B. B. Ray, Aoyama Shin'ichi, Kimura Masamichi on experimental topics related to X-rays.[15] According to Kondô, Nishina always came back for dinner to the boarding house and went back to the institute, working everyday including weekends. Then, according to Kimura Kenjirô, Nishina worked until very late and often had to get over the fence of the institute when he went back to the borading house. Nishina had the key to the building but not the key of the gate. Bohr was amazed at Nishina's diligence,

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13. Nishina Kôjirô, "Chichi Yoshio no ryûgaku seikatsu," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 270.

14. Shimizu Sakae, "Nishina Yoshio sensei to Kondô Kinsuke sensei: 70-nen mae no epsôdo, Kopenhâgen nite," *Isotope News*, December 1990, 30-33.

15. Nishina's published experimental works during this period includes: Dirk Coster, Yoshio Nishina, and Sven Werner, "Röntgenspektroskopie über die Absorptionsspektren in der *L*-Serie der Elemente La (57) bis Hf(72)," *Zeitschrift für Physik* 18 (1923): 207-11; Yoshio Nishina, "On the *L*-Absorption Spectra of the Elements from Sn(50) to W(74) and Their Relation to the Atomic Constitution," *Philosophical Magazine* 49 (1925): 521-37; Dirk Coster and Yoshio Nishina, "On the Quantitative Chemical Analysis by Means of X-Ray Spectrum," *The Chemical News* 136 (1925): 149-52; Shin'ichi Aoyama, Kenjirô Kimura, and Yoshio Nishina, "Die Abhängigkeit der Röntgenabsorptionsspektren von der chemischen Bindung," *Zeitschrift für Physik* 44 (1927): 810-33.

wondering if Nishina could continue working so late because he was doing experiments, not theory.[16]

Soon, however, the rapid theoretical development of this time in Copenhagen inevitably stimulated Nishina. Around 1926 and 1927, Nishina was determined to shift his focus to theoretical physics and began preparing his transition.[17] In August 1927, along with I. I. Rabi, he moved to Hamburg, probably in order to learn quantum mechanics from Wolfgang Pauli. His lecture notes at Pauli's seminar show that this seminar dealt with fundamental questions, especially the uncertainty relations. These considerations later formed the first part of Pauli's textbook of quantum mechanics. Nishina's understanding of quantum mechanics seems to show a kind of affinity with Pauli's. Later he wrote about "complementarity theory," which was probably more from Pauli's influence than Bohr's.[18] During his stay in Hamburg, his theoretical training bore fruit as a collaborative work with Rabi.[19] When Nishina came back to Copenhagen in March 1928, he began theoretical research, in cooperation with Oscar Klein. The result was, as we saw in the previous chapter, the famous Klein-Nishina formula, the first significant contribution to quantum mechanics by the Japanese.[20]

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16. Shimizu Sakae, "Nishina Yoshio sensei to Kondô Kinsuke sensei"; Kimura Kenjirô, "Kopenhâgen no Nishina hakase," 41-42.

17. Kimura Kenjirô, "Kopenhâgen no Nishina hakase," 40.

18. Nishina Yoshio, "Ryôshiron," in *Shizen kagaku shisô*, vol. 10, Nijûseiki shisô (Tokyo: Kawade Shobô, 1938), 101-40.

19. Yoshio Nishina and I. I. Rabi, "Absorptionskoeffizient der Röntgenstrahlen nach der Quantentheorie," *Verhandlungen der Deutschen Physikalischen Gesellschaft* 9 (1928): 6-9.

20. Oskar Klein and Yoshio Nishina, "Über die Streuung von Strahlung durch freie Elektronen nach der neuen relativistischen Quantendynamik von Dirac," *Zeitschrift für Physik* 52 (1928): 853-68.

During his stay in Copenhagen, Nishina also took interest in the philosophical issues of quantum mechanics, in particular, complementarity. Apparently, he was one of the attendees of the Como conference.[21] He helped Bohr to translate the Como paper from German to English in the winter of 1927 - 1928.[22] He further wrote a letter to Nagaoka about complementarity, and proposed inviting Bohr to Japan.[23]

3. The "Copenhagen Spirit" in Copenhagen

During his long stay in Copenhagen, Nishina must have had many opportunities to get in touch with young and active theoretical physicists, and to know the "Copenhagen spirit." Much has been written about Bohr's institute in Copenhagen and the "Copenhagen" spirit. Yet, among historians, it has not been entirely clear what exactly the "Copenhagen spirit" was. John L. Heilbron, for example, seems to have a very different thing in mind from, for example, what, as I discuss later, the Japanese physicists considered as the "Copenhagen spirit." He never gives an explicit definition of the "Copenhagen spirit," but he seems to regard it as the "Copenhagen interpretation." Indeed, he says, the purpose of his paper "The Earliest Missionary of the Copenhagen Spirit," is "to indicate how the Copenhagen interpretation of quantum physics became, for a few physicists, an

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21. The participants of this conference left their signatures on a sheet of paper, of which photocopy can today be on sale at the souvenir shop of "Volta's Temple" by Como Lake. Among the names of the participants, there is Nishina's. The one purchased by the physicist Nishijima Kazuhiko is reproduced in: Nishina Yoshio hakase wo shinobu kai, *Zenryokushissô no jinsei* (Satoshô: Kagaku Shinkô Nishina Zaidan, 2001), 26.

22. Nishina Kinen Zaidan, Gogôkan Shiryo.

23. The letter is reproduced in: Tamaki Hidehiko, "Butsurigakushi shiryô iinkai dayori, No. 7," *Butsuri* 39 (1984): 160.

epistemology of universal validity, a dialectic sharp enough to cut conundrums about the nature of life and the freedom of the will."[24] Moreover, Heilbron seems to consider the Copenhagen interpretation as a collective philosophical delusion and unnecessary appendage to quantum mechanics, which had been disseminated by its powerful "missionaries," personally inspired by Bohr's charisma, not by its scientific necessity. Finn Aaserud gives a different and less cynical account of the "Copenhagen spirit." He uses this term as a specific "atmosphere or style of work." As atmosphere, the "Copenhagen spirit" is characterized by its freedom and informality. As a style of work, Bohr's figure as a father, "Socrates," or "Jesus," and his use of discussion and collaborative work with his "helpers" are mentioned.[25]

The problem seems to be that, before asking what the "Copenhagen spirit" was, we do not even know what category it belonged to. It might be a kind of mental attitude, because when Rosenfeld defines the "Copenhagen spirit" as "that of a complete freedom of judgment and discussion," he seems to be implying that way.[26] It might be a collective delusion or the Copenhagen interpretation itself, as Heilbron suggests.[27] It might be a sort of guiding principle, since according to Heisenberg, it led the development of physics[28] It might be a certain set of

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24. Heilbron, "Earliest Missionaries," 200.

25. Finn Aaserud, *Redirecting Science: Niels Bohr, Philanthropy, and the Rise of Nuclear Physics* (Cambridge, New York: Cambridge University Press, 1990), Prologue.

26. Leon Rosenfeld, *Niels Bohr: An Essay Dedicated to Him on the Occasion of His Sixtieth Birthday, October 7, 1945*, Second ed. corrected (Amsterdam: North-Holland Publishing Company, 1961), 3.

27. Heilbron, "Earliest Missionaries."

28. Heisenberg, *Physical Principles*.

philosophical ideas and attitudes, because Leon Rosenfeld wrote that the "Copenhagen spirit" was coined to denote the "unity of view on the problems of science," and this unity seems to refer to the elucidation of the "apparent paradoxes of quantum theory" with the idea of complementarity.[29] It might be a Hegelian, trans-individual *Geist*, as Tomonaga, probably inspired by Heisenberg, suggested.[30] It might be a style of doing physics, because Weisskopf defined the *Kopenhagener Geist* as "the style of a very special character that he [Bohr] imposed onto physics."[31]

As I mentioned above, I analyze the practices of the Copenhagen physicist in terms of what was important and desirable among them. Two things were considered important in Bohr's group: physics and collaboration.

Physics is, of course, important for most of physicists. How and why it is, however, differ from one physicist to another. I claim that physics was important for physicists in Bohr's group, not because it had practical applications, or because the knowledge that it would produce had a certain intrinsic value (such as "truth"), because it satisfied their curiosity and playfulness, of which combination I call *playful curiosity.* Doing physics well is, in this view, in itself important, just as winning a game of chess or sports (or seeing one side win a game) is important for surprisingly many people.

This kind of motivation in physics was elaborated by Albert Einstein, who, in his praise of Max Planck distinguished three kinds of physicists:

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29. Rosenfeld, *Niels Bohr: An Essay*, 3.

30. Tomonaga Sin-itiro and others, "Zadan kisobutsurigaku kenkyûjo wo megutte," in *Hiakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakushû* (Tokyo: Misuzu Shobô, 1982), 246-47.

31. Victor Weisskopf, "Niels Bohr, the Quantum and the World," in *Physics in the Twentieth Century: Selected Essays* (Cambridge: The MIT Press, 1972), 55.

> In the temple of science are many mansions, and various indeed are they that dwell therein and the motives that have led them thither. Many take to science out of a joyful sense of superior intellectual power; science is their own special sport to which they look for vivid experience and the satisfaction of ambition; many others are to be found in the temple who have offered the products of their brains on this altar for purely utilitarian purposes. Were an angel of the Lord to come and drive all the people belonging to these two categories out of the temple, the assemblage would be seriously depleted, but there would still be some men, of both present and past times, left inside.[32]

By those "[m]any" who "take to science out of a joyful sense of superior intellectual power," I take Einstein as referring, and making a certain distance, to the kind of physicists in Copenhagen (although they hardly existed in 1918). Here again, Einstein and Bohr makes a sharp contrast. Whereas Einstein considered himself, along with Planck, as one of those allowed by the angel to stay inside the temple, for the physicists in Copenhagen under Bohr, doing physics waas just as fun as playing table tennis or chess (and many of them did the latter two as well).[33] Physics was practiced not because it was a pursuit of the absolute truth, but it was fun to play. This does not mean that they were less serious in physics than those who sought in physics the *Weltanschauung*. In a sense, those younger physicists were more devoted to physics than Einstein or Planck. These classical physicists preserved the conventional values outside physics (such as "truth"), and deemed physics as important in relation to these values, whereas for the new generation of physicists, doing physics well was in itself important. In this sense,

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32. Address delivered at a celebration of Max Planck's sixtieth birthday (1918) before the Physical Society in Berlin; Albert Einstein, "Principles of Research," in *Ideas and Opinions*, translated by Sonja Bargmann, reprint, 1918 (New York: Bonanza Books, 1954), 224.

33. As for the contrast between Einstein and Bohr in terms of personal tastes and values in physics, see: David Kaiser, "Bringing the Human Actors Back on Stage: The Personal Context of the Einstein-Bohr Debate'," *British Journal for the History of Science* 27 (1994): 129-52; Ito Kenji, "Bôa Ainshutain Ronsô," B. A. thesis (University of Tokyo, 1990).

they lived in the world on paper. The world of physics and its rules were the rules that governed their life and performance in physics.

Rosenfeld, for example, writes on the humorous and playful side of Niels Bohr:

> When he was working on the surface tension of water, he had to melt glass tubes to make jets: he took such a delight in this operation that, completely forgetting its original purpose, he spent hours passing tube after tube through the flame. There is also the memorable controversy---one of the bright spots in the minor history of Bohr's institute---about the mechanism of a "thought transmission" trick which was being performed at the Tivoli: with what genuine enjoyment did he advocate his own view of the case! It was an ingenious theory, too, involving ventriloquism as its basic principle.[34]

George Gamow gives another example of Bohr's whimsy. One evening, Bohr, Casimir and Gamow were returning from the farewell dinner for Oskar Klein:

> One the way home we passed a bank building with walls of large cement blocks. At the corner of the building the crevices between the courses of blocks were deep enough to give a toehold to a good alpinist. Casimir, an expert climber, scrambled up almost to the third floor. When Cas came down, Bohr, inexperienced as he was, went up to match the deed. When he was hanging precariously on the second-floor level, and Fru Bohr, Casimir, and I were anxiously watching his progress, two Copenhagen policemen approached from behind with their hands on their gun holsters. One of them looked up and told the other: "Oh, this is only Professor Bohr!" and
> they went quietly off to hunt for more dangerous bank robbers.[35]

Bohr's disciples shared similar playfulness. Otto Frisch writes that one day scientists at the institute saw George Placzek climbing out of a small window of a restroom and dropping onto a roof with a "fiendish grin." As it turned out, Placzek

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34. Rosenfeld, *Niels Bohr: An Essay*, 19.

35. George Gamow, *Thirty Years That Shook Physics: Story of Quantum Theory* (Garden City: Doubleday & Company, Inc., 1966), 57.

bolted the restroom behind him, so that people, to their great nuisance, had to go down to the restroom on another floor. Scientists had to bear the inconvenience until Felix Bloch climbed into the restroom window and unlocked the door. Another day, George Placzek and Hendrik Casimir wagered 20 kroner whether Casimir would swim across the lake surrounding the center of Copenhagen to make a shortcut. Casimir took off his coat, swam across the lake, and won 20 kroner. Next day at the station, Frisch and others saw Casimir off for his return to Holland, and found him in a dinner suit, apparently because those were the only dry clothes that he had. Frisch writes:

> Why is that scientists are liable to waste their time with such childish pranks? These were all grown-up men, men in their late twenties, with a considerable reputation for scientific achievement. Then why this schoolboy behaviour? Well, I think scientists have one thing in common with children; curiosity. To be a good scientist you must have kept this trait of childhood, and perhaps it is not easy to retain just one trait. A scientist has to be curious like a child; perhaps one can understand that there are other childish features he hasn't grown out of."[36]

I do not agree with this explanation of scientists' childishness, because not all the scientists behave so childishly. Yet, Frisch's point shows that childishness (or in my word, playfulness) and curiosity go hand in hand, and can be beneficial to scientific activities.

Many reminiscences attest to the importance of collaboration for Bohr. According to Stefan Rozental, a close assistant since the 1930s, "Cooperation was a fundamental element of NB's attitude to life."[37] Rozental remembers, for example, the way Bohr directed his disciples. In the morning, Niels Bohr would

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36. Otto R. Frisch, *What Little I Remember* (Cambridge: Cambridge University Press, 1979), 85-86.

37. Rozental, *Niels Bohr*, 118.

make a phone call to arrange the day's agenda: "[The telephone call] always started thus: 'if you have the time and feel like it, we could meet'. . . then came the time and place. . . . he did not give orders; it had to be an agreement."[38] On other members of the institute, Bohr imposed even less strict rules. According to Gamow, "The work in the Institute was very easy and simple: everybody could do whatever he wanted, and come to work and go home whenever he pleased."[39] Such freedom did not mean that members of the institute worked separately. According to Robertson, "Whether the task was writing a manuscript, planning a new direction in research, or simply drafting a letter, the issue at hand was always approached on a collective basis."[40]

In Victor Weisskopf's view, moreover, collaboration in science had an even deeper meaning for Bohr. Science created problems by enabling a massive destruction. At the same time, however, science seemed to suggest a solution for Bohr because "[s]cience is , in his mind, one of the most advanced forms of human collaboration. It therefore must lead the way to better human relations."[41]

These two values reinforced one another. If a collaborative approach was beneficial to the performance in physics, by all means one should adopt a collaborative approach, regardless of the conventional attitude about physics. According to Rozental, "[t]ime and again [Bohr] pointed out how little the individual, himself included, can accomplish singlehanded, and said that great

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38. Ibid., 32.

39. Gamow, *Thirty Years*, 55.

40. Peter Robertson, *The Early Years: The Niels Bohr Institute 1921-1930* (Copenhagen: Akademisk Forlag, 1979), 134.

41. Viktor F. Weisskopf, "Niels Bohr and International Scientific Collaboration," in *Niels Bohr: His Life and Work as Seen by His Friends and Colleagues*, edited by Stefan Rozental (Amsterdam: North-Holland Publishing Company, 1967), 265.

progress can only be achieved through extensive cooperation."[42] In particular, when the field of atomic physics was advancing rapidly, it was essential for the researchers to meet and exchange ideas, because published articles became obsolete very quickly.[43] A collaborative approach was, in turn, useful to intensify the *playful curiosity*, because by collaborating people were able to reaffirm the self-contained importance of physics by each other, creating a community where only the performance in physics mattered.

The second of the two values, high esteem of collaboration, took on a few different forms: Collaboration between theorists, collaboration between theory and experiment, international collaboration, and collaboration between physics and different branches of science.

Niels Bohr's collaborative style of research is well known. According to Rozental, Niels Bohr "did not like to do writing himself. . . he found it difficult to think and write at the same time."[44] More than his inability to think and write at the same time, he needed to discuss what he was working. "Therefore, he needed a human sounding board to talk over the smaller and bigger problems with."[45] He, therefore, chose a " human sounding board," a "victim," to whom Bohr dictated his thoughts.[46] This lucky "victim" had to voice honest and unreserved opinions, doubts, and suggestions, overcoming any inhibitions. Bohr was, however, very

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42. Rozental, *Niels Bohr*, 118.

43. Robertson, *The Early Years*, 135-36.

44. Rozental, *Niels Bohr*, 34.

45. Ibid., 37.

46. Victor Weisskopf, "Niels Bohr, the Quantum and the World," 61.

tolerant to any remarks including spontaneous and half-finished ones, and was able to develop discussion from them.[47]

As director of the institute, Bohr promoted a collaborative working style in the institute. Characterizing the period from 1922 to 1930, Weisskopf points out that there was no single paper written by Niels Bohr himself. Instead, "Bohr found a new way of working. He did not work as an individual alone; he worked in collaboration with others. It was his great strength to assemble around him the most active, the most gifted, the most perceptive physicists of the world."[48]

Collaboration occurred not only between Bohr and his disciples but also between the disciples. "Bohr's own preference for working in collaboration with others had remarkably infectious effect on the general style of research at the Institute."[49] Collaboration was not always successful and productive.[50] Nor did it occur because of the ideal of collaboration.[51] Yet, some cases worked well, including the collaboration between Oskar Klein and Nishina.

Cooperation crossed the boundary between theory and experiment. According to Rosenfeld, Bohr was able to handle both theory and experiment: "his tremendous power of intuition into natural phenomena was served from the start by an equal mastery of all the necessary mental tools, the experimenter's turn of mind as well as the mathematician's most refined methods of analysis."[52] Since

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47. Rozental, *Niels Bohr*, 37.

48. Victor Weisskopf, "Niels Bohr, the Quantum and the World," 55.

49. Robertson, *The Early Years*, 134.

50. For example, from hindsight, John Slater might have accomplished a better work had he not worked with Bohr and Kramers.

51. For example, collaboration between Heisenberg and Kramers.

52. Rosenfeld, *Niels Bohr: An Essay*, 6.

its inception in 1916, Bohr's institute, despite what its original name suggested (Universitetets institut for teoretisk fysik) aimed to accommodate both theory and experiment under one roof, keeping a close tie between them. According to Rozental, it was Bohr's idea that theory and experiment should work together under the same leadership.[53] Aaserud shows that in the application for a new institute submitted to Copenhagen University, Bohr stated that he needed funds to obtain experimental apparati, because recent theoretical physics had to rely on experiment and therefore cooperation between theory and experiment was necessary.[54] Interdisciplinary collaboration was not rare at Bohr's institute. Bohr's works had obvious relevance to chemistry. Chemists, such as George Hevesy, occupied a prominent place in the institute. Hevesy's work led to the use of radioisotopes in organisms and made biology and medicine relevant to nuclear physics.[55]

Niels Bohr supported international collaboration in his institute. The post-WWI cultural conditions and the geopolitical location of Denmark made Bohr's institute an ideal place for an international collaboration. When the institute was inaugurated in March 3, 1921, the University rector Otto Jespersen already emphasized and praised the international collaboration practiced in Bohr's group.[56] "Bohr counts himself lucky to have grown up in a small country," Rosenfeld wrote, "unhampered by any national pride of illusion of self-sufficiency---in which the great traditions of British and German science found a

53. Rozental, *Niels Bohr*, 15.

54. Aaserud, *Redirectin Science*.

55. As for Hevesy, see: Hilde Levi, *George de Hevesy: Life and Work: A Biography* (Bristol: A. Hilger, 1985).

56. Robertson, *The Early Years*, 9.

prosperous meeting place."[57] He appreciated Denmark's cosmopolitan nature so much that he declined the offer of a position at the Royal Society.[58] As Rosenfeld points out, Bohr's own work on the atomic constitution is none other than a creative synthesis of German theoretical physics by Max Planck and Albert Einstein and British atomic theories by J. J. Thomson and Ernest Rutherford.

The timing was fortunate. In the optimistic and idealistic atmosphere after the First World War, the Rask-Ørsted foundation was founded by the Danish government, with the purpose to encourage scientific relations between Denmark and other countries, in particular by providing funding to Danish students working at an overseas institution, or foreign students working in Denmark. The funding allowed Niels Bohr to invite young physicists to work at his institute. Nishina Yoshio was one of those students supported by the Rask-Ørsted foundation.[59]

Although, as Finn Aaserud shows, the relations between theory and experiment, or theoretical physics and experimental biology were not as idyllic as Bohr hoped, and other, socio-political, factors were involved, those (attempted) collaborations show what Bohr considered to be desirable.[60]

The combination of the values of collaboration and *playful curiosity* shaped an informal collaborative style of scientific research, where physics was conducted like a team sport, with similar enthusiasm, competition, and cooperation.

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57. Rosenfeld, *Niels Bohr: An Essay*, 6.

58. Robertson, *The Early Years*, 79-80.

59. As for the Rask-Ørsted foundation, see: Robertson, *The Early Years*, 50.

60. Aaserud shows how Bohr had to change his approach "from one based on a unity between theory and experiment to one based on theoretical discussion" in the 1920s and began a new effort to unite theory and experiment in the 1930s. See: Aaserud, *Redirectin Science*.

Since the only rule of the game that mattered was to produce good works in physics, social protocols did not regulate the activities of physicists in the Bohr group, where "a man was judged purely by his ability to think clearly and straight."[61] The neglect of social protocols in Bohr's institute appeared striking to new comers. Weisskopf writes:

> As a very young man, when I had the privilege of arriving there, I remember that I was taken a little aback by some of the jokes that crept into the discussions, and this seemed to me to indicate a lack of respect. I communicated my feelings to Niels Bohr and he gave me the following answer: "There are things that are so serious that you can only joke about them.[62]

Rudeness and outspokenness were accepted if not encouraged. A legendary figure of exemplary rudeness was Wolfgang Pauli. Here I do not write the many episodes showing the harshness of his criticism and sarcasm, which was directed toward everybody including Bohr (except Arnold Sommerfeld). If we believe Gamow, Pauli was humorous and light-hearted, and his critical comments did not always suppress lively discussion. One the contrary:

> His resonating, somewhat sardonic laughter enlivened any conference when he appeared, no matter how dull it was at the start. He always brought along new ideas, telling the audience about them as he continuously walked to and fro along the lecture table, his corpulent body oscillating slightly.[63]

The Russian physicist Lev Davinovich Landau was also known for his rudeness. It was perhaps inborn in nature, considering, for example, his comment

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61. Frisch, *What Little I Remember*, 101.

62. Victor Weisskopf, "Niels Bohr, the Quantum and the World," 55.

63. Gamow, *Thirty Years*, 62.

on Einstein's talk ("What Professor Einstein has told us is not so stupid"),[64] but he certainly felt at home in Bohr's institute.

> [Colloquia] were very informal occasions, and I still remember once when the young Russian physicist Landau (whom I mentioned earlier as ticking off Einstein after one of his lectures) sat down on the lecture bench, tired from his talk, and then lay down flat on his back. In that position he continued arguing and gesticulating up at Niels Bohr, who was bending over him earnestly trying to convince him that he was wrong. Neither of the two appeared to be aware that this was a very unusual way of conducting a scientific discussion in front of an audience. After six years in the rather conventional atmosphere of Germany, it took me a while to get used to the informal habits.[65]

One form of collaboration was free-wheeling discussion, which was conducted in this sort of informal atmosphere. Discussion could take place on various occasions, one of which was lunch. Physicists gathered in the "lunchroom" to have a lunch of bread, butter, jam, and tea, at the cost of 5 Øre. Rozental writes:

> Some people said the lunchroom at Bohr's Institute was its most important working area. There is some truth in this remark as it provided an ideal opportunity to exchange information and experiences. In difficult situations it was where good advice could be found or where we discussed which line of research to proceed with.[66]

Bohr's "House of Honor" next to the Carlsberg Brewery and villa in Tisvilde also provided places for informal discussion, where everything was discussed. Otto Frisch writes about the "spirit of Platonic dialogue" of an after-dinner discussion at Bohr's mansion:

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64. Frisch, *What Little I Remember*, 36.

65. Ibid., 101.

66. Rozental, *Niels Bohr*, 21.

> After dinner, we would sit around Bohr, some of us on the floor at his feet, to watch him first fill his pipe and then to hear what he said. . . . Here, I felt, was Socrates come to life, tossing us challenges in his gentle way, lifting each argument to a higher plane, drawing wisdom out of us which we didn't know we had, and which of course we hadn't. Our conversation ranged from religion to genetics, from politics to modern art. I don't mean to say that Bohr was always right, but he was always thought-provoking and never trivial. How often did I cycle home through the streets of Copenhagen, intoxicated with the spirit of Platonic dialogue![67]

Obviously, more scientific discussion took place in seminars and colloquia. Colloquia were sometimes scheduled and announced in advance, but they could be held without advance notice, when an unexpected visitor stopped by, or an interesting article was found in a new publication. Seminars were held at the main auditorium of the institute once a week.[68] On these occasions, people listened to a talk or a report first, and then engaged in a discussion, but participants were free to interrupt the speaker with questions and critical remarks. Bohr himself often interrupted the speaker, which occasionally, according to Rozental, "could open the lecturer's eyes to perspective he had not at all considered."[69] Discussion continued with no determined time limited in such an informal atmosphere. Intense and serious discussions were sometimes mixed with humorous remarks, inducing outbursts of laughter from the audience.[70]

Nishina himself participated in such a colloquium. Nishina presented his work with Klein, the derivation of what is known as the Klein-Nishina formula. As Nishina wrote down the final formula on the blackboard, one among the

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67. Frisch, *What Little I Remember*, 92.

68. Robertson, *The Early Years*, 135.

69. Rozental, *Niels Bohr*, 21.

70. Robertson, *The Early Years*, 135.

audience noted that a term in the formula had a different sign in the paper manuscript.

> "Oh," said Nishina, who was delivering the talk, "in the manuscript the signs are certainly correct, but here on the blackboard I must have made a sign mistaken in some place."
> "In *odd* number of places!" commented Dirac.[71]

The Bohr group also had fun in various activities related and unrelated to physics. *Journal of Jocular Physics* was published in every ten years of Bohr's birthday.[72] A satirical parody of Goethe's *Faust* was played after a symposium.[73] Table tennis was played in the library ("the readers didn't seem to mind an occasional game").[74] When his disciples were working in the evening (which, according to Gamow, was the most productive time for theoretical physicists), Bohr interrupted their work saying that he was too tired and would like to go to see a Hollywood Western movie. He had to interrupt his students, because he needed them to explain to him the plot of the movie:

> But his theoretical mind showed even in these movies expeditions. He developed a theory to explain why although the villain always draws first, the hero is faster and manages to kill him. This Bohr theory was based on psychology. Since the hero never shoots first, the villain has to decide

71. Gamow, *Thirty Years*, 121. Emphasis and omission of an indefinite article in the original.

72. For the analysis of this "journal," see: Mara Beller, "Jocular Commemorations: The Copenhagen Spirit," *Osiris* 14 (1999): 252-73. See also: Hans Bohr, "My Father," in *Niels Bohr: His Life and Work as Seen by His Friends and Colleagues*, edited by Stefan Rozental (Amsterdam: North-Holland Publishing Company, 1967), 325-99.

73. Robertson, *The Early Years*, 136-37. For the transcript of this play: Gamow, *Thirty Years*, 167-218. Also see Beller, "Jocular Commemorations".

74. Frisch, *What Little I Remember*, 90.

when to draw, which impedes his action. The hero, on the other hand, acts, according to a conditioned reflex and grabs the gun automatically as soon as he sees the villain's hand move. We disagreed with this theory, and the next day I went to a toy store and bought two guns in Western holders. We shot it out with Bohr, he played the hero, and he "killed" all his students.[75]

Weisskopf summarizes the *Kopenhagener Geist,* the atmosphere or the style that Bohr imposed on physics:

> We see him, the greatest among his colleagues, acting, talking, living as an equal in a group of young, optimistic, jocular, enthusiastic people, approaching the deepest riddles of nature with a spirit of attack, a spirit of freedom from conventional bonds, and a spirit of joy that can hardly be described.[76]

How Nishina Yoshio saw the way physicists conducted research in Copenhagen is not fully recorded. Unfortunately, Nishina Yoshio wrote very little about the "Copenhagen spirit." Years after Nishina came back to Japan, he had a chance to write about Bohr's institute. In a pamphlet about Bohr published in 1937, the year when Bohr visited Japan, Nishina described Niels Bohr's institute. After emphasizing the cosmopolitan character of the institute, he wrote:

> Many able people who are advancing the new physics had at some point a chance to learn from Niels Bohr, either directly or indirectly. In particular, those who gathered at Bohr's institute in Copenhagen, have been bred to what Heisenberg calls *Kopenhagener Geist.* There is no doubt that this is one of the great motive forces of the current developments in physics.[77]

4. Nishina in Riken

Nishina came back to Japan in December 1928. For a while, Nishina worked at Riken as an underling of Nagaoka's. Two things occupied Nishina's

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75. Gamow, *Thirty Years*, 55-56.

76. Victor Weisskopf, "Niels Bohr, the Quantum and the World," 55.

early scientific activity in Japan: to translate and publish Heisenberg and Dirac's lectures in Japan, and to deliver his own lectures on quantum mechanics at several universities.

In September 1929, Heisenberg and Dirac visited Japan. This visit was realized through Nishina, to whom Dirac wrote that he was able to visit Japan on his way back from the United States. Nishina showed Dirac's letter to Nagaoka, and Nagaoka was able to raise funds. Since Heisenberg was also invited to the United States at the same time, it was decided that both of them would visit Japan.[78] The lectures by Dirac and Heisenberg were about their current works, either recently published or soon to be published.[79] The lectures were held in Tokyo. Tomonaga Sin-itiro, who came to Tokyo to attend these lectures, was struck by the youth of these renowned physicists, and had confidence in himself when he found that he could understand their talks. Nishina translated the lectures by Dirac and Heisenberg, gave meticulous annotations, and published them in a volume in 1932. Nishina distributed copies of this volume to major research

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77. Nishina Yoshio, *Niels Bohr*, Iwanami kôza butsurigaku, gakusha denki (Tokyo: Iwanami Shoten, 1938), 2.

78. Tamaki Hidehiko, "Sekai no gakkai ni mado wo hiraku," in *Nihsina Yoshio: Nihon no genshi kagaku no akebono*, Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 84.

79. I am not going to discuss them in detail. The titles of the lectures by Heisenberg are: "Theory of Ferromagnetism," "Theory of Conduction," "Retarded Potential in the Quantum Theory," "The Indeterminacy-Relations and the Physical Principles of the Quantum Theory,"; and those by Dirac are: "The Basis of Statistical Quantuj Mechanics"; "Quantum Mechanics of Many-Electron Systems,," "Relativistic Theory of Electron," and "The Principle of Superposition and the two-Dimensional Harjmonic Oscillator." See: Sin-itiro Tomonaga, *The Story of Spin*, translated by Takeshi Oka (Chicago: The University of Chicago Press, 1997), 222-23.

centers in physics.[80]

For the dissemination of quantum mechanics in Japan, however, Nishina's lectures on quantum mechanics had more important consequences. In particular, his ten-day long intensive lecture course on quantum mechanics at Kyoto University in May 1931 played a pivotal role by encouraging young physicists in Kyoto and establishing a link between Riken and this university in Japan's old capital, making it an important source of young theoretical physicists. In the audience were Yukawa Hideki, Tomonaga Sin-itiro, Sakata Shôichi, and Kobayashi Minoru. Tomonaga and Yukawa found this lecture series based on Heisenberg's *Physical Principles of Quantum Theory* extremely clear and instructive (although Sakata and Kobayashi, still undergraduates, did not understand a word). At this point, those lonely students of quantum mechanics finally found someone who could be an authority figure for them. In particular, Nishina's lectures gave Tomonaga the assurance that he was not misunderstanding quantum mechanics, and he was heading in the right direction.

Other than Tomonaga, Nishina found a few other future theoretical physicists and members of his group. Sakata, a relative of Nishina's, often visited Nishina's hotel room. At Nishina's place, Sakata came across Tomonaga and Yukawa, who, too, visited Nishina to learn from him. They dined together, and discussed the problems of the nucleus, while Sakata, still an undergraduate, could not follow them.[81] On a weekend during Nishina's stay in Kyoto, Sakata took Nishina to Uji River for some sightseeing. Sakata invited Kobayashi Minoru, physics students, who wanted to do theory rather than experiment, to join them.

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80. Tamaki Hidehiko, "Sekai no gakkai ni mado wo hiraku," 84-85.

81. Sakata Shôichi, "Chûkanshi riron kenkyû no kaiko," in *Shinri no ba ni tachite*, Sakata Shôichi Yukawa Hideki, Taketani Mitsuo (Tokyo: Mainichi Shimbunsha, 1951), 42.

This was how Sakata and Kobayashi, who joined Nishina's group when they graduated, began studying quantum mechanics.[82]

In July 1931, Riken promoted Nishina to a group leader (a "research scientist in chief" or *shunin kenkyûin*) and Nishina finally had a free hand in building his own school. Nishina's group started on a modest scale. Nishina wrote to Tomonaga and invited him to join, which Tomonaga, always unconfident about his ability, reluctantly accepted anyway.[83] The theory subgroup of Nishina's group had Nishina himself and Tomonaga. Nishina's group had only two rooms: one was Nishina's office, the other was still an empty laboratory. Due to lack of space, Tomonaga had to have his desk in a storage room, which housed old issues of Riken's journals. There, Tomonaga daily encountered mice, who regarded with black eyes this pale-faced intruder curiously. The other daily visitor to Tomonaga's "office" was, of course, Nishina himself, who asked about the progress of Tomonaga's work.[84]

From this humble origin, Nishina built an active group of theoretical physicists. As I mentioned above, Nishina after his return to Japan was seen as bringing the "Copenhagen spirit" from Copenhagen into Japan. For example, Tamaki Hidehiko, one of Nishina's earliest disciple, describes the practice at Bohr's institute, which I suspect, was the ideal of what was practiced in Nishina's group.

> Bohr's way of doing was an even more advanced form of cooperative research [than Rutherford's]. Scientists discussed scientific matters not

82. Ibid., 42-43.

83. Tomonaga Sin-itiro, "Wagashi wagatomo," in *Chôjûgiga*, vol. 1 of *Tomonaga Sin-itiro chosakushû*, reprint, 1962 (Tokyo: Misuzu Shobô, 2001), 200.

84. Tomonaga Sin-itiro, "Omoide banashi," in *Chôjûgiga*, vol. 1 of *Tomonaga*

> only through writings, but also in person, discussing and working in the same place collaboratively. . . . First, they read paper from all around the world, by dividing the work of reading. Then, they talked about and discuss what they read. Sometimes, they continued discussing for days. Once having reached a new idea, they, again dividing the work, calculated it, or confirmed it by experiments, on its various aspects. Then, they examined and compared various results. They then would repeat this whole process.
> In Bohr's institute, thus, people paid attention to research all around the world. There was also an atmosphere, where one could say anything without hesitation. People were used to listen attentively, not swallowing or ignoring what others said. Then, they carried out scientific research with remarkable power of execution.
> Such a new atmosphere and method attracted young scientists from all around the world. Since Bohr's institute of theoretical physics was located in Copenhagen, the way of this institution was called the "Copenhagen spirit," and became famous among the scientists in the world. Nishina Yoshio acquired this "Copenhagen spirit," and brought it back to Japan, taking the initiative in applying this spirit to practice. By this very reason, young scientists around Japan gathered under Nishina, and grew up splendidly.[85]

Tomonaga Sin-itiro considered what Nishina brought to Japan to be a methodology of physics: "What was brought to us by him [Nishina] was more important than scientific discoveries or cyclotrons. He brought to us awareness of the modern methodology of physics research."[86]

Even Yukawa Hideki thought in the same way. In his autobiography written in 1951, he wrote:

> At that time, the phrase, "Copenhagen spirit," was frequently heard in the physics world, referring to the Institute of Theoretical Physics at Copenhagen University, with Niels Bohr as its head. The best theoretical physicists came from all over the world to learn from Bohr, including some Japanese scientists. Yoshio Nishina had a particularly long stay in Copenhagen. His lectures were not only explanations of quantum physics, for he carried with him the spirit of Copenhagen, the spirit of that leading group of theoretical physicists with Niels Bohr as its center.
> If I were asked to describe the spirit of Copenhagen, I would not be able to do so in a few words. However, it is certain that it had much in common

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Sin-itiro chosakushû, reprint, 1962 (Tokyo: Misuzu Shobô, 2001), 204.

85. Tamaki Hidehiko and Iwasaki Masao, *Nishina Yoshio* (Tokyo: Kokudosha, 1976), 90-91.

86. Tomonaga Sin-itiro, "Nishina sensei," *Kagaku* 21 (1951): 212.

> with the spirit of generosity. Having been liberally educated, I was especially attracted by that, but I was also attracted by Professor Nishina himself. I could talk to him easily, although I was usually very quiet. Perhaps I recognized in Nishina the kindly father figure that I could not find in my own father. Whatever it was, my solitary mind, my closed mind, began to open in the presence of Professor Nishina.[87]

Finally, Sakata Shôichi, too, had a similar view about the later developments of quantum physics in prewar Japan:

> Elementary particle physics in Japan, which started with Dr. Nishina and reached its hiatus with Dr. Yukawa and Dr. Tomonaga, had two characteristics from the beginning. The first was the close and systematic collaboration among many scientists in a free atmosphere, and the other was the powerful methodology by Dr. Taketani. Both of them were further developments of the Copenhagen spirit, transferred by Dr. Nishina.[88]

Moreover, the next generation of physicists inherited these views. Hiroomi Umezawa, a disciple of Sakata Shôichi's,[89] writes how the "Copenhagen spirit" was brought into Japan and disseminated there:

> Niels Bohr, who has made the greatest contribution to the discovery of quantum mechanics, after having learned from Rutherford, became the leader of the Copenhagen Institute, and applied in this institute the method that he experienced at Cavendish Laboratory. This method was transmitted by Yoshio Nishina, who studied and worked with Bohr, and is called the Copenhagen spirit. . .
> After coming back to Japan in the end of 1928, Dr. Nishina founded the first laboratory for atomic and nuclear physics. Because at that time, there was no other place to study such a new science, young scholars with aspiration for the atomic physics gathered around Dr. Nishina from other universities, and initiated cooperative researches in a friendly atmosphere which greatly emphasized free discussion . . . With this new research environment, a laboratory of nuclear physics was founded at the college of

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87. Hideki Yukawa, *"Tabibito" (The Traveler)*, translated by Laurie Brown and R. Yoshida (Singapore: World Scientific, 1982), 177.

88. Sakata Shôichi, "Chûkanshi riron kenkyû no kaiko," 91.

89. As for Umezawa, see: Hiroshi Ezawa and others., eds., *Selected Papers of Hiroomi Umezawa* (Tokyo: Editorial Committee for Selected Papers of Hiroomi Umezawa, 2001).

> science, University of Osaka, and there Dr. Yukawa's meson theory was born. Dr. Nishina fostered cooperative research groups, ranging widely from theoretical and experimental studies on nucleus and cosmic ray, training many disciples. Many of those who came from other universities to Dr. Nishina, and learned from him, came back to the original universities to continue their research, bringing back not only their academic achievements, but also the atmosphere of his laboratory.[90]

Furthermore, according to Umezawa, new research groups of theoretical physics were created in several places in Japan by these students of Nishina, including Tomonaga's Tokyo group at Tokyo Bunrika Daigaku, Sakata's Nagoya group, and Yukawa's Kyoto group. The author even talks about how Japanese physicists needed to "develop further the Copenhagen spirit by their own" after the Second World War.[91]

In what follows, I describe what Nishina did, how the Nishina group carried out physics, and what its relation to other groups was, by focusing on theoretical physics. I show that the way the Nishina group conducted physics was parallel to the description of Bohr's institute above in several, but not all, aspects.

Just as Bohr had, Nishina valued collaboration. According to Nakayama Hiromi, Nishina often said that collaboration by two was more than twice as efficient as working alone.[92] Just as Bohr had, Nishina promoted collaboration between a theorist and oather, between experimentalists and theorists, between different disciplines, and international collaboration.

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90. Hanada Keisuke, Umezawa Hiroomi, and Shizuma Yoshitsugu, "Nihon no kagaku to shisô," in *Kindaikato dentô*, vol. 8 of *Kindai Nihon shisô kôza* (Tokyo: Chikuma shobô, 1959), 334.

91. Ibid., 335.

92. Tomonaga Sin-itiro and others, "Zadan Nishina sensei wo shinonde," in *Hirakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakusû*, reprint, 1951 (Tokyo: Misuzu Shobô, 1982), 80.

When Tomonaga joined Riken, Nishina emulated the method he used with Oskar Klein in Copenhagen. Each made calculations independently, and compared the result at the end of the day, then moved on. By this way, they could not only be sure of their results and keep going but they were also able to transmit their research know-how from one to the other. Nishina told his students that it was the most efficient way, and this method allowed him to detect numerous errors in his work with Oskar Klein.[93]

After Sakata Shôichi joined the Nishina group in the spring of 1933, Nishina left most of the actual work to his disciples. First, Nishina and then Tomonaga decided the topics, and Tomonaga and another member of the group carried out the calculation. With Tomonaga, Sakata first worked on the calculation of the pair creation of the electron caused by a photon. Next year, Kobayashi Minoru and Tamaki Hidehiko joined the group. Again, Tomonaga worked with each of them.[94]

Quantum physics at this point, unlike when its formulation was under investigation, required extensive calculations, as much as in classical mechanics

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93. Kobayashi Minoru, "Riron kenkyû," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 99.

94. Yoshio Nishina, Sin-itiro Tomonaga, and Shôichi Sakata, "On the Photo-Electric Creation of Positive and Negative Elctrons," *Supplement to Scientific Papers of the Institute of Physical and Chemical Research* 17 (1934): 1-5; Yoshio Nishina, Sin-itiro Tomonaga, and Minoru Kobayashi, "On the Creation of Positive and Negative Electrons by Heavy Charged Particles," *Supplement to Scientific Papers of the Institute of Physical and Chemical Research* 27 (1935): 137-77; Yoshio Nishina, Sin-itiro Tomanaga, and Hidehiko Tamaki, "On the Annihilation of Electrons and Positrons," *Supplement to Scientific Papers of the Institute of Physical and Chemical Research* 18 (1934): 7-12; Yoshio Nishina, Sin-itiro Tomonaga, and Hidehiko Tamaki, "A Note on the Interaction of the Neutron and the Proton," *Supplement to Scientific Papers of the Institute of Physical and Chemical Research* 30 (1936): 61-69.

and electromagnetism around the turn of the century. Young Japanese physicists were able to carry out such calculations. At the same time, the method that Nishina introduced prevented them from being consumed by tedious calculation. The Cooperative approach enabled them to relax and pay attention to aspects of the problem other than straight calculations. The method allowed them to err, because errors would eventually be corrected. It allowed them not to become mere calculating machines.

As Niels Bohr did, Nishina had both theorists and experimentalists in his group. The first people he hired were experimentalists, such as Sagane Ryôkichi and Takeuchi Masa. The theory and experiment subgroups were in a close contact under the leadership of Nishina. Tomonaga Sin-itiro remembers that when he joined the group in 1932, both experimental and theoretical works were discussed at Riken's colloquia for atomic physics. The experiments of the "Wonder Year" excited Tomonaga and other participants greatly. In this year, James Chadwick discovered and published neutron,[95] Harold Urey deuterium,[96] Carl D. Anderson (and others) positron.[97] These discoveries set the foundation for further developments of nuclear physics.[98] Tomonaga's later writings show his great

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95. James Chadwick, "Possible Existence of a Neutron," *Nature* 129 (1932): 312 For a historical study, see: Roger Stuewer, "The Nuclear Electron Hypothesis," in *Otto Hahn and the Rise of Nuclear Physics*, edited by William R. Shea (Dordrecht: D. Reidel, 1983), 19-67.

96. H. C Urey, F. G Brickwedde, and G. M. Murphy, "A Hydrogen Isotope of Mass 2," *Physical Review* 39 (1932): 164-65.

97. Carl. D. Anderson and Robert. A. Millikan, "The Apparent Existence of Easily Deflectable Positives," *Science* 76 (1932): 238-39.

98. Helge Kragh, "The Rise of Nuclear Physics," in *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton: Princeton University Press, 1999), 174-89; Emilio Segrè, "The Wonder Year 1932: Neutron, Positron,

familiarity with the experimental apparatus in this area.[99]

Collaboration crossed the inner boundaries in Riken. The Nishina group kept close ties with the groups of Nagaoka, Takamine, and Nishikawa. They regularly shared seminars and colloquia. After 1935, they jointly founded the Nuclear Physics Laboratory, where the construction of cyclotrons was undertaken as a collaborative enterprise.[100]

Though loyal to Riken, Nishina was immune to institutional chauvinism, and welcomed those who were outside. In particular, from Tokyo University, the only scientific institution in Tokyo that could rival Riken, young physicists from the Terazawa School of Tokyo University, such as Kotani Masao, Inui Tetsurô, and Nagamiya Takeo, often visited the Nishina's group, attending seminars and colloquia.[101]

Collaboration in Nishina's group crossed disciplinary boundaries, too. Nishina's first disciple, Takeuchi Masa, was in fact trained as an applied chemist at Tokyo Higher Technical School (Today's Tokyo Institute of Technology), who knew little about physics. The collaboration between the Nishina group and Kimura Kenjirô's group of chemists at Tokyo University produced eight papers

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Deuterium, and Other Discoveries," in *From X-Rays to Quarks: Modern Physics and Their Discoveries* (San Francisco: W. H. Freeman and Co., 1980), 19-67. Whereas the actual incidents were more complex than to be called "discoveries," I do not delve into this issue.

99. Tomonaga Sin-itiro, "Kenkyû seikatsu no omoide," in *Butsurigaku to watashi*, vol. 2 of *Tomonaga Sin-itiro Chosakushû* (Tokyo: Misuzu Shobô, 1982), 302-03.

100. Takeuchi Masa, "Nishina kenkyûshitsu monogatari," in *Nihsina Yoshio: Nihon no genshi kagaku no akebono*, Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 218.

101. Tomonaga Sin-itiro and others, "Kizobutsurigaku kenkyûjo wo megutte," 248.

from 1938 to 1942 on uranium. Kimura Kenjirô was another Copenhagen alumnus, who had already worked with Nishina there on the dependence of the X-ray spectrum on chemical binding.[102] The most important result of their collaborations in Tokyo was the discovery of Uranium 237. It was made possible by a combination of physical technique (illumination of fast neutrons generated by the Li-Deuterium reaction and the 27-inch cyclotron constructed by Riken) and chemical technique (chemical separation of non-uranium).[103]

Just as Bohr had been, Nishina was interested in collaborating with biologists. Nishina often talked with Bohr over the question of life,[104] and he was also close to George Hevesy. When Nishina's group first produced a beam from the 27-inch cyclotron on April 3, 1937, Nishina asked Murati Kôiti, a specialist of radiobiology, to see the effect of the beam on an organism. Murati and others studied the effect of neutrons on guinea pigs. Nishina delightedly wrote to Bohr the result of the experiment, and reported that for the first time in Japan physicists and biologists were working hand in hand.[105] At the same time, the use of radio isotopic tracers on organisms started in the Nishina group. In May 1937, Nishina Yoshio talked to a professor of biology at Tokyo University to recommend a

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102. Shin'ichi Aoyama, Kenjirô Kimura, and Yoshio Nishina, "Die Abhängigkeit der Röntgenabsorptionsspektren von der chemischen Bindung," *Zeitschrift für Physik* 44 (1927): 810-33.

103. Saitô Nobufusa, "Nishina Yoshio to aisotôpu," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 128-29; Saitô Nobufusa, "Nishina Kimura no mei konbi," *Nihon Genshiryoku Gakkai shi* 32, no. 7 (1990): 697-98.

104. Takeuchi Masa, "Nishina sensei to hôshasen seibutsugaku," in *Nihsina Yoshio: Nihon no genshi kagaku no akebono*, Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobô, 1991), 154.

105. Ibid., 155.

young scientist for tracer experiments with radioactive isotopes. The biologist recommended Nakayama Hiromi, a graduate student, who immediately joined the Nishina group and started repeating Hevesy's recent experiments.[106] In these projects, Nishina was obviously emulating Niels Bohr's efforts in Copenhagen to cross disciplinary boundaries in scientific collaborations.

Japan's geographical location did not allow much international collaboration. Nishina, nonetheless, gave a considerable effort to invite foreign scientists to Japan. Among the scientists whose visit to Japan involved Nishina were: Werner Heisenberg, P. A. M. Dirac, George Hevesy, Niels Bohr, and Irvin Langmuir. Often, Nishina himself translated their lectures into Japanese and published them, as we saw in Dirac and Heisenberg's case.[107]

The collaboration with scientists in Asian countries, however, did not happen. It is not clear whether it was Nishina or the scientists in Asian countries who were not interested. As far as I am aware, the Nishina group had only one Korean (or potentially Chinese) member. No Indian scientist appears to have been involved in Nishina's group, although Nishina had worked with an Indian physicist, B. Ray, in Copenhagen.

Apparently, Nishina was too serious and too busy to appreciate playfulness. He was generally friendly when talking one on one, but at a lecture, Nishina was very blunt, and never told any jokes.[108] Nishina's disciples were,

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106. Nakayama Hiromi, "Torêsâ to shokubutsu seiri no kenkyû," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, Tamaki Hidehiko and Ezawa Hiroshi (Tokyo: Misuzu Shobo, 1991), 135-37.

107. Werner Heisenberg and P. A. M Dirac, *Ryôshiron sho mondai*, translated by Nishina Yoshio (Tokyo: Keimeikai, 1931).

108. Tomonaga Sin-itiro, "Taidan kagaku no imi," in *Butsurigaku to watashi*, vol. 2 of *Tomoanga Sin-itiro chosakushû* (Tokyo: Misuzu Shobô, 1982), 344.

however, able to have fun. In particular, they found enjoyment and excitement in the competition with European and American scholars. Takeuchi Masa writes:

> It was fun then. When we received and opened *Physical Review*, people were doing similar things over there. We used to say,"We were just two weeks behind them, the amount of time for mail," and really had fun.[109]

In addition, the Nishina group members had fun making nicknames for each other. Nishina was originally called "paipan," meaning the "white tile" of the game of mah-jongg, because of his white squarish face.[110] Later he was usually called "oyakata," the *padrone*, the word to refer to a boss, generally among artisans or gangsters, where "oya" means "parent." Tomonaga was called "Shako-san," squilla or mantis shrimp, which is eaten as sushi in Japan. Someone associated this white seafood with Tomonaga's skinny pale face. Sakata had a slightly likable nickname, "Bonji-san," after a famous cartoon character of the time, "Tadano Bonji" (of which English approximation would be Mr. Mediocre), because Sakata resembled this character in appearance. Sagane was "Gane-san," from his name. Takeuchi Masa was "Getaya," Tamaki Hidehiko, "Eiboko," Ymazaki Fumio, "Donchan," Sugimoto Asao, "Genji," Kigoshi Kunihiko, "Aodaishô," and so on.[111]

The scientists in Nishina's group had fun together in various activities. In particular, they had short excursions from time to time to scenic places near

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109. This comment by Takeuchi refers to the subgroup of experimentalists, but Tamaki Hidehiko confirms that it was also the case in the theory subgroup: Tomonaga Sin-itiro and others, "Nishina sensei wo shinonde," 65.

110. Tomonaga Sin-itiro and others, "Nishina sensei wo shinonde," 84.

111. Partially based on the reminiscence by Yokoyama Sumi (Nishina's secretary):

Tokyo, such as Hakone or Katsunuma, often with members of other groups. In town, they often went to watch movies. Tomonaga remembers that they once saw a samurai film, "Tange sazen," when Sakata left the Nishina group to join Yukawa, they went to see the motion picture version of "Tadano Bonji," in honor of their "Bonji."[112]

To complete a certain work, some of the theorists had an extended "summer camp," for which Nishina probably paid with his own money. In 1933, Nishina Yoshio, Tomonaga Sin-itiro, and Sakata Shôichi went to Gotenba, a resort near Mt. Fuji, to finish their calculation on the pair creation of electrons by gamma-ray during the summer, and stayed there for about a month. In 1935, Tomonaga, Tamaki Hidehiko, and Kobayashi Minoru went to Karuizawa, a mountain resort town north of Tokyo, to translate P. A. M. Dirac's textbook on quantum mechanics.[ref]

Discussion was an important feature of the Nishina group. His disciples remember that Nishina at this point was extremely fond of chatting, a characteristic that I cannot find in his earlier life (being talkative is not a virtue in the traditional Japanese value system, and Nishina was, to a great extent, a man of traditional values. See Chapter 6). Whenever he met a member of his group he began talking and kept on, even forgetting the time of dinner. Once, when Nishina and Tomonaga were reading a journal in the library, they began discussion, first whispering, but soon talking loudly, unaware of where they were, until the chemist Katsurai Tominosuke reminded them that they were in the library, and

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Yomiuri Shinbunsha, ed., *Shôwa shi no tennô*, vol. 4 (Tokyo: Yomiuri Shinbunsha, 1968), 89.

112. Tomonaga Sin-itiro, "Sakata-kun no koto," in *Butsurigaku to watashi*, vol. 2 of *Tomoanga Sin-itiro chosakushû*, reprint, 1970 (Tokyo: Misuzu Shobô, 1982), 244.

asked them to be quiet.[113] Taketani Mituo, when he joined the group in 1941, was amazed by Nishina's zeal in discussion. Discussion could start after lunch and continue, without a break or a meal, until 10 p.m. Nishina would ask young scientists in dead earnest, "I cannot believe that. How come is that so?"[114]

As in Bohr's institute, lunch was important in Nishina's group. When established, the Nishina group was physically located in Building No. 3, which they shared with the group of Takamine Toshio, a spectroscopist and Copenhagen alumnus. Young members of these groups (Takeuchi Masa, Tomonaga Sin-itiro from the Nishina group, and Suga Tarô, Fujioka Yoshio after his return to Japan in June 1932, and, sometime, Tomiyama Kotarô from the Takamine group) gathered in a room of the Takamine group and chatted over lunch or tea. Though the room was rather dirty, with messy shelves and half-broken chairs, they had a good time chatting over frivolous topics. One of the topics discussed was the romantic night life of Tomiyama Kotarô, a young member of the Takamine group, who, due to his after-hours perambulation, would always show up when everyone finished lunch, and therefore became a convenient target of the other scientists' curiosity.[115] Then, Nishina and Takamine began to eat lunch in Takamine's room from time to time with some of their disciples.[116]

Construction of new buildings followed the establishment of Riken's Nuclear Physics Laboratory in 1935. Nishina's group finally had their own lunchroom. Since the summer of 1936, they secured the new meeting room in

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113. Tomonaga Sin-itiro and others, "Nishina sensei wo shinonde," 68-69.

114. Yomiuri Shinbunsha, *Shôwa shi no tennô*, 164.

115. Tomonaga Sin-itiro, "Tomiyama san no omoide," in *Butsurigaku to watashi*, vol. 2 of *Tomoanga Sin-itiro chosakushû* (Tokyo: Misuzu Shobô, 1982), 253-54.

116. Takeuchi Masa, "Nishina kenkyûshitsu monogatari," 217.

Building No. 29 as the meeting place and lunchroom of group members.[117] The daily luncheon meeting became an important opportunity, almost a sacred ritual. It helped to maintain group integrity, especially to keep theorists and experimentalists in a close contact. Everyday, all the members of Nishina's group would take lunch together in the cafeteria of Riken[118] and chat after that on various topics. In the mid-1930s, when the Nishina group became large enough, they no longer had lunch at the Riken's cafeteria. Nakayama Hiromi, who joined Riken in 1937, writes that those who were involved in the Nuclear Physics Lab (consisted of members from the Nishina, Nagaoka, Takamine, Nishikawa groups) had lunch in a meeting room everyday (apparently they took lunch out from the cafeteria). In particular, all the members of the Nishina group, including Nishina himself, had lunch there everyday at one table. This custom continued even during the war. When the cafeteria had to be closed down, members of the Nishina group went out to buy meals and maintained this tradition.[119] The lunchroom was the place where newcomers were initiated. Nakayama writes that the lunch enabled the group members to talk to one another in a friendly way. When he had just joined the group, Nakayama learned, by listening to what other people talked, to recognize other members of the group (there were a few dozens of them), and to "understand the atmosphere of the group."[120] Taketani Mituo, who joined the group in April 1941, described the atmosphere of the luncheon discussion:

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117. Ibid., 218.

118. Riken provided either a bowl of rice or a roll free of charge. See: Takeuchi Masa, "Nishina kenkyûshitsu monogatari," 216.

119. Nakayama Hiromi, "Torêsâ to shokubutsu seiri no kenkyû," 138.

120. Ibid.

> All the members would meet in the dining room at noon, and have lunch, talking boisterously. Everything was discussed. Nowhere could one find here the dull, feudalistic, and depressed atmosphere of a university. We talked whatever we would like, freely, without considering seniority. There was no etiquette, and outspokenness was welcomed.[121]

The seminar was no different from the lunchtime discussion. New members of the Riken were surprised at the way people discussed with each other freely. For outsiders, the heated atmosphere of the group was almost unbearable. For example, when Tomonaga moved form Kyoto University to Riken, he was astonished at the unfettered atmosphere, where the old and the young talked to each other without formality. "The seminars went on lively with the discussions of young foulmouthed and quick thinking youth, with no deference to formality and etiquette."[122]

Those young physicists were sometimes more than outspoken. Tomonaga writes: "Back then, [in the 1930s], we are all mean, but it was fun and we are full of vitality." Nakayama Hiromi remembers a conversation at the lunch table in 1937 when a meson was discovered by Anderson, Neddermeyer and, later, by the Nishina group. All were saying, "we wish Bohr-san had been here with us."[123] What Nakayama seems not to have realized was that they were not missing Bohr. They probably wished that they could see the reaction of Bohr, who had been negative towards Yukawa's theory.

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121. Taketani Mitsuo, "Soryûshiron gurûpu no keisei: watashi no me de mita," in *Shinri no ba ni tachite*, Hideki Yukawa, Shôichi Sakata, and Mitsuo Taketani (Tokyo: Mainichishimbunsha, 1951), 187.

122. Tomonaga Sin-itiro, "Wagashi wagatomo," 201.

123. Nakayama Hiromi, "Torêsâ to shokubutsu seiri no kenkyû," 138.

Ogura Shimbi, a scientific journalist, who often asked Nishina and other scientists in his group to write articles for a popular magazine for which he was the editor, described the Nishina group in the late 1930s as a "bunch of foulmouthed bright boys." Before opening the door to the Nishina group, the poor journalist often had to take a deep breath to prepare for the ordeal. In particular, he asked Tomonaga to write for his magazine several times, which Tomonaga always declined. Tomonaga told the poor editor that he was doing an important work and had not time for Ogura's popular science magazine, always with a sarcastic grin on his face.[124]

In many aspects, therefore, what happened in the Nishina group was similar to the way Bohr ran his institute, but there are certain differences. Before analyzing them more fully, however, I am going to examine the group at Osaka University, where the first major theoretical work in quantum physics, namely the creation of meson theory, took place, and where, according to some Japanese physicists, the "Copenhagen spirit" was transmitted from the Nishina group.

5. Dissemination of the "Spirit": Osaka University

Imperial universities tended to stagnate with time because of their socially prestigious status and inherently bureaucratic nature. In the field of science and technology, where development was relatively rapid, it was necessary to provide new jobs for young scholars. At imperial universities, however, old professors with outdated interests continued to occupy the positions. One way to resolve this problem was to create new institutions. Tohoku University. founded in 1917, was the first to serve for that purpose. Then in the 1931, the same year of Nishina's

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124. Ogura Shimbi, "Sensei no seikatsu to iken," in *Shizen, 300gô kinen zôkan*, reprint, 1965 (Tokyo: Chûôkôronsha, 1971), 308.

independence, Osaka University was founded, with the principal objective of advancement of science and technology. Nagaoka Hantarô became its president.

Young and talented scientists gathered at Osaka University. Yagi Hidetsugu, an able electrical engineer, famous for the Yagi antenna, headed the department of physics, which had Kikuchi Seishi and Yukawa Hideki as its members. Kikuchi Seishi was another son of Kikuchi Dairoku, who was producing first class experimental works. He began forming a research center of experimental atomic physics at Osaka, and would later follow the Nishina group in the construction of cyclotrons.

Nagaoka had also great expectations forYukawa. Nagaoka, who considered himself a research scientist, not an administrator, was not at all happy to "be forced to become president," but was nevertheless rejoiced at having at Osaka University young good scientists, such as Kikuchi and Yukawa. When his son asked how bright Yukawa was, Nagaoka replied, "What is the use of those 'bright and best', who are just evenly good at the subjects that the ministry of education determined? . . . Yukawa has originality. That is what counts. He is not one of those 'brilliant' boys who just fit in the rules of the old people."[125]

Not all the physicists at this university were receptive to the new physics. Professor Okaya Tokiharu, a specialist of relativity theory and Nagaoka's son-in-law was the direct superior of Yukawa. He teased quantum physicists during his lecture; Writing "Ψ" on the blackboard, he said, "Some gentlemen think this represents the universe."[126]

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125. Nagaoka Haruo, "On'yônaru bishô," in *Tsukiai*, edited by Yasutaka Tanigawa (Tokyo: Kôdansha, 1968), 211-16.

126. Uchiyama Tatsuo, "Handai kyôju Yukawa hakase," in *Tsukiai*, edited by Yasutaka Tanigawa (Tokyo: Kôdansha, 1968), 170.

When Yukawa took the job of lecturer at Osaka in 1933, except for Kikuchi's experimental group, he must have been quite alone in Osaka. Furthermore, Yukawa was unproductive for a year or two. Yagi Hidetsugu was not happy with Yukawa from the beginning. Yagi, who wanted Tomonaga, accepted Yukawa in the department only because Tomonaga was taken by Riken. Yukawa's apparent sterility made Yagi even less happy and he often scolded Yukawa for not publishing.[127]

The situation began to change in 1934. Sakata Shôichi, who had been a research student (*kenkyûsei*) under Nishin, gained a job at Osaka, as a research associate to Yukawa. A research school of theoretical physics began to form around Yukawa. Aristocratic and introverted, he was the type of scientist who worked alone and produced original works in isolation, and had a completely different personality from Nishina. Uchiyama Tatsuo writes that when he, as a student, knocked on the door, Yukawa and Sakata would turn from the desks to him. While Sakata would show an amiable face with a slightly surprised smile, Yukawa looked always ill-tempered, as if asking "what's your business here?"[128] In contrast to Yukawa, Sakata was, in Taketani Mituo's words, a "genius of organizing people into a collaborative research." "Against him, no one could have antipathy. Without hiding himself, he could be able to create an atmosphere of agreement with anybody."[129] Furthermore, Sakata, trained by Nishina and having witnessed his school-building, was aware of the new cooperative method of atomic physics. He used the same method in Nishina's school here. When Tanigawa Yasutaka, the earlier disciple of Yukawa and Sakata joined, Sakata

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127. Ibid., 168-69.

128. Ibid., 167.

129. Taketani Mitsuo, "Soryûshiron gurûpu no keisei," 165.

worked with him. Tanigawa copied Sakata's calculation notes, in which Sakata meticulously wrote down necessary formulae. Then Tanigawa did his own calculations and compared the result with Sakata's.[130]

Similarly important to the theoretical physics group in Osaka University were Kikuchi Seishi and his experimental physics group in nuclear physics. Kikuchi was an able and young experimentalist, another son of Baron Kikuchi Dairoku, who had been to Europe, spending about three years in Leipzig and Göttingen. Since he came back to Japan, he had been working at Riken, until he was appointed to Osaka University. Kikuchi was working on experimental nuclear physics, and although starting late, this group was going to construct the first cyclotron in Japan, one month before Nishina's cyclotron. Yukawa had a closer relation to Kikuchi's group than to his official superior, Professor Okaya Tokiharu.

The Kikuchi and Yukawa a groups had lunch together in the room called "the Kikuchi Dining Hall," a simple laboratory room with a large table, located opposite to Yukawa and Sakata's office.[131] It was customary for them to play games after lunch (or for some, while eating lunch). Yukawa and Kikuchi always played the game of go. Others played the Japanese chess. While the two senior physicists were playing the game of go quietly at the end of the table, their disciples played chess with youthful clamor. The young physicists, so engrossed in the game, began to play chess longer and longer, eventually until the teatime at 3 p.m. At this point, Kikuchi had to ban the game temporarily.[132]

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130. Taniakawa Yasutaka, "Aru jidai," in *Tsukiai*, edited by Tanikawa Yasutaka (Tokyo: Kôdansha, 1968), 157.

131. Uchiyama Tatsuo, "Handai kyôju Yukawa hakase," 168.

132. Taniakawa Yasutaka, "Aru jidai," 159-60.

The greatest incentive for the development of collaborative work in theoretical physics at the Osaka University was nothing other than Yukawa's meson theory. When Yukawa presented his theory at a conference in 1934, the audience did not receive it very favorably. As mentioned, however, Nishina encouraged Yukawa. Yukawa, with his wife's help, wrote his paper in English for the first time, which was published in 1935.[133] Nishina's encouragement was important, since the significance of Yukawa's paper was not at all clear. Niels Bohr, for example, when he visited Japan in 1937, teased Yukawa by asking "Do you like new particles?"[134] Tomonaga, too, showed strong interest in Yukawa's theory. Not only did he write letters to Yukawa asking his recent works, he also guaranteed the value of Yukawa's paper to Fujioka Yoshio, an experimentalist at Riken, who was wondering whether he should write a review article on Yukawa's theory for a science magazine.[135]

Dissemination of the "Copenhagen spirit" was not limited to Osaka University. When Yukawa succeeded Tamaki Kajûrô's chair at Kyoto University, he took half of his group (Sakata and Tanigawa) to Kyoto, whereas Kobayashi and Taketani remained in Osaka. In 1941, Tomonaga gained a position at Tokyo Bunrika Daigaku, and later created an important research group there.[136] In the next year, Sakata Shôichi founded his group in Nagaoka, too. In addition, Umeda

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133. Hideki Yukawa, "On the Interaction of Elementary Particles I," *Proceedings of the Physico-Mathematical Society in Japan, Series III* 17 (1935): 48-57.

134. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Zadankai: Nihon ni okeru soryûshiron no reimei," *Kagaku* 38 (1967): 395.

135. Fujioka Yoshio, "Yukawa-san ni hajimete atta koro no hanashi," in *Tsukiai: Yukawa hakase kanreki kinen bunshû*, edited by Tanigawa Yasutaka (Tokyo: Kodansha, 1968), 7.

136. Silvan S. Schweber, *QED and the Men Who Made It: Dyson, Schwinger, Feynman, and Tomonaga* (Princeton: Princeton University Press, 1994).

Kwai at Hokkaido University, and Ozaki Masamaru at Tohoku University, were also trained in the Nishina group. The list will be expanded significantly, if the third generation is included.[137]

6. Did the "Copenhagen Spirit" Work in Japan?

As we have seen above, some Japanese physicists perceived that the "Copenhagen spirit" brought by Nishina shaped the theoretical physics community in Japan. In many aspects, the research activity in the Nishina group in Riken was similar to that of Copenhagen, and the atmosphere in Riken seems to have been transferred to Osaka University: The importance of lunch, discussion, neglect of protocol, lively atmosphere, collaboration between theorists and experimentalists, and between physicists and non-physicists.

There are, however, some difficulties in seeing this process of the growth of quantum physics in Japan in terms of the dissemination of the "Copenhagen spirit."

First, there are a few aspects in which the style of physics in Nishina's group was different from that of Bohr in Copenhagen. There was no philosophical bent among the disciples of Nishina. As I mentioned, Nishina himself was interested in complementarity and foundational problems of quantum mechanics. His interest, however, did not turn out to be infectious to his fellow physicists and disciples, as I discuss in Chapter 7.

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137. Yoshinori Kaneseki, "The Elementary Particle Theory Group," in *Science and Society in Modern Japan: Selected Historical Sources*, Shigeru Nakayama, David L. Swain, and Yagi Eri (Tokyo: University of Tokyo Press, 1974), 221-35.

Neither did Nishina himself allow philosophical considerations to interfere with his physics. As mentioned above, when Yukawa Hideki presented his seminal idea of meson theory in the 1932 and 1933, Nishina has been supportive. When Bohr visited Japan in 1937, Nishina took the trouble of introducing Yukawa to Bohr. Bohr's response was, as I have mentioned above, "Do you like new particles?"[138] Evidently, for Bohr, solving a problem by creating a new particle was a naive realist attitude and unacceptable to him. Such a philosophical nicety, however, did not concern Nishina.

There was another aspect where Nishina differed from Bohr. Nishina's way of directing his group was much more dictatorial than Bohr's. Nishina could fire the group members who disagreed with him about the research direction, and was able to impose his ideas on the group. The relation between Nishina and his group was much more formal than the relation between Bohr and other scientists in his institute. Between Nishina and his disciples, there was a definite generational difference.[139]

The disciples had to devise a way to "control" Nishina, without his knowing. Sometimes, Nishina would demand that a group member should carry out an impossible task. A smart disciple, such as Tomonaga, would not say that his demand was unreasonable, which would lead to a direct confrontation. Rather, he would accept the demand at the moment, and go back to Nishina in a few days, tell him that the requested task would take several hundred sheets of papers to

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138. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Nihon ni okeru soryûshiron no reimei," 395.

139. If a disciple disagreed with Nishina on an important issue, such as how to construct a cyclotron, he had to leave the group. See Ishii Chihiro's remark in: Tomonaga Sin-itiro and others, "Nishina sensei to kakubutsuri no hatten," in *Hirakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakusû*, reprint, 1961 (Tokyo: Misuzu Shobô, 1982), 115.

calculate, and several hundred hours of time, and ask Nishina whether he should continue the work. It seems that Nishina's disciples managed to "control" Nishina in many cases, but the very necessity of such a slightly dishonest tactic indicates the difference between Nishina and Bohr.[140]

We can also say the same thing about Yukawa's group in Osaka, as the scene of after lunch games in the "Kikuchi Dining Hall" suggests. The group leaders played a different game, in a different manner, at the end of the table, without joining their disciples. It was a clear indication of the fact that they were not equal to other group members.[141]

Obviously, there were many other personal differences between Bohr and Nishina. Other than relative lack of humor on Nishina's side, he was not such a Socratic figure as Bohr. Nishina did not indulge in philosophizing. Nor did he converse with his students as much as Bohr did. As the construction of the cyclotron went on, Nishina was so occupied with the activities outside the institute, mostly to raise funds for the cyclotrons, that he did not have much time to talk with many group members, of which number eventually exceeded one hundred.[142]

Second, the relation between the Osaka group and Riken, or rather Yukawa Hideki, cannot be understood if the skills necessary to quantum theorists dubbed as the "Copenhagen spirit," could only be transmitted through personal contacts. We have already seen that Yukawa was not a person like Nishina or Bohr, who would manage an organized research group. It was Sakata, who created

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140. Tomonaga Sin-itiro and others, "Nishina sensei wo shinonde," 69-70.

141. See above.

142. Rikagaku Kenkyûjo, *Rikagaku Kenkyûjo annnai* (Tokyo: Rikagaku Kenkyûjo, 1943). Also see Chapter 6.

the Osaka group of theoretical physicists. The "Copenhagen spirit" on the one hand, explains the rise of the Osaka group well. It fails, however, to account for Yukawa, who had only little contact with Nishina. Yukawa attended Nishina's intensive lecture course on quantum mechanics in 1929, asked questions to him after the lectures, and had a dinner together. Yukawa presented his theory at a conference, which Nishina commented on encouragingly. These occasions were important for Yukawa, who considered Nishina as his mentor. Yet, it is hard to believe that Yukawa could know the "Copenhagen spirit" through these occasions. More definitive evidence is the conversation that took place in 1967 (15 years after he wrote about the "Copenhagen spirit" in his autobiography "Tabibito" as quoted above), between Yukawa, Tomonaga, and their college friend Tamura Matsuhei. Yukawa asked Tomonaga what the "Copenhagen spirit" was: "I have been wanting to ask you, Tomonaga-san. Until today, I have never understood what the 'Copenhagen spirit' is."[143] It suggests that Yukawa was outside the tradition of the Copenhagen school, from Bohr to Nishina to Tomonaga. Yet, Yukawa was able to produce his theory of mesons, the first important quantum mechanical work in Japan. This implies that there were already conditions in Japan that allowed someone to become a successful theoretical physicist without any contact with the "Copenhagen spirit."

Third, Nishina might not have been the only person responsible for the atmosphere of his group. There were other physicists, especially young physicists who came back from Europe in the early 1930s who greatly contributed to the creation of a certain atmosphere. In particular, Fujioka Yoshio, who studied in Leipzig from 1929 to 1932 with Heisenberg, and Kikuchi Seishi, 1929 to 1931,

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143. Tamura Matsuhei, Tomonaga Sin-itiro, and Yukawa Hideki, "Nihon ni okeru soryûshiron no reimei," 394.

with Born and Heisenberg. Tomonaga testifies that these two young physicists were crucial in shaping the atmosphere of the colloquia in Riken.[144] In particular, Fujioka, in Heisenberg's group, was impressed with the way collaboration was carried out there. Around 1930, Fujioka wrote to Nagaoka about the theoretical physics seminar at the University of Leipzig:

> Discussions at the seminar are often inspiring. The most important thing about this gathering of the first rate scientists is its scholarly atmosphere. . . . Discussion and research are carried out very smoothly and naturally, which creates a certain atmosphere. It is very enviable, and something that we should lean from them.[145]

When Fujioka came back to Japan, he organized a symposium format presentation and discussion at the semi-annual conference at Riken, in an attempt to emulate the *Leipziger Vorträge* under Heisenberg. Tomonaga remembers that Kikuchi and Fujioka were sometimes too forthright with old professors. Fujioka criticized Kimura Masamichi, a professor of Kyoto University and authority in spectroscopy. Kikuchi also made a harsh comment on the talk by Honda Kôtarô, a legendary experimental physicist famous for his metallurgical studies.[146] Kikuchi played an important role in creating a research environment when he moved to Osaka, as we have seen above. Such attitudes of young physicists apparently had roots in the rebellious student cultures discussed in Chapter 3.

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144. Tomonaga Sin-itiro, "Keikaku onchi: Fujioka-san no omoide," in *Butsurigaku to watashi*, vol. 2 of *Butsurigaku to watashi* (Tokyo: Misuzu Shobô, 1982), 278-79.

145. Tomonaga Sin-itiro, "Ryôshirikigaku to watashi," in *Nihon no butsurigakushi*, Nihon Butsurigakkai (Tokyo: Tôkai Daigaku Shuppankai, 1978), 649.

146. Tomonaga Sin-itiro, "Fujioka-san no omoide," 278-79.

Fourth, the general situation of physics in the late 1920s also prepared for the introduction of quantum mechanics. Young rebellious students of theoretical physics were shifting interests to quantum mechanics, and with advanced mathematical training, were ready to move ahead given the right leadership. Morever, there was already a favorable institutional setting at Riken for the development of theoretical physics. Riken itself had a freer atmosphere before Nishina. The case of Fujioka and Kikuchi suggests that Riken already had the conditions to allow something like the "Copenhagen" spirit, even before Nishina created his school there. Tomonaga, for example, points out that Riken's free atmosphere was not limited to Nishina's group.

Finally, not all the Japanese physicists were so sympathetic to Bohr. Physicists around Yukawa, especially Taketani Mituo developed a methodology of physics, which was totally alien to Bohr's philosophical tendencies. Being Marxist, Taketani regarded Bohr's philosophy as a kind of "bourgeois Machian idealism," while attributing the success of Yukawa's theory and the Yukawa group to its realistic attitude (such as the prediction of a new particle).[147]

7. Conclusion: Revisiting the Metaphor of "Spirit"

While physicists in Niels Bohr's group and Japanese physicists under Nishina's leadership considered themselves imbued with the "Copenhagen spirit," they had both similarities and differences. As for the collective working style, they both shared the ideal of collaboration between the members of their group, between theorists and experimentalists, and between scientists in different disciplines. Nishina's group, however, did not realized much international

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147. See Chapter 7.

collaboration, while at Bohr's institute internationalism was an essential part of the "Copenhagen spirit" in Copenhagen, both in theory and practice.

Both groups operated under a single male leader. Leadership was certainly present in the both groups and played a crucial role. Although never imperious, Bohr was the boss of the institute, and scientists were under his leadership.[148] Both Bohr and Nishina can be seen as paternal figures to younger physicists of their groups. While Bohr's management of the group was subtler, Nishina was much more patriarchal, reflecting Japan's more autocratic society.

Playfulness was an integral part of those groups, but somewhat in a different way. Physicists in both groups enjoyed doing physics, and other related group activities. Nevertheless, the leaders were different from each other. Niels Bohr participated eagerly in youthful whimsy, sometimes surpassing his younger colleagues in this respect. Nishina was much more sober and restraint, while his disciples matched the physicists in Copenhagen.

The place of philosophical consideration was strikingly different. While philosophical discussion (in particular on quantum mechanics) took a very important place in the Copenhagen group philosophizing did not attract much interests from Nishina's students.

In this connection, the philosophy of quantum mechanics itself, in particular, Bohr's idea of complementarity, or any other part of the "Copenhagen interpretation" of quantum mechanics, did not constitute the "Copenhagen spirit." In Bohr's group, discussion over interpretive and philosophical questions on quantum mechanics was carried out with the style discussed here: collaboration, *playful curiosity*, Bohr's leadership, and so on, but the specific interpretation of

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148. For an analysis of Bohr's leadership, see: Beller, "Jocular Commemorations," 254-57.

quantum mechanics cannot be considered as synonymous to the "Copenhagen spirit." In Nishina's group, such discussion did not exist. The standard interpretation of quantum mechanics was simply taken for granted.

The place of correspondence principle is similar to the "Copenhagen spirit," although I did not discuss it in details here. The correspondence principle was a guiding principle before the advent of quantum mechanics in Bohr's group. This is therefore one of the foci of the group discussion and collaborative works at Bohr's institute. The discussion on this was conducted with, so to speak, the "Copenhagen spirit," but the correspondence principle itself should be differentiated. In Japan, the consideration on the correspondence principle did not happen. When the Japanese group became active, quantum mechanics was already formulated without the correspondence principle.

The style, method, and values that Japanese physicists perceived in the "Copenhagen spirit" were certainly instrumental in creating a fairly successful research school of theoretical physics in Japan, and driving Japanese theoretical physicists to new problems and new fields. Yet, the "Copenhagen spirit" was not the only factor that enabled the creation of a productive research tradition of theoretical physics in Japan. It was one of a few major factors. Nor was the "Copenhagen spirit" brought by Nishina exactly the same as the original one.

The metaphor of the spirit, therefore, does not work in this case. Behind this metaphor seems to be our tendency to reify intellectual activities. Intellectual activity is, however, not something that one can carry and move around. It is an event, or a phenomenon, rather than an entity.

Instead of talking about transplantation of the "spirit," I propose to see the dissemination of quantum mechanics as a "resonance," which occurred through various kinds of mediation, such as human (Nishina) or material (physics journals) ones. This model implies three things. First, it involves a mediator. In the case I study here, where the geographical and cultural distance is vast, it seems more reasonable to set up a mediator between two parts. Second, the process of translation across cultures transformed the practice, incorporating the new into the old. Practice (and therefore knowledge) is not a stable entity that one can carry around. It is rather a process, and transmission of quantum mechanics from Europe to Japan was a resonance of two events, mediated on multiple levels, including formal mathematical theories, cultural values, skills, techniques, and meanings. Third, such mediation does not have to take place on all the levels, and the mediation does not imply a global or a total relocation of contexts. Tuning forks do not need to be identical for them to resonate. To resonate to the progress of theoretical physics, Yukawa did not have to know the "Copenhagen spirit."

If Erwin von Baelz felt that many Japanese in the early 20th century regarded science as if it were a "machine which can turn out so much work every year, and therefore as a machine which can without further ado be transported from the West to any other part of the world there to continue its labours,"[149] he probably had good reasons to think so. Yet, it was a mistake on his part to think that there was such a thing as the "spirit" of science, which could simply be "implanted" by Western practitioners of science. Even in this relatively small scale of knowledge transfer, the situation was more than simply transplanting the "Copenhagen spirit." As for the introduction of Western science to Japan as a whole, the story would have been even more complex than transplanting the spirit.

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149. Baelz, *Awakening Japan*, 149.

Chapter 6
Rebuilding the House, Rebuilding Physics:
Norms in Nishina Yoshio's Scientific Activities and Familial Life

1. Introduction: Nishina Yoshio's Homecoming, 1928-1929

When Nishina returned to Japan, it was probably with more regret than satisfaction and more anxiety than hope. When he left Japan at the age of thirty, he did not plan for such an lengthy absence. Nor did he expect to join Niels Bohr's group in Copenhagen, an enviable position for all aspiring young physicists. Certainly, his accomplishments abroad were not unimportant. However, they did not satisfy Nishina, who could not help comparing his works with those by his colleagues in Copenhagen, the ablest physicists of all time, such as Werner Heisenberg, Wolfgang Pauli, and Paul Dirac. Just before leaving Europe, Nishina wrote to Bohr with a mixture of gratitude and self-incrimination:

> It is just a fortnight ago since I left Copenhagen, from which my existence is getting at a greater and greater distance both in space and time. The further I stand from it, the better I see things in their proper proportion, and I feel a great thankfulness to you for letting me stay in your Institute for so many interesting years. Owing to my inability I have not accomplished anything valuable in physics during this long stay. The more I think of it, the more grateful I am to you for my stay which has only been possible through your kindness towards me. . . . Now it is the time to say good-bye to Europe where I spent fruitless seven and a half year, which is not a small part of a man's life[1]

This letter addressed to Bohr was unlikely to be a show of Nishina's false modesty. After spending more than five years in Copenhagen, Nishina must have

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1. Yoshio Nishina, A letter to Niels Bohr, October 31, 1928 in *Y. Nishina's Letters to N. Bohr, G. Hevesy and Others, 1923-1928*, NKZ Publication (Tokyo: Nishina

been aware that Bohr would hardly be pleased by such modesty. On the contrary, Nishina might be comparing himself with those heroes in modern physics such as Heisenberg or Dirac. Certainly, Nishina's work, although significant, did not rank with the kind of work by Heisenberg, Dirac, Pauli and others, which laid foundations for further developments in physics. More importantly, I argue, his achievement was not enough to bring him the fame visible to his family and relatives.

The letter alarmed Niels Bohr, who replied to Nishina assuring him that he "[could] look back on much fruitful work based from the first to the last so largely on your own initiative." Bohr enclosed a letter of recommendation for him.

In Japan, what waited him was not relief at familiar sights, but the strangeness of the culture that differed so much from the one in which he spent happy seven and a half years. Moreover, Tokyo was no longer the same as what he had known in his student years. He wrote to George Hevesy, an eminent Hungarian chemist, with whom Nishina had worked closely in Copenhagen, "Tokio has changed very much since the great earthquake of 1923, so much in some places that I could not recognize them at all."[2]

In the personal sphere, Nishina experienced a more radical reverse cultural shock. Immediately after his return to Japan, his life went through a fundamental change. He married. Or, as he put it, he "had to marry." Following the advice of his relatives and friends, he decided to wed Nawa Mie, a sister of Nishina's close friend, Nawa Takeshi. Takeshi was a navy officer and graduate of the electrical engineering department who would head the Navy's electromagnetic weapons

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KInen Zaida, 1981), 23.

2. Yoshio Nishina, A letter to George Hevesy on April 1, 1929 in *Supplement to the Publications*, NKZ Publication (Tokyo: Nishina Kinen Zaidan, 1986), 6-7.

research. The wedding took place on February 28, 1929, two months after he landed in Yokohama.[3]

The problem was that Nishina hardly knew Nawa Mie. Complaining about his marriage, he wrote to Bohr a few days before the wedding:

> This is surely an old fashioned marriage and now a days there are not many who do such an inconsiderate thing even in Japan. I have, however, sufficient reasons to do this; you will perhaps know about it when you see me next time here in Japan. Anyhow this is a dangerous[sic] experiment I have ever had in my life and it is curious enough that everybody seems to take it as a matter of course and nobody seems to realize it to be a reckless adventure. There are some things which they do often way round in Japan than in Europe, for example, they read from right to left. I think the old fashioned marriage is another example. "Love" precedes "marriage" in Copenhagen, and it is expected to be reversed in my case.[4]

Nishina saw two different sets of appropriate ways of life, one in Japan, the other in Europe. In the case of marriage, they conflicted. The unwritten code of conduct in Japan that Nishina felt obliged to follow demanded that he pursue an arranged marriage—at the same time he was very much aware that in the way of life he had grown accustomed to in Europe, such behavior was unimaginable. Having perceived this conflict, Nishina decided to follow the Japanese way because of mysterious "sufficient reasons" although he regarded such an act as reckless and inconsiderate. This conflict that Nishina perceived in his personal life seems to suggest conflicts in his scientific career. On the one hand, Nishina should have perceived a certain set of acceptable conducts in Japan, even in his scientific activities, in particular in relation to the people outside the laboratory, such as his family. On the other, Nishina as a scientist had a set of standard norms, which he became used to during his long stay in Europe.

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3. Ibid.

4. Yoshio Nishina, A letter to Niels Bohr on February 19, 1929, Niels Bohr Archive (Copenhagen).

The problem that Nishina faced seems to be well-addressed by what sociologists call "norms." Robin M. Williams, Jr., and Jack P. Gibbs define "norm" in its entry in *International Encyclopedia of the Social Sciences*:

> A norm is a rule, standard, or patter for action (from the Latin norma, a carpenter's square or rule). Special norms are rules for conduct. The norms are the standards by reference to which behavior is judged and approved or disapproved. A norm in this sense is not a statistical average of actual behavior but rather a cultural (shared) definition of desirable behavior."[5]

Generally following this definition, I use the word "norm" to refer to the tacit or explicit rules prescribing what conduct or thing is appropriate or inappropriate in a certain specific situation. In addition, as a way of shorthand, I also use "norm" as such an appropriate conduct or an appropriate item to be employed. A norm is, for example, a rule that one should wear black attire at funeral. In this case, black attire at funeral is also a norm. The latter usage has merit, because a norm as a rule sometimes exists only in a Platonic sense.

I cannot emphasize enough that a "norm" is a prescriptive ideal, not a statistical average of the way people behave. Norms are not always followed. A "norm" is not necessarily normal. An example of the way I do not use this word appears in the title of an essay by Stephen Jay Gould's "Morton's Ranking of Races by Cranial Capacity: Unconscious Manipulation of Data May Be a Scientific Norm." In this paper, Gould shows that Samuel George Morton manipulated the statistical data unconsciously, probably biased by his racial preconception. This unconscious manipulation presumably occurred in spite of his conscious belief about what would be the appropriate statistical treatment.[6] Apparently, Gould is

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5. Robin M. Williams and Jack P. Gibbs, "Norms," in International Encyclopedia of the Social Sciences, vol. 11, edited by David D. Sills (New York: The Macmillan Company & The Free Press, 1968), 204.

using the term "norm" as a normal and common conduct. This is a clear example of the usage of "norm" that I do not employ here.

A norm concerns what is appropriate, not what really is. It is about the rules that justify a certain behavior, not the true motive of a certain behavior. In this sense, this work is about pretexts, excuses, and even hypocrisy: rather than what historical actors really thought and felt, I focus on what they thought appropriate in relation to the social groups to which they belonged.

A study of norms would not be useful to explain behavior of historical figures or to depict their true motives and real feelings. For these purposes, one would need to know psychology of historical actors. Psychohistory, however, invokes several serious methodological problems. We do not always know, for example, the psychological states of historical actors. They are not always documented. Even if they are, historians do not always know whether they can trust historical actors' reports of their psychological states. In addition, it is often difficult to connect a psychological state to a certain action. Finally, unless we can believe in a certain psychological theory (such as Freudian psychology), there is no way to discuss unconsciousness. By focusing on norms, I am trying to evade these problems.

Norms have no explanatory power because they can be followed or violated. My interest lies not in explaining the actions of historical actors, but in excavating their cultures that lie deep below the visible phenomena of their actions. Norms, incorporated into such cultures, are useful in analyzing and characterizing those cultures of scientists. Whereas the psychology of an individual scientist, even

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6. Stephen Jay Gould, "Morton's Ranking of Races by Cranial Capacity: Unconscious Manipulation of Data May Be a Scientific Norm," *Science* 200 (1978): 503-09.

if we can meaningfully talk about it, reveals only the personal characteristics of this individual, norms indicate traits of the group where they are shared.

This study shows how norms in and outside of science interact. The system of scientific norms in my picture is not necessarily self-contained, incommensurable to other systems, and independent of the outside world. Scientists as a group are not an isolated tribe with their own esoteric customs and unique norms, distinguishable from ordinary (whatever "ordinary" means) people. I consider scientific norms as something closely linked to (if not the same as) norms in other spheres of activities, norms in personal spheres or in the society at large, and I try to study how they are connected.

A study on normativity in and outside science is hardly novel. For one, there is Robert Merton's classical work, *Science, Technology & Society in Seventeenth Century England,* which attempts to tie the "ethos" of Puritanism with the rise of "new science" in the 17th century England (and possibly other European countries).[7] An important difference, however, is the scale. The classical studies that attempt to connect normativity with science aim to cover a geographically and culturally large area and large number of people with a certain umbrella concept (such as Puritanism), and thus often fail to capture details. My approach here is much more modest, attempting to see a set of local norms in an individual scientist in his relation to groups to which he belonged, and to connect those norms to his scientific activities.

Merton's study was, of course, not the last word on normative aspects of science. Rather, any sociological study of science almost always involves examination of normative aspects of science. One of the central concerns of post-

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7. Robert K. Merton, *Science, Technology and Society in Seventeenth Century England* (New York: H. Fertig, 1970).

structuralist sociologists like Pierre Bourdieu was to link human agents and their practices with objective social structures, without falling prey to the danger of subjectivism or psychologism.[8] In this relation, Bourdieu proposed the notion of *habitus,* a "system of organic and mental dispositions and of unconscious schemes of thought, perception and action," which "allows the generation . . . of all thoughts, all perceptions and actions in conformity with objective regularities."[9] In the sense that *habitus* is a reflection of the objective social structures and regulates production and improvisation of practices, it has a close relation to normative aspects of human behaviors. As the norms that I am going to discuss below, *habitus*, as conceived by Bourdieu, is not just a set of rules that determine agents' actions.[10]

For a historian, however, it seems to be more productive to deal with concerete historical acts or patterns than to try to excavate the governing principles of human actions that presumably lie deep down in the collective unconsciousness of a social group. In this regard, for example, it might be useful to mention Thomas Kuhn's notion of "examplar," which could be much more useful (but seems to be used much less frequently) than his famous "paradigm."[11] Like "examplars," norms are fairly concrete actions, life patterns, and career goals.

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8. Pierre Bourdieu and Jean-Claude Passeron, "Sociology and Philosophy in France Since 1945: Death and Resurrection of a Philosophy Without Subject," *Social Research* 34 (1967): 162-212.

9. Pierre Bourdieu, "Structuralism and Theory of Sociological Knowledge," *Social Research* 35 (1968): 705-06.

10. Pierre Bourdieu, *Outline of a Theory of Practice*, translated by Richard Nice (Cambridge: Cambridge University Press, 1977), 72-78.

11. Thomas Kuhn, "Postscript," in *Structure of Scientific Revolutions*, 2nd (Chicago: Unversity of Chicago Press, 1970), 174-210.

However, "examplars" are individual scientific works, whereas norms are usually set by several such "examplars."[12]

The problem of avoiding both subjectivism and objectivims leads to another concern regarding the use of the term "norm" for an individual. Sociologists contend that norms are by definition sociological and therefore require at least two persons to be discussed.[13] This problem, however, seems to be only apparent. Whereas I focus my attention on Nishina, I consider that his norms developed in a close tie with the groups to which he belonged (in particular, his family). I will discuss not Nishina's personal peculiarities, but what Nishina perceived as the social norms of the groups to which he belonged.[14]

The focus of this chapter is the relation between perceived appropriate conducts in Nishina's scientific activities and in his private life. I show that there was a translation of the native and local norms into scientific norms. I argue that norms in Nishina's scientific activities fit well into the native or local norms of the Nishinas, and that Nishina was able to substitute the latter with the former through nationalism, which made his scientific activity acceptable. I do not claim that this was Nishina's conscious strategy; rather, I present this argument as a valid equation in the calculation of norms. The present work does not show what Nishina actually thought. Nor does it claim that Nishina's scientific activity was "influenced" by his native or local norms. In particular, my account does not explain Nishina's behavior in a strong sense.

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12. In addition, my scope here is obviously not limited to scientific practices narrowly conceived.

13. For example, see: Williams and Gibbs, "Norms," 205.

14. I thank Naomi Oreskes for raising this issue.

The conclusion of this chapter implies that there were certain native roots in the introduction of the new science, quantum physics, into Japan. In the previous chapter, I have described Nishina Yoshio's role as the organizer of modern physics in Japan. I discussed what was the "Copenhagen spirit," which Nishina presumably "brought" to Japan. In this chapter, I look at Nishina's organizing act in science in a completely different way. Whereas the previous chapter dealt with the aspects of scientific cultures and methodology, this chapter discusses the aspect of values and norms across the boundary between science and non-science. Whereas the previous chapter focused on what was "brought in" (and what was not), in this chapter emphasizes what native elements Nishina might have incorporated in his practices. The beginning of quantum physics research in Japan has at least one root in the familial cultures of a rural society and political cultures of Japan.

I start my narrative with Nishina Yoshio's early years from 1890 to 1920. Then, the story jumps to Nishina Yoshio's scientific activities in the 1930s. Finally, I examine the period in-between, seeking the link that connects these two.

2. The Nishinas

In a letter to George Hevesy written in 1929, Nishina mentioned his "accumulated duties" for his family: "First of all I have had to deal with a good deal of family affairs which have accumulated during last eight years and the duty of which I have neglected to do. There is an endless chain to follow."[15] Nishina did not explain in detail these "family affairs," but a glance at Nishina's upbringing indicates his deep entanglement in the Nishina family, especially his close relation

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15. Nishina, *Supplement to the Publications*, 6.

with his mother and brothers.[16]

Before an analysis of the above-mentioned norms, an account of Nishina Yoshio's early life and his birthplace is in order. Nishina Yoshio was born in 1890 in a hamlet called Hamanaka. Part of Shinjô Village (within today's Satoshô Village) in Okayama Prefecture, in Nishina's time Hamanaka contained about 75 households (Satoshô as a whole had 1044 households).[17] Nishina Yoshio was the eighth child of a relatively affluent farmer's family. He spent his childhood in this village, until he moved to a middle school in Okayama at the age of 14. Okayama Prefecture is located along the Setonaikai See (Japan's inner sea) between Kobe and Hiroshima in the middle western region of Japan's mainland. It is the sunniest prefecture in Japan, with the fewest rainy days in a year. Satoshô forms the western end of the prefecture, near Hiroshima Prefecture.

The Nishinas were a distinguished family in the area, as I will discuss later. Nishina's grandfather, Arimoto, and an uncle, Arihito, were employed by the local fief Aoki, and given samurai status. The Nishinas, however, returned their samurai status at the Meiji Restoration, and their names were officially registered as commoners. Nishina's father, Arimasa, the fourth son of Arimoto, inherited part of the farming and salt-making fields (See Fig. 6.1 for the family tree of the Nishina clan).

Arimoto had three houses and four sons. His eldest son inherited the "head house" of the Nishinas (*Nishina honke*, literally the Main House). The second son Arihito established a branch of the Nishina clan called *Nakayashiki-ke* (the Middle House). The third son was adopted by the Abe clan in the neighboring village and

16. Here, however, I will not write much about his mother.

17. This statistics is from 1881. The population of Satoshô did not change much through the Meiji and Taishô Eras. See, Oka Michio, *Satoshô son shi* (Satosho: Oka Shôkosai Zôhan, 1927), 37-38.

took on the new name Abe Kengo. The fourth son, Arimasa, established another branch, *Nishina Motoyashiki-ke*, called the "Original" House of Nishina because the house that Arimasa inherited was the one that Arimoto first built and occupied.[18] Although the Nishina brothers officially divided the family properties in 1902,[19] they shared the family business of salt-making.

Yoshio's father Arimasa wed Tsune, a daughter of the headman of the distant town of Takafuta, in Hiroshima.[20] He died when Yoshio was sixteen years old. His elder brothers, especially the eldest brother Teisaku, who were twenty older than Yoshio, became Yoshio's father figures. Teisaku inherited the house and the family business of salt-making and farming. Empei, an inventor, lived primarily in Tokyo. Yasuo, the third son of Arimasa, lived in Takayama in Gifu Prefecture. The youngest brother, Masamichi, was born three years after Yoshio but died young in 1919 when he was studying at a school in Kumamoto, Kyushu.[21]

The eldest of Nishina's four sisters, Kiyo, married her cousin, Nishina Tôtarô of the Nakayashiki-ke branch of the Nishinas. The second sister, Riku, was a local celebrity whose biography appears in the official history of the Satoshô Village. She was known as a *waka* poet, but more importantly according to the

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18. Nishina Akira, "Nishina Hakase no omoide," *Takahashigawa*, no. 32 (August 1975): 4-19.

19. "Nishina honbetsu sanke zaisan bunri nitsuki keiyaku," Nishina Kaikan (1902).

20. Takafuta is a post station of the Saijô Way in the eastern part of today's Hiroshima Prefecture. See: Inoue Izumi, "Nishina Yoshio hakase wo hagukunda fûdo Satoshôchô," *Isotope News*, October 2001, 23.

21. Nishina Kajio writes that Masamichi was studying at the Fifth Higher School in Kumamoto, whereas Nishina Akira writes that he was studying at the Kumamoto Higher Technical School. See: Nishina Kajio, "Oji Nishina Yoshio no omoide," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, edited by Hidehiko Tamaki and Hiroshi Ezawa (Tokyo: Misuzu Shobo, 1991), 189; Nishina Akira, "Nishina Hakase no omoide," 9.

values of the time, she was a wise mother and a good wife. Marrying Nishina Katsumi of the head family of the Nishinas, a cousin once removed, she raised three sons, two of whom earned doctorates. One became a metallurgist and worked with Nishina Yoshio. The other became a medical doctor and worked at a hospital of the Manchurian Railroad Company.[22] The third sister, Toyo, married Abe Tarô, again, a cousin, whose father inherited the Abe clan. The youngest sister, Toku, married into the Uchidas, the family of a successful industrialist in the nearby city of Kurashiki. Very close to Yoshio, she left extensive correspondence with him. Later, the Uchida family supported Nishina Yoshio's study abroad.[23]

Nishina Yoshio entered the elementary school (*jinjô shôgakkô*) in the hamlet of Shinjô at the age of 7. The school taught Japanese, arithmetic, and ethics, in all of which Nishina earned A's.[24] Upon his graduation in 1901, he advanced to a higher elementary school (*kôtô shôgakkô*) in Shinjô, and when the school was closed in 1904, he was transferred to a higher elementary school in Kamogata, from which he graduated in 1905 with an award from the prefectural governor for distinguished achievements. This was shortly after a new educational provision was implemented allowing one to skip the last two years of higher elementary school to advance to a middle school. Still, many pupils finished the higher elementary school before entering a middle school.[25]

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22. Nishina Akira, "Nishina Yoshio hakase to watashi," *Okayamaken Ishikaihô*, no. 400 (1963): 22.

23. Information on Nishina's sisters' marriage is based on Nishina Akira, "Nishina Hakase no omoide".

24. Until the end of World War II, Japanese used Chinese calendrical signs (*jukkan* in Japanese, or *tian gan* in Chinese) to indicate grades (and others), which goes: kô, otsu, hei, tei, ... I replace them with English letters.

25. Takeshi Kimura, "Nishina Yoshio," *Sanyô Shimbun Evening Edition*, May 13 to August 30 1960, 44.

In 1905, Nishina was accepted to Okayama Middle School and moved to Okayama City. He spent five years there (later, one was able to enter a higher school after four years at a middle school, but in Nishina's time, five years' schooling was required).[26] Nishina did very well at school again, earning A's in all subjects throughout these five years, except, ironically, physics in his fifth year, when extracurricular activities and his duty as president of the dormitory council (*ryôchô*) kept him too busy to study. His grades, nonetheless, set a record unmatched since the founding of the school. At the recommendation of the principal, the Sixth Higher School in Okayama City accepted Nishina without an entrance examination.[27]

Nishina's years at the Sixth Higher School and later will be detailed in what follows. Here is a chronology of his life. In 191, before the school began in September, Nishina contracted pleurisy and had to take a one-year leave. In September 1914, Nishina entered the Department of Electrical Engineering at Tokyo University. As described in Chapter 4, he specialized in alternating current theory. In the first year, pleurisy prevented him from advancing to the next year. Upon his graduation in 1918, Shibaura Engineering Works (today's Toshiba) offered him a job, which he turned down.[28] Instead, he entered graduate school and became a research student (*kenkyûsei*) of Riken. The rest need not be repeated here.

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26. A notable student in Nishina's time was Uchida Eizô, later Uchida Hyakken, a famous novelist and essayist, one of Natsume Sôseki's disciples. Only in the fifth year of the middle school, his had his prize winning essays published in a literary journal, *Bunshô sekai*, which made him famous throughout the school. Nishina was three years behind Uchida and apparently had no direct contact with him.

27. Kimura, "Nishina Yoshio," 61.

28. Shibaura Engineering Works offered the job, probably because Nishina already worked there, not because Nishina applied for the job.

In what follows, I discuss three norms that appear to have regulated Nishina Yoshio's behavior in relation to his family. The first norm was entrepreneurial success, a norm among the Japanese youth around the turn of the century. Numerous biographies of successful people, in particular famous industrialists such as Andrew Carnegie, or their writings, set this norm among the Japanese youth. The second norm was the career of engineering entrepeneur. In the Nishina clan, success was tied to engineering skills. The third was the norm of restoration of the family fortune, which motivated members of the Nishina clan.

2.1. Going Out into the World

To seek entrepreneurial success was one of the norms that motivated young Nishina Yoshio. This was a prevalent norm among the elite youth in the Meiji Era, and Nishina Yoshio himself stated it explicitly. As Karl Mannheim did, I distinguish "success," which is accompanied by public recognition, from "achievement." A commonly used Japanese term for this notion was: *shusse*, literally to go into the world.[29] Other two frequently used terms were *risshin* and *seikô,* literally meaning "to rise oneself (in the world)" and "to achieve an accomplishment."

The kind of success that I discuss here was not simply making money or attaining a high rank. It is the kind of success tied to social recognition and conformity to the values and norms imposed by society. The tie between success and ethics was already present in the works of Samuel Smiles, in which historical heroes achieve success through virtuous qualities, such as diligence, wisdom, and

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29. In the old usage, it could mean "to go out of the world," which is, however, not relevant here.

abstinence.[30]

The young Nishina Yoshio exhibited the same ethos of self-advancement, but he, at least in the early years, had no specific idea about what he would like to achieve. A letter that Nishina Yoshio wrote to his younger brother, Masamichi, in April, 1910, indicates his earliest conception of success. Nishina had just graduated from the Okayama Middle School and was working hard to prepare for the entrance examination of the Sixth Higher, not yet knowing that he would be exempt from the entrance examination requirement.

The letter was a detailed recipe for success written in a dominantly ethical tone. While Yoshio suggested various strategies for academic (and lifelong) success, some of his suggestions were heavily charged with moral implications. He advised that Masamichi, who was going to be in his fourth year at the middle school, should now work hard, because many questions in the entrance examination of higher schools would be taken from the materials in the third and fourth years. Yoshio recommended steady study habits and advised against cramming, because one would soon forget the materials memorized in haste. Such an act, Nishina warned, would be dishonest tothe teachers, because at the examination students were supposed to show their understanding of the materials. He urged his younger brother to be attentive in the classroom and listen to lectures carefully. "When the climate gets warmer, one tends to fall asleep or lose concentration and pay little attention to the lecture. This way, you will not succeed. (*seikô wa obotsukanashi*). Attention is the most important thing."[31]

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30. Such a notion of success was called "*hinkôshugi*" (literary "ethical behaviorism," which Earl Kinmonth translated as "success ethics." See Earl H. Kinmonth, *The Self-Made Man in Meiji Japanese Thought* (Berkeley: University of California Press, 1981).

Yoshio continued his detailed instructions of how to study. He wrote to his younger brother that it would be useless only to take notes at the lectures. Learning was to memorize and to understand, and lecture notes were just tools for these purposes. Yoshio recommended that Masamichi prepare the material the previous day, listen carefully in the classroom, and review it the next day. In addition, Yoshio suggested, Masamichi should review all the material learned during the week on weekends. He guaranteed that this way one could easily achieve good grades because that was what he did.[32]

Discussing study habits at school, Nishina Yoshio was eyeing more than academic success per se. According to him, the schools would just train one to be able to read books. One must study by oneself by reading books; otherwise there would be no progress. He illustrated this idea of self-teaching with a metaphor:

> Learning at school is like a fledgling's learning from his parents how to fly. Once he learns to fly, he must fly on himself and find food. He must make a great flight in the sky (*ôini yûhi subekinari*).[33]

Yûhi (literally "manly flight") was therefore for Nishina a metaphorical expression of being successful, doing something important and influential in the world.

Reading was important. According to Yoshio, reading was not only an act of "flight" but also a means to make such a "great flight" in the future. "Everyone who acquired fame in the past and present had tremendous ability to read. . . . Famous Benjamin Franklin in the United States and the unparalleled physicist Isaac

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31. Nishina Yoshio, A letter to Nishina Masamichi, April 7, 1910 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 29.

32. Ibid., 31.

33. Ibid.

Newton were both voluminous readers, who bought and read books whenever they had time and money."[34] Yoshio, however, would not recommend all types of books. According to him, reading just novels would be useless. Academic books were fine, but he also recommended books that would improve one's character. The best thing, according to him, was to read biographies of great people.

Yoshio also emphasized the importance of maintaining physical health. According to Yoshio, those who had poor physiques did not have good brains. Even if they did, "they would not achieve an important thing (*daiji wo nasu*) with their brain. Their enterprise would inevitably fail in the middle."[35]

The nineteen-year-old Nishina Yoshio did not know exactly what he want to do in the future. Yet, evidently, it was important for him to succeed. He expressed this goal in vague terms, such as "make a great flight" (*yûhi suru*), "make a great accomplishment" (*daiji wo nasu*), or "be extremely active" (*ôini katsudô suru*). Success was a norm for Nishina Yoshio, one that he tried to share with his brother Masamichi.

Whatever Nishina envisioned, or did not envision, the style of his letter to Masamichi was remarkably similar to the genre of writing at that time, namely writings on the secret of success. Since the late nineteenth century, Japanese youth were exposed to various forms of success ethics, such as the one promoted by Samuel Smiles, as closely documented by Earl Kinmonth.[36] In the case of

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34. Ibid., 33.

35. Nishina Yoshio, A letter to Nishina Masamichi, April 7, 1910, 34. It should be noted that emphasis on physical health was closely tied to nationalism. Being healthy is an expression of readiness for the military service (being unhealthy, at the same time, was a way to evade the compulsory military service). In this particular case, however, it is not clear whether Nishina was aware of such an implication.

36. Kinmonth, *The Self-Made Man*.

Nishina, the notion of success was intimately connected to some moral virtues, such as diligence, discipline, honesty, and attentiveness. Being successful entailed making examples of the lives of past "great people," and reading biographies of those great men, as Smiles recommended in his book. In fact, Nishina left a caligraphic work, probably in his middle schooldays, which says "ten wa mizukara wo tasukuru monowo tasuku," Nakamura Masanao's translation of "Heaven helps those who help themselves," an old maxim that appears on the first page of Smiles' *Self Help.*[37].

In Nishina's time, the notion of success was shifting from the one in the early Meiji period. In 1902, Andrew Carnegie's *The Empire of Business* was translated into Japanese[38] and became a best seller, read mostly by college students, including the future founder of Nissan, Ayukawa Gisuke.[39] The genre of writing about the secrets of business success flourished. Numerous articles of a similar kind were published in various magazines. These articles offered a new definition of success. Previously, *shusse* meant advancement in the government. The country's elite went to the government or a university, and *shusse* was measurable in terms of their rank as higher civil servants. After the Sino-Japanese war, Japanese capitalism began to grow rapidly, and business became one of the

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37. The first edition of Nakamura's translation appeared from 1870 to 1871 from various publishers. One of them is: Samuel Smiles, *Saigoku risshi hen*, translated by Nakamura Masanao (Tokyo: Kariganeya Seikichi, 1871). The original work has also various editions. The first edition was: Samuel Smiles, *Self-Help: With Illustrations of Character and Conduct* (London: Ward, Lock, 1859).

38. Andew Carnegie, *The Empire of Business* (New York: Doubleday, Page, and Co., 1902); Andrew Carnegie, *Jitsugyô no teikoku*, translated by Koike Seiichi (Tokyo: Jitsugyô no Nihon sha, 1902).

39. Takeuchi Yô, *Nihonjin no shusse kan* (Tokyo: Gakubunsha, 1984), 106.

options for elite youth.[40] In this sense, entrepreneurial success was a norm for some Japanese youth in the early 20th century.

As Nishina's vision of success materialized, it turned out to be this kind of success, entrepreneurial success. Just before he graduated from Okayama Middle School, the principal of the middle school asked him about his future plans. Being the best student in the school, from a family with reasonable means, he naturally intended to enter a higher school. Yoshio chose the Sixth Higher School instead of the most prestigious First Higher School in Tokyo, probably partly because the Sixth Higher School was located in nearby Okayama City, partly because he wanted to avoid decadent and distracting metropolitan life. Nishina also had to choose his prospective major. Like other higher schools, the Sixth Higher was structured so that a student could major in one of five tracks: law, literature, engineering, science, agriculture, or medicine. His choice was either engineering or medicine, meaning that the career of a civil servant, for which learning law would be essential, was not his first choice at this point.[41] Nishina excluded other options, namely, science, literature (humanities), and agriculture, because these would not make him "successful." Science students and literature (humanities) students had considerably lower employment rates, compared with law, engineering, agriculture, or medical students, and had much fewer choices of future professions, virtually limited to teaching jobs.[42] Nishina's choice indicates, therefore, his

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40. Kinmonth, *The Self-Made Man*, 157-9.

41. Nishina Yoshio, A letter to Nishina Teisaku, February 26, 1910 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 19.

42. *Tokyo Teikoku Daigaku Ichiran,* an annual publication of the Imperial University of Tokyo, carries a table of statistics concerning occupations of graduates of each College.

orientation toward non-bureaucratic and non-academic success.[43] Then, he gave up the career of a doctor because he lost his sense of smell, due to a clumsy surgery he had in his childhood to treat his ozena, and he thought that the sense of smell would be essential in medicine. Therefore, he advanced to the engineering track at the higher school.

The atmosphere of the Sixth Higher reflected very much the personality of its president (*kôchô*), Kaneko Sentarô, a retired Army captain, recently promoted from the principal of Kôchi Middle School in Shikoku. He was known for imposing strict discipline and was successful in pacifying the school of his former post, which had been plagued with student disturbances. During his tenure as president of the Sixth Higher from 1910 to 1918, the school, according to the official history of the Six Higher's dormitory, had become "united," "very well-organized," and "standardized."[44] Not surprisingly, Kaneko seems to have introduced a militaristic culture into the school. He publicly declared that "Sixth Higher School does not aim to produce a scholar or a genius. Its goal is to make men who can endure hardship." Ironically, as we have seen in Chapter 3, Kaneko later became the president of the Third Higher, where students disliked him and ultimately drove him to a discharge with a massive student strike in 1922. Tomonaga and Yukawa entered the Third Higher School the next year and, liberated from Kaneko's strict discipline, enjoyed the Third Higher lief. Kaneko's strict approach to education, however, fit well in the Sixth Higher school. As the new president imposed a stricter discipline, the campus was beautified, the garden

43. As for the importance of engineering in the Nishinas, see the next section.

44. Dairoku Kôtôgakkô seitoryô, *Rikuryô ryô shi* (Okayama: Dairoku Kôtôgakko seitoryô, 1925), 147.

was well-groomed, and an atmosphere of Spartan simplicity and fortitude was formed in the school, which some perceived as the "Sixth Higher spirit."[45]

What counted as the "Sixth Higher spirit" was, in fact, a matter of intensive discussion. In 1910, Ikeda Takuichi, a third-year student, took pride in the fact that the Sixth Higher school spirit was not simple enough to capture in a word, whereas the school sprits of its rivals, the First Higher and the Third Higher, were no more than barbarism or liberalism. He claimed that the Sixth Higher spirit consisted of four elements: love of school, solidarity, fortitude, and prudence.[46]

An incident that occurred while Nishina was at the Sixth Higher ignited an even more serious discussion of the Sixth Higher spirit, and ultimately induced a self-disciplining. In May 1915, an article in Osaka Asahi Newspaper reported on the deteriorating morality of the youth in Okayama, such as those enrolled in Okayama First Middle School, Okayama Medical School, and the Sixth Higher. The article reported that some youth were even breaking the laws, and that presently more Sixth Higher students than Okayama Med students troubled the police.[47] The newspaper article enraged students of the Sixth Higher, who took pride in their disciplined behavior. Residents of the dormitory were especially indignant and gathered to discuss the issue until midnight. Some residents wept over this insult. As a consequence, the student council (*Kôyûkai*) convened an all-student rally, where Nishina Yoshio read the declaration of their resolution. An approximate[48] translation of this resolution is:

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45. Ibid.

46. Tanaka Tamito and Morita Yoshiaki, *Rikuryô gaishi*, Kyûsei gakko monogatari (Tokyo: Zaikai hyôronsha, 1965), 514-15.

47. Quoted in Dairoku Kôtôgakkô seitoryô, *Rikuryô ryô shi*, 182.

> The recent death of the emperor saddened the world. It was unexpected that in such a time a slander would defame our Sixth Higher. We, who for fifteen years since its establishment have been developing an atmosphere of fortitude inside, and fighting with the decadence outside, consider ourselves as the examples of all the students, and cannot help being enraged by such a libel. Yet, if we reflect, the tide of the day appears to stand against us. The corruption of the outside world is eroding the purity of our sanctuary. Unless we rise now, elevate the morale of all the fellow students, and devise a means to resist the corruption, we will regret in the future. Even if the outside world corrupts, we should resist, rejecting decadence, restraining ourselves, and working hard, so as to complete our learning and in the future to become of use to the country. We all must inspire and caution each other, nourish both our body and mind, develop the atmosphere of simplicity and fortitude, so that we can maintain our sincere school character. Otherwise, what would happen to our glorious past and future developments? Here we declare that all the six hundred students unite in heightening the school discipline and further elevating our sound school spirit.[49]

An obvious indication of loyalty to the emperor and nationalism, this declaration also indicates students' firm determination to impose on themselves very high moral standards, isolating themselves from the outside world, which they perceived as corrupt and decadent. Nishina, even if he did not pen this declaration, had very probably approved its content.

The student culture that Nishina experienced at the Sixth Higher was, therefore, diametrically opposed to that of the young physicists of the late 1920s discussed in Chapter 3. This opposition was both generational (the early 1910s versus the late 1920s) and geographical (schools in a political or cultural centers versus a school in a provincial city). This culture was not meant to produce independent and original thinkers, never mind rebels. It was the place for those who were well-disciplined to follow the established moral codes and contribute to

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48. The original declaration written in archaic style is impossible to translate literally into English.

49. "Kakukumi iinkai hôhoku," *Kôyûkai shi*, no. 39 (June 1914): 139-40.

the good of society. It was a culture accepting of those who would work laboriously, follow rules, put forth their maximum effort, and thereby attempt to achieve a success and to become of use to the country. Nishina Yoshio was in the middle of this Spartan student culture of Japan's province, where samurai-like simplicity and fortitude were valued and loyalty to the state and emperor was unquestioned.

As the day to enter the university approached, Yoshio had to decide precisely what he would do in the future. The Nishina brothers began exchanging correspondence on this subject in February 1913. In his letter of February 20, Teisaku discussed three alternatives: scholar, civil servant, and businessman. He thought Yoshio fit to become a scholar, but "a scholar would not make much income, and would lack the financial basis to be happy."[50] According to Teisaku, Yoshio would not make a good businessman or civil servant. Having rejected all of the three choices, he then brought up the fourth alternative. It was the career of an engineer hired by a large company or mine, which Teisaku considered "something between a civil servant and a businessman" and "close to a scholar" and the best way to succeed in an engineering career.[51]

Soon, the nature of the decision that Nishina Yoshio had to make became apparent. It was a choice between financial or academic interest. In a letter long after Teisaku's, Yasuo advised Yoshio that mining and civil engineering would allow him to earn money, but that mechanical and electrical engineering would be

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50. Nishina Teisaku, A letter to Nishina Yoshio, February 20, 1913 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 85.

51. Ibid., 86.

more interesting academically.[52] Half a year later, Empei corrected Yasuo by writing that electrical, civil, or mining engineering would allow him to become wealthy, but to become a scholar, mechanical engineering would be better.[53]

When Yoshio received Yasuo's long letter of June 1, he had probably already submitted his application for the Department of Electrical Engineering. This letter contradicted the one Yoshio had received previously but probably it determined his choice. In his letter, Yasuo recommended civil engineering and electrical engineering. According to Yasuo, civil engineering would require the ability to manage people. Managing people, Yasuo wrote, would be much more enjoyable than using machines. Contradicting Teisaku, he suggested that Yoshio had a propensity for law, and civil engineering was the closest thing to it in the college of engineering. Yoshio could decide later whether to attain a post in the government or to participate in public enterprises. "The goal is, in any case, to gain fame and fortune," Yasuo wrote, "so you only need to choose the best career to promote yourself."[54] "On the other hand," he mentioned, "if your wish is to become a scholar, electrical engineering would be the most interesting, because it is a new field, leaving a lot of possibility to make new inventions. However, a scholar must be prepared to give up in the matter of money."[55]

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52. Nishina Yasuo, A letter to Nishina Yoshio, October 2, 1913 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 91.

53. Nishina Empei, A letter to Nishina Yoshio, May 14, 1914 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 96-97.

54. Nishina Yasuo, A letter to Nishina Yoshio, May 31, 1914 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 107.

55. Ibid., 108.

Apparently, Yoshio could not give up making money. Yoshio submitted a request on June 14 to the Dean of the College of Engineering that he would like to change from the Department of Electrical Engineering to the Department of Civil Engineering, due to a "family matter."[56] The request was, however, denied, and Yoshio had to enter the Department of Engineering, as we have seen in Chapter 4, but it clearly shows his final decision and his vision of success. His preference was to become a civil engineer, to "manage people," and to make money, rather than to pursue academic interests and his inventions. His decision did not come from his own interest, but from his consideration of the family affairs. Although his brothers did not force Yoshio to pursue a certain career, he decided to choose the most promising career for the sake of his family.[57]

Nishina Yoshio's preference probably remained unchanged in 1918 when he graduated from Tokyo University. Upon his impending graduation, he received a job offer from Shibaura Engineering Works, one of Japan's top manufacturers of electric appliances. Getting a job at a private company after graduation was a natural career pattern for graduates of the Electrical Engineering Department. Among 22 graduates of the Department of Electrical Engineering of the year 1918,

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56. Nishina Yoshio, A letter to Watanabe Wataru, June12, 1914 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 113.

57. I discuss later why he needed to be successful for his family. Nishina Yûichirô, a son of Nishina's, offers a somewhat different observation. According to him, Nishian changed his mind because of a close friend of his at the Sixth Higher, who had entered the Department of Civil Engineering and told Yoshio how much fun he was having in that department. Nishina Yûichirô, however, also admits that restoring the Nishina clan was Yoshio's prime concern, and that he was going to achieve that by becoming an engineer. See: Nishina Yûichirô, "Wazawai wo tenjite fuku tonasu: chicih no kaisô," *Isotope News*, December 1990, 23

ten were known to have obtained positions in a private companies.[58] Nishina, however, wrote to his brother Teisaku that he would like to enter the graduate school. According to Yoshio, there would not be much more development of electric machinery in a job in the private sector. Therefore, he decided to study electrical chemistry in graduate school, which would have much broader application. After a year of graduate study, he planned on taking a "practical job."[59] Even at this point, therefore, Nishina's goal was not success as a scholar in academia, but in the real world of business and enterprise. He figured that entering graduate school would maximize his chances for this kind of success.

For Nishina Yoshio, success was a norm, but he had a specific notion of success. For him, to be successful—to make a "manly flight"—was to be "active in the world." It was a kind of success to be achieved, not within the isolated ivory tower of academia but *within* society . Unlike the young physicists in the 1920s, who were disconnected from society, gave up worldly success, and pursued their personal interest in scientific research, Nishina Yoshio sought success within the given social framework, conforming to conventional values. Nishina was also different from many other contemporary youth who sought bureaucratic success in the government. Catching the tide of rising capitalism, Nishina seems to have envisioned an engineering-based business success outside the government.

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58. According to the year 1919 directory of the Society of Batchelors (Gakushikai: Literary, "Bachelors' Society." At this point, it was virtually an alumni society of Tokyo University and, to a lesser extent, Kyoto University).One had a position at Teishinshô (Ministry of Telecommunication), one (i.e., Nishina) became a graduate student, and four did not report their occupation (possibly they did not have jobs). Others, it appears, did not join Gakushikai.

59. Nishina Yoshio, A letter to Nishina Teisaku, April 8, 1918 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 138-39.

2.2. Engineer-Entrepreneurialism: Success through Technology

There were many ways to succeed, even if not enough for everyone. One way to achieve entrepreneurial success was to launch a business or pursue a career with technological knowledge and skills. I claim that, for the Nishinas, conducting, or even creating a business through engineering skills was an appropriate way to achieve prosperity. Nishina Yoshio had examples in his family: his grandfather Arimoto, his second brother Empei, and his third brother Yasuo. Nishina Yoshio's choice of career shows that he, too, followed this norm.

The notion of creating a new business through engineering was a familiar one to the Nishinas. Efforts to reclaim the shoal in nearby Yorishima and Kasaoka by drainage have been underway since the Edo Era—and still are today. Nishina's birthplace, Hamanaka, which literally means "middle of beach," is now completely landlocked after several land reclamations, which created a large area of rice field. In Nishina's time, water was not very far, and land reclamation was still occuring near Hamanaka (See Fig. 6.2).[60]

Although the Nishinas were not involved in large scale land-reclamation, civil engineering was a forte of this family, especially of Yoshio's grandfather Arimoto. People in Satoshô remember Arimoto as a remarkable person, and the Nishinas considered him as exemplary figure. The official history of the Satoshô village gives a long description of Arimoto's life in its collected biographies section. Teisaku, Nishina's eldest brother, told his nephew Akira that he had been considering the old Arimoto as his example, whereas young people like Akira should make Yoshio their model.[61] The legends about Arimoto, although their

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60. As for the land reclamation in this area, see: *Kasaoka chihô kantakushi* (Kasaoka: Kasaokashi, 1959).

61. Nishina Akira, "Nishina Yoshio hakase to watashi," 23.

veracity is doubtful, set a moral example for the Nishinas of Teisaku's generation.

Nishina Arimoto was born in 1795.[62] In his youth, he learned *waka* poetry and Confucianism at Keigyokan, a private school in the nearby city Kasaoka, run by local scholar Odera Yûen. Arimoto became the headman of the village at the age of 38. He contributed to the area with his civil engineering skills[63] by repairing embankments, constructing debris barriers, and creating agricultural reservoirs at his own cost. Hamanaka and neighboring areas were an enclave of the Aoki clan, for whom mainland was located near Osaka. Aoki Shigeyoshi, the lord of the clan, impressed and pleased by Arimoto's achievements, decided to place this enclave under Arimoto's rule, giving him samurai status in 1842.[64] Hence, Arimoto was called "magistrate" (*daikan*) of Hamanaka.[65]

The legend of this local hero does not end here. To the south of Hamanaka was a village called Yorishima. Located between the sea and hills, the village had little space for rice farming and therefore was very poor. Believing that salt-making would make the village prosper, the village headman asked Arimoto, whose civil engineering skills were so highly reputed, to reclaim the land in the sea off the coast of Yorishima village and create a salt-field. Arimoto agreed to help.[66]

As the construction of the salt-field proceeded, however, two villagers claimed ownership of the land. They insisted the land belonged to them because they had thrown stones in the area before Arimoto. Yorishima belonging to

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62. With the Japanse old era, Kansei 6.

63. Oka Michio, *Satoshô son shi*, 176.

64. Tenpô 13.

65. Kimura, "Nishina Yoshio," 27.

66. Ibid.

another feudal lord (the Ikeda clan of the Kamogata fief), the central government in Edo[67] ruled that the matter should be settled between the Nishinas and the Kamogata fief. The Ikeda clan proposed acceptance of Arimoto's claim if he would finish the construction of the salt-field in twenty days. To avoid lengthy litigation, Arimoto accepted their proposal. He then hired workers from nearby villages, introduced night shifts, and personally directed the workers in the construction site. Villagers in Yorishima enthusiastically collaborated, hoping the salt making business would elevate the village fortune. Arimoto managed to finish the construction by the deadline. With other salt-fields constructed after his, salt made in Yorishima became a national brand. Villagers became happy, Yorishima prosperous, and the Nishinas even richer.[68]

In this family legend, therefore, Arimoto was truly a hero who fought and vanquished the villains and brought happiness and prosperity to the locals. The weapon, moreover, that he wielded against his enemies was his skill in civil engineering.

Creation of new business enterprises did not necessarily involve modification of the landscape. Introduction of new technology allowed inventors to launch venture businesses and engineers to make areers in such a venture enterprise. Two of Nishina's brothers set examples of such careers.

Nishina Yoshio's second brother, Empei, born in 1873, became a well-known inventor. Apparently, he had a very good friend in the Yomiuri Shimbun Newspaper, one of Japan's major national papers. On September 30 and October 1, the Yomiuri Newspaper published a short biography of Nishina Empei.[69] The

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67. Today's Tokyo.

68. Kimura, "Nishina Yoshio," 27-28.

article, entitled "Assiduity of a Great Inventor," depicts the first half of Nishina Empei's life as a success story of an inventor who rose from abject poverty to become a "great inventor," overcoming numerous difficulties. Like the Nishina Arimoto legends, the accuracy of the Yomiuri newspaper articles is, at best, in suspect; I can, for example, easily detect a few chronological errors. It is, nevertheless, of interest to describe the myths made out of Empei's life, since often a myth sets a norm more than a fact.

Existing letters reveal that the young Empei wished to be a naval officer. He came to Tokyo and entered a private middle school. On August 1, 1891, he sat for an entrance examination at the naval academy in Tokyo, but he failed the physical examination because of his bad teeth.[70] Seeing that no academic effort would ensure his an acceptance at the naval academy, he decided to abandon a military career. Instead, he decided to go to Hokkaido as a settler in search of a totally new life.[71] Hokkaido was the northernmost of the four main islands of Japan. Originally inhabited mostly by the Ainu people, a small ethnic group, this large island had been developed by Japan's central government since the Meiji Restoration. In 1893, facing his lack of education, Empei entered the Department of Agricultural Arts (*Nôgei Denshûka*) of Sapporo Agricultural School (*Sapporo Nôgakko*). Sapporo Agricultural School was a prestigious institution of higher education run by the Hokkaido prefectural government, accredited to grant the

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69. "Dai hatsumeika no kushin (jô): Nishina Empei shi no funtôteki seikatsu," *Yomiuri Shimbun*, 30 September 1908, 3; "Dai hatsumeika no kushin (ge): Gendai no mohanteki fujin," *Yomiuri Shimbun*, 1 October 1908, 3.

70. Empei Nishina, A letter to Nishina Arimoto, August 1, 1891, Nishina Kaikan (Satoshô).

71. Empei Nishina, A letter to Nishina Arimoto, September 4, 1891, Nishina Kaikan (Satoshô).

bachelors degree. Its Department of Agriculture produced important intellectuals and educators, including Uchimura Kanzô and Niijima Jô. Whereas the famous Department of Agriculture, which meant to produce bachelors, taught academic subjects, the Department of Agricultural Arts offered a more practical two-year program, mostly for farmers in Hokkaidô and those who were certain to settle there. The prefectural government paid for the necessary expenses for most of the students, including Empei, who was already regarded as a Hokkaido resident.[72]

From here, I rely on the newspaper article. The education at the Sapporo Agricultural School was apparently of little help to Empei, who did not succeed as a settler. Then he turned to try his luck in business abroad, going to Bombay and Vladiostock, but again he did not succeed. The desperate Empei threw away a fortune in debauchery and drinking. The eldest brother Teisaku officially severed his family ties. Without faltering, Empei attempted another business in Nagasaki and failed. He then tried rice speculation in Tokyo and failed again. Lost and broke, he struggled at low paying jobs such bathhouse boy, fireman, and miner.[73]

Mining business seems to have suited Empei, who rose from the mining ranks to the administrative tier. Around 1905, Empei went to Hokkaido's hinterland, hoping to find a coal mine. After having crossed numerous rivers, he found a mine of smokeless coals. When he brought the coal back for inspection, however, the coal turned out to contain too much water to be used for steam engines. Disappointed and desperate, he tried to find anything valuable in his expedition. He found a sample of diatomaceous earth and send it to Tokyo to be evaluated for usefulness. The earth turned out to be of good quality and suitable

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72. *Sapporo Nôgakkô Ichiran, Meiji Nijûrokunen* (Sapporo: Sapporo Nôgakko, 1893).

73. "Dai hatsumeika no kushin (jô)."

for papermaking. Ôji Paper Manufacturing Company, a major paper manufacturer in Tokyo, offered to purchase from Empei five hundred tons of diatomite a year. Rejoicing, Empei raised funds, went to Hokkaido, and shipped five hundred tons of the diatomaceous earth from Hokkaido to Tokyo. The quality of the earth that he brought from Hokkaidô, however, did not meet the standard of the paper company, which regarded Empei as a deceiver and canceled their contract. Empei was left with five hundred tons of earth and a moutain of debt.[74]

At this point, the newspaper article turns to Empei's newly wed wife, Shûko. Calling her "today's exemplary woman," the newspaper reporter praises her heroic and sacrificial efforts to support her husband. To purchase daily supplies, she sold women's necessities, such as clothes and combs. Hoping the paper manufacturer would buy some of the earth, she sifted it, staining her "flawless skin" with dirt and "using her slender arms in the hard labor."[75] Empei, moved by his wife's sacrifice, renounced his business, which consisted of primarily risky speculations. He was now determined to start a more solid business. A possible way out was to make something useful out of the 500 ton stock of diatomite. Empei began reading physics and chemistry books, consulting experts in the related areas. First, he made paints, which did not work. Then, he made glue, soap, and cleanser, but to no avail.[76]

Empei finally achieved a success when he made a thermal insulation from his diatomite. He obtained a patent for his newly invented "Nishina thermal insulation" in December 1907. His brother Teisaku restored the family's relationship with Empei, came to Tokyo, and set up a company, Nishina & Co.

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74. Ibid.

75. "Dai hatsumeika no kushin (ge)."

76. Ibid.

(*Gômei Gaisha Nishina Shôkai*) to sell Empei's invention. According to the Yomiuri reporter, this invention created seventy thousand yen a month in revenue.[77]

The article ends with praise for Empei's moral virtues. "Amazing abstinence," the article proclaims. Empei, who used to drink several liters of sake and smoke fifty to sixty cigarettes a day, now gave up his old habits because, Empei said, "in order to achieve success[78] and great accomplishments as an inventor, one has to be healthy." His old friends teased him for his change, but he did not mind because he became an inventor "for society and the public welfare."[79]

This poignant success story contains moral lessons. Nishina Empei, a son of a distinguished family, declined because of his failures and was cut off from the family because of his drinking and debauchery. He endured many misfortunes and hardships. Moral virtue and the sacrifices of his wife made Empei repent for his past, launch a diligent study of physics and chemistry, and remake himself as an inventor.The moral virtues of Empei (effort, diligence, and abstinence) and his wife (temperament, constancy, and devotion) combined with his "scientific" knowledge eventually yielded success.

Although we have no direct evidence, it is almost certain that Nishina Yoshio saw this newspaper article. The Nishina family must have read and reread this article on Empei, proud to have such a celebrity in their family.

Empei's career as a successful "inventor" did not end with the Nishina insulation. The next thing he made out of his stock of five hundred tons of

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77. Ibid.

78. In the original Japanese, "*yo ni tachi,*" literally to rise in the world.

79. Ibid.

diatomite was a fireproof paint, which he named "Empel," after himself.[80] A pamphlet entitled "Fireproof Paint Empel" (*bôkazai Empel*) published around 1908 describes the many benefits of Empel. Empel, the pamphlet declares, is "the most advanced" fireproof paint for buildings, with guaranteed efficacy. It is also effective as a waterproof paint, making it suitable for roofs, walls, water tanks, and so on. It never freezes and cracks at a low temperature, which allows its use in the northern area. It is elastic, and therefore suitable for roads, playgrounds, and bathrooms, making them soft to the touch, which, the pamphlet claims, is "very cultivated" (*taihen bunkateki*). Empel lasts longer than concrete and is impenetrable by mice. Since it is porous, it also insulates sound and heat. Empel is 30 percent lighter than cements. It is available in any color other than white. Unlike cements it has a long lasting sterilizing effect and is therefore well-suited to hospitals, public bathhouses, restrooms, and sewerage facilities.[81] Empel consists of two substances: Empel powder and Empel liquid. The users are advised to mix them well before use. If they are not mixed well, Empel loses its effects. Once mixed, Empel must be used immediately, or it will lose most of its effects. After it is applied, Empel must be dried in shade for five days.[82]

There is no way to know whether Empel was as effective as Empei claimed, and the above advertisement sounds extremely suspicious. Because of porous nature of diatomite, Empel might partially insulate sound and heat. It is, however, hard to believe that Empel had a sterilizing effect, never cracked, froze at no temperature, was impenetrable by mice, and did not leak water. The

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80. "Empel" is the actual spelling used by Empei. In (romanized) Japanese, "emperu." See: Nishina Shôkai, *Bôkazai empel* (Tokyo: Nishina Shôkai, c1908).

81. Nishina Shôkai, *Bôkazai empel*, 1-2.

82. Ibid., 18-20.

instructions for the actual use of Empel are also dubious. By requiring such complicated procedures, Empei could make excuses in case Empel did not work as advertised. Most likely, the advertisement was an exaggeration, and, in spite of all the moral virtues emphasized in the Yomiuri Newspaper article, Nishina Empei was perhaps more of a quack than a "great inventor."

However, the Yomiuri Newspaper, again, enthusiastically applauded Empei's invention. An article entitled "No More Fire on Earth Since Today: Empel is a Great Invention of the Worldwide Importance," explains the various effects of Empel, as mentioned above. It also points out that cement, which is also resistant to fire, was three times as expensive as Empel, and that "considering the present wealth of Japan, cement is too expensive to use as a common construction material." The newspaper predicts that the Empel would benefit society by eliminating all the fires, to "the terror of the fire insurance companies."[83] Alas, we now know how spectacularly these predictions failed.

The same article also announced a "public experiment" to demonstrate the efficacy of Empel to be carried out on October 1, 1908 in the Mitsubishigahara field in Tokyo. The "experiment" was also advertised in newspapers and attracted tens of thousands of spectators, including, the pamphlet of the Nishina &Co. claims, the Superintendent-General of the Metropolitan Police, the governor of Tokyo, the secretary of the prime minister, the chief of the fire department, and other high-ranking officers, government engineers, and university professors.[84]

This demonstration consisted of two parts. In the morning, there was a comparative experiment. Heat approaching 2858 degrees Fahrenheit was applied

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83. "Kaji wa kyôkagiri chikyûjô yori nakunaru: Empel wa sekaiteki daihatsumei," *Yomiuri Shimbun*, 29 September 1908, 3.

84. Nishina Shôkai, *Bôkazai empel*, 15.

for two hours on four plates made of different materials: tiles, cement, plaster, and Empel. Each plate was five inches thick.[85] After exposure to the heat, the plates turned out to be burnt up to 3.3 inches for tiles, 2.6 for cement, 2.4 for plaster, and only 1.8 for Empel.[86]

The second experiment probably impressed the crowd even more. Empei prepared a Japanese-style warehouse and a wall, both painted with Empel. He placed several inflammable objects inside the godown, including a paper lantern, paper flags, blankets, and paper bills. He included the issue of the Yomiuri newspaper with the above-mentioned articles detailing the hardships that he and his wife endured, as a symbolic wager on the effectiveness of Empel. Then, Empei had a few hundred wooden logs piled up around the warehouse and the wall, poured oil over them, and ignited the pile. The newspaper article narrated what ensued:

> The raging flames scorched the sky,. . . . The warehouse and the wall, aflame, did not even flicker. Only their surfaces were damaged. After an hour, Empei opened the warehouse, produced hundreds of flags and waved them, to show that they were intact. In exultation, the crowd of twenty to thirty thousand applauded, clapping hands madly.[87]

The success of these "experiments" was obviously big news among the members of the Nishina clan. Nishina Yoshio, then a pupil of Okayama Middle

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85. In the original literature (the newspaper articles and the pamphlet on "Empel"), length was expressed in terms of *sun,* a Japanese traditional unit of length. One *sun* equals approximately 1.2 in inches.

86. Nishina Shôkai, *Bôkazai empel*, 14.

87. "Mitsubishigahara no bôka jikken: Empel no dai seikô," *Yomiuri Shimbun*, 2 October 1908, 3.

School, wrote a letter to Teisaku, celebrating the success of the demonstration of Empel.[88]

The third brother, Yasuo, followed a little different path, moving up the corporate ladder as a hired engineer. He entered Tokyo Higher Technical School (today's Tokyo Institute of Technology) and graduated from the department of electrical engineering. He then entered Mitsubishi Mining Company. After having worked for a few different companies as an electrical engineer, he became the chief engineer and an executive officer of Hida Takayama Electrical Company.[89]

Nishina's choice to pursue an engineering education and career was, therefore, more than appropriate according to the norms set by his brothers. In particular, considering Empei's dramatic failure, the precedent set by Yasuo would be more acceptable.

Even as late as 1922, when he was studying physics in Europe, Nishina Yoshio contemplated the possibility of becoming an entrepreneur. Impressed by the high quality of German scientific toys, he thought of manufacturing them. His son, Kôjirô, writes that the relatives had an impression that Yoshio thought, "physics is not interesting enough to be a lifelong profession." According to them, Yoshio thought, "German science distinguishes in the world, and the existence of very advanced scientific toys for children is one of the reasons for that. Perhaps I should quit physics, go back to Japan, and devote myself to the development and manufacture of scientific toys so as to make science in Japan equal to that of European countries."[90] In particular, Nishina seems to have been interested in

88. Yoshio Nishina, A letter to Nishina Teisaku on October 2, 1908, Nishina Kinen Kaikan (Satoshô).

89. *Satoshô chô shi* (Satoshô: Satoshô-machi, 1971), 484.

90. Nishina Kôjirô, "Chichi Yoshio no ryûgaku seikatsu," in *Nishina Yoshio:*

making radio-controlled toys, such as radio-controlled minature airships or wireless controlled explosives.[91] Such toys would contribute to Japan's science through educating youth, and might make him a successful businessman, successful in the sense discussed in the previous section.

For Nishina Yoshio, therefore, the appropriate means to achieve business success was to acquire and apply engineering skills. In particular, in the case of Arimoto, engineering skills changed the landscape, created a new environment, launched a business, and allowed a large number of people to work together.

Yet, Nishina Yoshio also saw a few different examples set by his grandfather and brothers. Whereas Nishina Arimoto's approach, as far as it is remembered by people, appears to have been thoroughly ethical, Nishina Empei might be seen as a mountebank, who advertised the efficacy of his product in a grossly exaggerated way.

2.3. Rebuilding the House

The massive political, social, and economical changes that followed the so-called modernization of Japan in the late 19th century produced the successful and the unsuccessful, forcing many once-prosperous families into decline. To restore the family fortune was often the ultimate goal of the youth of these families. The house of Nishina was one such declined family, and Nishina explicitly stated that he had an obligation to restore the Nishinas.

In September 1911, Nishina Yoshio contracted pleurisy and had to have a leave of absence for the first year of higher school. During this period, Nishina was

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Nihon no genshi kagaku no akebono, edited by Tamaki Hidehiko and Ezawa Hiroshi, > (Tokyo: Misuzu Shobô, 1991), 269.

91. Nishina Yûichirô, "Chichi no kaisô," 23.

prohibited from studying, and unbearable boredom led Nishina to read literary works in spite of his advice against novels in the above-mentioned letter to Masamichi. One of Nishina's favorite authors was Masamune Hakuchô, a naturalist novelist and essayist, who wrote mostly gloomy short novels.[92]

Nishina seems to have read Hakuchô's "Ni kazoku" (Two Families), originally published between 1908 and 1909.[93] It depicts two old, locally respected, and originally wealthy families in a village called Setoura in Okayama prefecture, near the Setonaikai Sea, around the turn of the century. Those distantly related families, the Okitanis, have contrasting patriarchs. One, Okitani Seikichi, is a conservative and steadfast man, who considers maintaining the family fortune that he inherited as his primary obligation. The other, Okitani Kisuke, is a man of entrepreneurial drive, who attempts various business enterprises and always fails. After consecutive failures, the house of Kisuke hopelessly declined. Takeo, the 14-year-old son of Seikichi, who is the top student at the local higher elementary school, consoles his uncle by saying that he respects Kisuke more than his own father because, whereas Kisuke attempts new enterprises, his father is only concerned with preserving what he has. Kisuke replies that his only wish now is to see Takeo's future success.[94] Nishina Yoshio must have found this story very impressive and familiar, not only because the story took place in the neighborhood, but also because the story of failed enterprises, decline of an old family, and a promising and highly expected young man, must have been very familiar to him.

Originally, the Nishinas occupied a uniquely prominent place in the hamlet of Hamanaka, as evidenced by the village cemetery. The tombs of the Nishinas

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92. Kimura, "Nishina Yoshio," 100.

93. Ibid.

were located in an elevated place of the cemetery and separated from the tombs of other villages by surrounding walls (See Fig. 6.3).

Nishina Arimoto's reputation and his status as the magistrate of the area further increased the Nishina clan's stature in the village. As magistrate, Arimoto collected taxes and presided over the local court. He also issued the local paper bills, called "Hamanaka bills," which, with Arimoto's reputation, was highly trusted.[95]

An aspect of the locally noble status of the Nishinas appears in their frequent inbreeding. With the family status so high, the Nishinas apparently had a problem in finding suitable mates, who had to be from a family of a similar social status. Some found wives and husbands in a remote region, as Arimasa did. Others resorted to consanguineous marriages. We have already seen that three of Nishina Yoshio's four sisters married a cousin or a cousin once removed. This practice was so frequently repeated that some family members became concerned. When in 1918 a relative proposed a marriage between Masamichi and a daughter of the Satô clan, which had a blood relation to the Nishinas. Yoshio, in particular, strongly opposed. He was finishing his bachelor's thesis in Tokyo but insisted in the strongest tone to his mother Tsune and the eldest brother Teisaku in Hamanaka: "The Nishinas in the past have repeated intermarriage so often. Yet, people seem to be unaware of its bad effect, which is truly horrible."[96]

The family fortune of the Nishinas used to be substantial, at least by the standard of Japan's rural society. In 1922, Nishina Teisaku wrote that when he

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94. Masamune Hakuchô, "Ni kazoku," reprint, 1908-09, Masamune Hakuchô zenshû (Tokyo: Fukutake Shoten, 1984), 364-428.

95. Kimura, "Nishina Yoshio," 32.

96. Yoshio Nishina, A letter to Nishina Tsune, March 31, 1918, Nishina Kaikan

inherited the house, the family fortune of the Nishinas amounted to about 12620 yen in 1892, which is about 70 million yen today (2000).[97] Apparently, the family fortune of the Nishinas in Arimoto's time was much more.

Children of the Nishina clan were made aware of their nobility. A man who attended grade school in Shinjô with Nishina Yoshio remembers that the Nishina brothers were distinct at school because of their more formal attires and much better boxed lunches.[98] Nishina Yoshio was sometimes alienated from his classmates because of his status. On a trip, they would take second-class seats, rather than the ordinary third class; even 15 year old Yoshio did so, when he went to Okayama City to sit for an entrance examination of Okayama Middle School.[99]

To the members of the Nishinas, the welfare of the family, not its individuals in the family, was the greatest concern. For example, Nishina Yoshio wrote to his mother and brother regarding Masamichi's marriage, insisting: "The bad effect on the Nishinas would last for a century."[100] The issue was not whether this marriage would bring happiness to Masamichi. Such a perspective was only a short-sighted one for the Nishinas, whose concern was the prosperity of the family.

The Nishinas were not special in this respect. In prewar Japan, especially in rural society, the sense of obligation to the family or *ie*, appears to have been very strong. The notion of *ie* should be differentiated from the modern notion of the

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(Satoshô).

97. Teisaku Nishina, A letter to Nishina Yoshio, 1922, (Draft), Nishina Kaikan (Satoshô).

98. Kimura, "Nishina Yoshio," 59.

99. Ibid., 62.

100. Yoshio Nishina, A letter to Nishina Teisaku and Nishina Tsune, June 2, 1918, Nishina Kaikan (Satoshô).

"family." *Ie* is not simply a relation or a group of particular individuals. It is a social institution that transcends a particular generation of individuals.[101]

The tension between *ie* and an individual (or individualism) became a preoccupation among Japanese intellectuals in the late Meiji and Taishô Eras. In particular, in the 1910s, it was a preferred subject among naturalist writers. These authors often considered *ie* antithetical to modern subjectivity. In their aspiration for freedom, Japanese intellectuals often described how *ie* oppressed individuals. It was in this context that Henrik Ibsen's *Doll's House* was translated and performed in 1910, with a remarkable success. The spectators saw in this play the theme of liberation of an individual from a family bond, not liberation of women from a sexist social system.[102]

The decline of the Nishinas started with the Meiji Restoration in 1868. The feudal system was abolished, and a new constitutional monarchy was installed. The central government began issuing its own bills, and the local paper bills issued by feudal lords were either exchanged with the new ones, or simply became valueless. The paper bills issued by Arimoto lost value. Arimoto threw away his own fortune to make up the loss, selling most of his salt fields.[103] After this, the Nishina family's decline began.

The failure of Nishina & Co. accelerated the decline of the Nishinas. Teisaku and other members of the Nishina clan invested heavily in Nishina & Co. Their business, however, did not go well. Empei lost his credibility when the

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101. Kitano Seiichi, *Ie to dôzoku no kisoriron* (Tokyo: Waseda Daigaku Shuppanbu, 1976), 12.

102. Phyllis Birnbaum, *Modern Girls, Shining Stars, the Skies of Tokyo: 5 Japanese Women* (New York: Columbia University Press, 1999), 20-27.

103. Sugai Jun'ichi, "Nishina Yoshio," in *Nijûseiki wo ugokashita hitobito: Shizen no nazo ni idomu* (Tokyo: Kôdansha, 1963), 334.

Ôkura Museum in Kurashiki, its buildings painted with Empel, had cracks and water leaks As the business of Nishina & Co. faltered, the family fortune of the Nishinas further deteriorated.[104] In particular, the head family Nishina clan and Teisaku's branch, which invested heavily in Empei's inventions, lost a large portion of their family fortune, including the salt-field in Yorishima.

Moreover, the Nishina Middle House branch (Nishina Nakayashiki-ke) lost its property to embezzlement. Nishina Tôtaro (Yoshio's cousin) temporarily lent the ownership of the house to someone, in order to help him raise donations for a local Buddhist temple. That person turned out to be duplicitous, and the Nakayashiki-ke branch lost its ownership of the house and land.[105]

Details of this process of financial decline are not clear. The first indication appears in Yoshio's letter to his nephew Kajio (Teisaku's son) on December 8, 1911. Writing from home in Satoshô to Kajio in Okayama City, Yoshio refused the latter's request for money, saying that he did not have money at all, and that Kajio should borrow money from someone if his need was urgent.[106] Yoshio, however, soon managed to collect the requested 7 yen, and sent a money order seven days later.[107] The next indication is Masamichi's letter to Yoshio on November 4, 1913, where Masamichi in Satoshô told Yoshio in Okayama City that Teisaku stopped paying for his educational expenses. According to Masamichi, Teisaku said that he would not pay for Masamichi's study, so Masamichi was free to do whatever he

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104. *Satoshô chô shi*, 479.

105. Nishina Akira, "Nishina Hakase no omoide," 9.

106. Yoshio Nishina, A letter to Nishina Kajio, December 8, 1911, Nishina Kaikan (Satoshô).

107. Yoshio Nishina, A letter to Nishina Kajio, December 15, 1911, Nishina Kaikan (Satoshô).

liked, and that Teisaku did not care whether Masamichi borrowed money and went to a school, or got a job. Moreover, Teisaku said that he would give money to his son Kajio for one year of study until he finished the middle school, but no more. Masamichi attributed Teisaku's sudden parsimony to an "emotional conflict" between him and Teisaku, but this might have been caused more by Teisaku's own financial problems.[108] In a letter to Yoshio on the same day, Teisaku wrote that he did not send the money to Yoshio in October, because he had so little. With this letter, Teisaku sent 10 yen of the monthly quota of 15 yen, promising that he would soon send the remaining 5 yen and this month's 15 yen.[109] In 1914, the financial situation became even tighter for Teisaku. In a letter to Yoshio on February 4, Teisaku wrote that he had talked with Riku of the head family (also a sister of his) about Yoshio's educational costs. It was decided that the head family would pay for this expense until Teisaku could recover his fortune and repay the debt. For the moment, however, the head house had difficulty sending money, Teisaku promised that he would send Yoshio as much money as possible.[110] In the following months, Teisaku and Riku sent Yoshio a few letters explaining the delay in sending money. In 1915, the situation became worse. Yoshio's letter to Teisaku on September 4 indicates that now the head family was unable to send any money to Yoshio, and he apparently expected nothing from Teisaku. Yoshio, now in Tokyo, wrote that he would stay and eat at Empei's place and Yasuo, the third brother in Hida Takayama, would send 15 yen monthly, from which Yoshio would

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108. Masamichi Nishina, A letter to Nishina Yoshio, November 4, 1913, Nishina Kaikan (Satoshô).

109. Teisaku Nishina, A letter to Nishina Yoshio, November 4, 1913, Nishina Kaikan (Satoshô); Nishina, A letter to Nishina Yoshio, November 4, 1913.

110. Teisaku Nishina, A letter to Nishina Yoshio, February 4, 1914, Nishina Kaikan (Satoshô).

give 2 yen to Empei.[111]

The recovery of the family fortune became the shared wish of the Nishina family. Nishina Yoshio, as the child prodigy of the Nishina clan, was therefore burdened with a high expectation, and he was aware of them. Even as early as in 1910, in the letter to Masamichi discussed above, Nishina Yoshio explained why their health was especially important:

> Since you and I have the responsibility to rebuild the House of Nishina. We have to build enterprises in the world, and be engaged in many activities. Therefore, we have to take good care of our physical health.[112]

Having provided practical advice, he then wrote to his brother, "I have another piece of advice. You should be a man of principle." At the end of a very long paragraph explaining how a man of principle should behave (for example, Yoshio wrote, one should not join a school strike even if all the schoolmates force one to do), he wrote: "Note what I say, and be a man of principle. And try to rebuild the declined Nishina House."[113] The apparent lack of logic here in Yoshio's insertion of the phrase of "rebuilding the declined Nishina House" suggests that this was a familiar and recurring idea, which did not require further explanation for Masamichi.

As the Nishina clan declined in the following years, the old brothers lost their hope for the restoration of the family fortune by their own hands, hoping instead that their young brothers and sons could do so. Empei, who fell heavily ill

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111. Yoshio Nishina, A letter to Nishina Teisaku, September 4, 1915, Nishina Kaikan (Satoshô).

112. Nishina Yoshio, A letter to Nishina Masamichi, April 7, 1910, 36.

113. Ibid., 39.

in July 1914,[114] wrote in a letter to Teisaku that since his body was now broken, he only hoped that he would enjoy in his old age seeing the success of Yoshio, Masamichi, and Kajio in the future.[115] Yoshio must have felt even more acutely the burden of his duty to restore the family and probably remembered Masamune Hakucho's novel.[116]

In sum, Nishina Yoshio's great goal was to restore the house of Nishina. His search for success, his training to be an engineer, his entrepreneurial ambitions—all were aimed at the restoration of the family fortune of the Nishina clan.

3. Rebuilding Physics in Japan

In this light, we can now interpret differently Nishina's 1928 and 1929 letters back to Copenhagen and his subsequent activities in Japan.

As we have seen in Chapter 4, Nishina left his homeland for Tokyo, graduated from college with outstanding achievements, had a chance to travel to Europe, studied under Niels Bohr, and accomplished an important piece of theoretical physics. Then he came back to Japan in December 1928. While Nishina's work with Klein was a significant contribution to theoretical physics, this work and the resultant fam was probably not enough to impress Nishina's family and relatives, or so it appeared to Nishina, who wrote that "I have not

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114. Nishina, A letter to Nishina Teisaku, September 4, 1915.

115. Empei Nishina, A letter to Nishina Teisaku, March 22, 1915, Nishina Kaikan (Satoshô).

116. Restoration of the family fortune was not only the appropriate course of action for Yoshio, but also something that he wanted to do to please his mother. Later, when his mother died, he wanted to please his mother by rebuilding the house of Nishina. This is a rare occasion when the psychology of the historical actor is revealed.

accomplished anything valuable in physics during this long stay."[117] Nishina's strong tie to the Nishina clan explains both why he "had to marry" and the nature of his "accumulated duties" to the family.[118]

As we have seen in Chapter 5, Nishina Yoshio became a group leader[119] at the Institute of Physical and Chemical Research in July 1931 and had an independent group of physicists with a budget under his control.[120] His subsequent activities were increasingly focused on rebuilding the physics community in Japan, creating a strong group of atomic physicists, and then managing it. After his return to Japan, Nishina never produced an individually authored paper. Nor did any of his coauthored works approach the standard of work that he did with Oscar Klein. In Japan, Nishina was primarily a teacher and organizer of Japanese physics, not a rank-and-file research scientist. This aspect of Nishina's scientific style was in part a result of his experience in Copenhagen, as we have seen in the previous chapter. In this chapter, however, I try to relate some aspects of Nishina's scientific style to Japan's local and native roots. I point out three characteristics of Nishina Yoshio's scientific activities. The first characterstic is the entrepreneurial style of science. Nishina managed his group as if managing a business enterprise, occasionally recalling Nishina Empei's somewhat charlatanish business practice. The second was Nishina's reliance on engineering in his scientific activities. Rather than developing human skills and relying on ingenuity, Nishina was more interested in building large instruments to produce good experimental results. Finally,

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117. Nishina, A letter to Niels Bohr, October 31, 1928, 23.

118. Nishina, A letter to George Hevesy on April 1, 1929.

119. In Japanese, *kenkyûshitsu shunin taru kenkyûin,* or a research fellow in charge of a research group.

120. Nishina began to manage a budget in 1932.

Nishina's scientific activities centered on rebuilding the Japanese physics community, rather than on furthering his own scientific achievements. As he was hoping to rebuild the Nishina clan in his youth, Nishina as a scientist was trying to rebuild Japan's physics.

These characteristics might appear too commonplace today to be of any historical significance, and might seem to be natural developments in physics, a part of the worldwide trend toward big science.[121] One might say that large-scale experiments became necessary in nuclear physics, and that was why Nishina began building cyclotrons. These characteristics might also be related to the increase of state sponsored scientific research. I do not claim that these scientific and social factors were insignificant. I show, however, that, in the 1930s, alternatives to these approaches did exist, and I argue that Nishina's adoption of a particular approach in physics, emerged from his perception of that approach as an appropriate course of research to take.

3.1. Making Quantum Noises in the World

In *Lawrence and His Laboratory,* John Heilbron and Robert Seidel claim that Ernest Lawrence's "creation of the 27-inch cyclotron called for an unusual blend of faith, energy, and entrepreneurism," which they claim to be an "unusual combination," and illustrate its rarity by the reluctance of other physicists in, for example, Cavendish Laboratory, to follow Lawrence.[122]

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121. As for "big science," see: Peter Galison and Bruce Hevly, eds., *Big Science: The Growth of Large-Scale Research* (Stanford: Stanford California Press, 1992).

122. John. L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory*, vol. 1 (Berkeley: University of California Press, 1989), 132.

Interestingly, in explaining Japan's construction of a cyclotron in 1937 and the fact that an institute in Japan, not a "great center of nuclear physics" in Europe built the first working cyclotron outside the United State, Heilbron and Seidel do not attribute the Japanese physicists' success to their "blend of faith, energy, and entrepreneurism."[123] Instead, they offer somewhat different explanations. According to the authors, the Japanese physicists' construction of the cyclotron was due to a "precociousness," which was "born of a conjunction of forces characteristically Japanese: a conviction on the part of government and industry that excellence in Western science was essential to Japan's place in the sun; an ability to assimilate foreign designs; and no vested interest in any machinery for splitting atoms."[124] They continue: "Just as the great substantive discoveries and instrumental improvements in experimental nuclear physics were being made in Europe and the United States, the Japanese, pulling themselves out of the Depression by military adventure and economic aggression, found the money and motive for multiplying particle accelerators in Tokyo."[125]

A closer glance, however, will reveal at least a form of entrepreneurism in the construction of cyclotrons and other scientific activities of Nishina Yoshio and his disciples. For Nishina, a scientific activity was like a business enterprise, involving public relations, networking, fund-raising, and management of

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123. In addition, Heilbron and Seidel are not accurate in assuming that Nishina's cyclotron was the first working cyclotron outside the United States. Osaka University's 28-inch cylotron was complete one month before the one at Riken. This, however, is a minor point especially because the Osaka group continued modification of their cyclotron until much later. See: Kiyonobu Itakura, Tôsaku Kimura, and Eri Yagi, *Nagaoka Hantarô den* (Tokyo: Asahi Shinbunsha, 1973), 554-56.

124. Heilbron and Seidel, *Lawrence and His Laboratory*, 317.

125. Ibid.

organization. Nishina was aware of such a new feature of scientific research. This feature also struck his contemporaries. This was a novel style of research in physics in Japan.

Nishina was probably one of the earliest Japanese scientists to realize that science would need public relations efforts. Certainly, there were many other scientists who devoted time and energy to the popularization of science. Among physicists, for example, Ishiwara Jun was the foremost popularizer of science in prewar Japan. Their actions, therefore, originated from a patronizing intent to enlighten the uneducated, not to make them a reliable ally for science. In the case of Nishina, he had to popularize science, because that was the only way he could conduct some of the researches that interested him.

For a few years after his return from Europe, Nishina did not write much for popular magazines. According to Tomonaga, Nishina did not like journalism, saying, "news reporters write lies."[126] In this regard, he was not unlike his mentor, Niels Bohr, who hated to be quoted and subsequently distorted by journalists.[127] However, Niels Bohr, the national hero of Denmark, could afford to ignore journalists, but Nishina, virtually anonymous in Japan when he formed his research group, could not.When introducing himself, he had to explain how to spell his name.[128] Nishina's active publication of popular articles began in 1933 as a reaction to the "Wonder Year" of 1932, when a series of important discoveries took place

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126. Tomonaga Sin-itiro, "Kenkyû seikatsu no omoide," in *Butrurigaku to watashi*, vol. 2, Tomonaga Sin-itiro chosakushû (Tokyo: Misuzu Shobô, 1984), 314.

127. Stefan Rozental, *Niels Bohr: Memoirs of a Working Relationship* (Copenhagen: Christian Eilers, 1998).

128. Tomonaga Sin-itiro and others, "Zadan Nishina sensei wo shinonde," in *Hirakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakushû*, reprint, 1951 (Tokyo: Misuzu Shobô, 1982), 77.

back to back.[129] Nishina wrote two articles on recent developments on nuclear physics in general and two articles on the discovery of the positive electron. These articles were, however, published in *Kagaku*, a general science magazine, with a primary readership of scientists, his articles, it seems, were not intended for non-scientists (See Fig. 6.4).

Nishina began to write in a more popular venue in 1934, publishing most of his articles in 1935 in popular magazines and newspapers. Excluding the end-of-war period, Nishina maintained his steady publication of popular science articles until he died in 1951.

Along with writing popular articles, Nishina gave popular lectures with demonstrations. One of his favorite demonstrations involved a living geranium. First, the experimenter (usually Nakayama Hiromi, an assistant of Nishina who was working on plants using radioactive tracers) let the plant absorb radioactive materials from the roots and then keld the Geiger counter near the leaves. After a while, the Geiger counter began to buzz, detecting the radioactive tracers that came up from the roots.[130]

Nishina engaged in a less innocent demonstration. Nishina took Mr. Kato, a handyman from Riken, to one such lecture, and let the man drink a radioactive salt. Then Nishina or his assistant moved a Geiger counter closer to him, which made a cracking sound as it approached the man's body. A newspaper reported it next day in an article entitled, "Human Radium." The man was later rewarded with

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129. See Chapter 5.

130. Nakayama Hiromi, "Torêsâ to shokubutsu seiri no kenkyû," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, Hidehiko Tamaki and Hiroshi Ezawa (Tokyo: Misuzu Shobô, 1991), 141.

a bottle of sake for his role in this human experimentation.[131] This, scientifically unnecessary and medically dangerous experiment makes sense only as a way to attract popular attention. Nishina was probably attempting to show how nuclear physics could be useful in medicine. Tomonaga remembers that Nishina lectured and wrote in various places that nuclear physics would cure diseases.[132]

The Japanese public seems to have received Nishina's advertising activities favorably. An article in the Asahi Shimbun Newspaper, one of Japan's national papers, reported in April 1937 on the completion of Nishina's small cyclotron, describing his laboratory as "the Magic Laboratory," that produced "artificial radium."[133]

Nishina's popularizing activities aimed to raise funds for scientific research in his field, in particular, for the construction of high-energy physics instruments. Even Riken was not rich enough to finance the construction of a cyclotron.

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131. Tomonaga Sin-itiro and others, "Zadan Nishina sensei wo shinonde," 76.

132. It appears that Nishina did not hesitate to push his quackery further when negotiating with a bureacrat, although he was much more careful not to mislead the general public. After WWII, when negotiating with a bureacrat of the Ministry of Agrictulre and Forestry to acquire funding for research on isotopes, Nishina claimed that isotopes would be useful for agriculture, because with heavier isotopes, one could make heavier cows, and accordingly more food. The adherent Nakane Ryôhei, who was at the negotiation, recollects that Nishina looked serious. Nishina was serious probably because it was true that isotopes might benefit agricultural research by tracking nutriiious substances or by creating mutations. Also, it was his firm belief that production of food was of utmost importance in postwar Japan, which, Nishina believed, would lead to further developments of science in Japan. However, he did not know how to explain it to a bureaucrat, who was apparently not particularly literate in atomic physics. Nishina apparently succeeded in appearing serious enough for the bureaucrat to believe. The funding was granted. Inoue Izumi, ed., *Zenryoku shissô no jinsei: Nishina Yoshio* (Satoshô: Kagaku Shinkô Nishina Zaidan, 2001), 50.

133. This newspaper article is translated and cited in Charles Weiner, "Cylotrons and Internatinoalism: Japan, Denmark and the United States, 1935-1945," in *XIVth*

The timing was suitable for Japanese physicists. In the mid-1930s, as the semi-war situation in Manchuria continued, the Japanese government began to become seriously involved in scientific research. The creation of the Japan Society for the Promotion of Science changed the funding structure of Japanese science. Top priority was given to a project to compile the historical records of legislation. The second was medical research on tuberculosis. The third was cosmic ray and nuclear physics research, which was virtually led by Nishina.[134]

It is, however, a misconception to overstate the role of the state and military sponsorship. A large portion of the outside funds for Japan's first cyclotron came from the private sector. Nishina's task was therefore considerably more difficult and complex than begging for money from the state (or its agencies, such as the Japan Society of Promotion of Science). Yet, Nishina was able to receive funding from a few philanthropic foundations. By far the most significant was Hattori Hôkôkai, established by the Hattori Clock Shop (today's Seiko), which contributed a total of 25,420 yen from 1936 to 1943. In the 1940s, however, support from the military overwhelmed all other sources.[135]

As the research projects grew larger, Nishina's role in his group became more managerial. Nishina's tendency to do everything by himself had to be corrected. An article first published in 1946 indicates that Nishina at some point had become conscious of the changing character of the scientific enterprises and

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International Congress of the History of Science, Proceedings, No. 2 (Tokyo: Science Council of Japan, 1974), 356.

134. Hirosige Tetu, *Kagaku no shakaishi: Kindai Nihon no kagaku taisei* (Tokyo: Chûôkôronsha, 1973).

135. Based on Riken's internal documents: "Kenkyûshitsuhi kessanhyô," 1931-1941, 1943, 1944; "Kenkyûshitsu yosan," 1931-1944; "Kenkyûshitsu shôshûnyû," 1936-1939, 1941, 1943 (Wakôshi: Riken Kinenshiryôshitsu).

the role of scientists. Nishina wrote, "There are two kinds of people. The first kind people do everything by themselves, without asking others' help. The second kind of people, instead of doing things with their own hands, assign many other people in various posts and accomplish a work with the combined force." According to Nishina, until recently, the genius of the first kind of people had driven the development of science. However, he continued, since society had become complicated and the areas studied by science became vast, the work had to be divided. A collaborative effort, then, would achieve far more than what an individual could ever accomplish. "This," Nishina concluded, "shows the power of an organization."[136] After his return to Japan, Nishina Yoshio primarily played the role of the latter, thus maximizing the "power of an organization."

The nature of Nishina's scientific activity was different from that of the previous leader of Japanese physicists, Nagaoka Hantarô. As the leading physicist of the time and head of the physics department at Tokyo University, where most Japanese physicists received their undergraduate education. Nagaoka was not averse to writing popularized articles and giving lectures. Apparently, he considered it part of his duty to educate the general public.[137] Unlike Nishina, his motive was neither to raise funds, nor to link science and the society. Nagaoka himself did not need to raise funds to conduct his research. Moreover, Nagaoka disliked large-scale research collaboration. He worked alone, or only with a few assistants. He even complained that there were too many collaborative works in Japan, compared with other countries.[138]

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136. Nishina Yoshio, "Soshiki no chikara," in *Genshiryoku to watashi* (Tokyo: Chûôkôronsha, 1951), 175-77.

137. Itakura, Kimura, and Yagi, *Nagaoka Hantarô den*.

138. Itakura Kiyonobu, *Nagaoka Hantarô* (Tokyo: Asahi Shimbunsha, 1976), 15.

Not only older people, but also younger physicists found Nishina's style strange. Tomonaga Sin-itiro, one of Nishina's closest disciples, later characterized Nishina's scientific style in the following way: "He [Nishina] always liked big projects. . . . Since he always planned a huge project, he appeared to us like a mountebank entrepreneur (*yamashi*). In fact, he had such a trait."[139]

Tomonaga and other young disciples were not happy at all when their papers languished unread on Nishina's desk while Nishina was busy with popularizing and advertising science. Nishina, for example, often wrote in newspapers that radioactivity from a cobalt isotope was an effective treatment for cancer.[140] Near Riken, there was a clinic of a quack doctor, who was advertising "electron treatment." One day, when drinking, they conspired to switch the signboard of this doctor with the doorplate of the Nishina group, a plan they dared not carry out.[141] Later, when Tomonaga had to assume an administrative position, he felt ashamed because he realized that without such popularizing activities, fundraising for scientific research would have been impossible in Japan. This episode shows that even Nishina's students, rebellious and playful, did not have a deep understanding of the fund-raising aspect of science at this point.[142]

Among younger physicists, Husimi Kôdi, who would become a politician of physics himself, understood the significance of Nishina's style. Characterizing Nishina with the cultural qualities of an idealistic and dreaming scientist and the

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139. Tomonaga Sin-itiro and others, "Zadan Nishina sensei wo shinonde," 71.

140. Tomonaga Sin-itiro, "Kenkyû seikatsu no omoide," in *Butsurigaku to watashi*, vol. 2 of *Tomonaga Sin-itiro chosakushû*, reprint, 1971 (Tokyo: Misuzu Shobô, 1982), 316.

141. Tomonaga Sin-itiro, "Kenkyû seikatsu no omoide," 315-16.

politico-entrepreneurial character of a man who coped unfalteringly with the dry and harsh reality, Husimi commented:

> A mere scientist could not accomplish construction of a large cyclotron. One needed the abilities to gather funding sources and to mobilize industry and technology in Japan. That was an enterprise, rather than research. . . The physics institute was becoming similar to a factory, and such a tendency matched well Nishina's style.

Riken, Nishina's lifelong home institute, was a place conducive to such an entrepreneurial style of physics. As I have mentioned in the previous chapter, in Nishina's time, this institute functioned as a stock holding company, owning many patents. The companies under its control manufactured inventions developed by the institute, returning a substantial part of the profit to the institute. In other words, Riken itself was a venture business, but its ultimate purpose was to advance science, not to make money. Nishina's group was able to flourish in this environment.[143]

Nishina's entrepreneurial research style also complemented the collective and collaborative scientific activities, which, as we saw in Chapter 5, Nishina introduced from Copenhagen. Had scientific research of the group remained a collection of independent and solitary works of a modest scale, fund-raising and management of researchers would not have been a problem.

For Nishina, thus, doing physics was like a business enterprise, and he sought to succeed in this enterprise. The worldly activities Nishina conducted in his efforts to build a cyclotron were aligned with a norm he espoused in his youth. Connecting science with money and business was an appropriate endeavor. Rather

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143. Saito Satoshi, *Shinkô kontserun Riken no kenkyû: Ôkôchi Masatoshi to Riken sangyôdan* (Tokyo: Jichôsha, 1987); Miyata Shimpei, *Kagakusha tachi no jiyûna rakuen: Eikôno rikagaku kenkyûjo* (Tokyo: Bungei Shunjûsha, 1983).

than retreating to an ivory tower of pure scientific research, Nishina committed himself to maintaining close ties between his research and the society. Such an attitude was fitting in view of the norms of entrepreneurial success, or "being active in the world."

3.2. Science through Engineering

If the first characteristic of the Nishina's scientific research was its entrepreneurial style, the second characteristic was Nishina's use of engineering in his scientific research. Rather than relying on ingenuity of experimental designs or skills of experimental practices, Nishina depended on machines to achieve the success in his scientific enterprise. Nishina's scientific activity turned out to be less scientific inquiry and more an engineering enterprise of instrument building.

In hindsight, the path toward big science might appear inevitable, and Nishina's commitment to it natural. As I discuss below, however, Nishina's contemporaries, in particular his disciple Tomonaga, were aware of other paths that might have been more reasonable in the given infrastructure of Japanese physics.

One can also point out the Nishina group's strong tie to the Lawrence group at Berkeley, mostly through Sagane Ryôkichi, which suggests the international roots of this research direction, in addition to those of the Copenhagen group.[144] Whereas I admit that foreign factors are not negligible, my goal here is not to find deterministic conditions for Nishina's research directions, but to find its possible native roots.

Nishina Yoshio's group began constructing a 27-inch cyclotron in 1936 and completed it in April 1937. The experimentalists of Nishina's group placed construction of a cyclotron at the heart of their work. When Nishina's group finished constructing the first 27-inch cyclotron in 1937, Nishina immediately started the next project, building a 60-inch cyclotron. The construction of the new cyclotron would mobilize almost all the manpower of the Nishina group, leaving them unable to conduct experiments.[145] Nishina's disciples, unhappy to miss the chance to conduct experiments with the cyclotron, objected, but Nishina's authority prevailed, and the group proceeded with the construction of a 60-inch cyclotron at full speed.

The construction of a 60-inch cyclotron was, however, far more difficult, lasting until 1944. Riken's scientists soon faced a shortage of material resources when the war with China began in 1937. Inspite of the Japanese Imperial Army's apparent advancement, the war against the immense land and population was quickly exhausting Japan's resources, leaving little for non-essential activities, such as construction of a cyclotron. In 1937, Nishina thought they might not raise enough money to build a cyclotoron.[146] Although Nishina's worst fear did not come true, and the assembly of the 60-inch cyclotron was finished in February 1939, the machine, as it turned out, did not produce as strong a beam as expected. Scientists of Riken tried in vain to make it work until 1940, but seeing their fruitless efforts, Nishina decided to send his disciples to Lawrence. Yazaki

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144. As for Sagane Ryôkichi's actvities in Berkeley, see: Weiner, "Cylotrons and Internationalism".

145. Yamazaki Fumio, "Nishina kenkyûshitsu ni haitte kara," in *Nishina Yoshio: Nihon no genshi kagaku no akebono*, Hidehiko Tamaki and Hiroshi Ezawa (Tokyo: Misuzu Shobô, 1991), 230.

146. Nishina thought that they could not get sufficient funds if the war See: Yoshio Nishina, A letter to Niels Bohr, August 28, 1937 in *Supplement to Publications*, NKZ Publications (Tokyo: Nishina Kinen Zaidan, 1986), 20. Also quoted in: Weiner, "Cylotrons and Internationalism," 358.

Tameichi and two others went to Berkeley in August 1940. Being citizens of a hostile country, however, they were not admitted into the laboratory, where classified research was underway. Lawrence, nonetheless, secretly gave some blueprints of his already completed 60-inch cyclotron to the Japanese scientists.[147] With blueprints and the newest model of vacuum pump that they purchased, Yazaki and others returned home in November. The scientists at Riken had to decide whether to do experiments using the existing defective cyclotron or, before starting their experiments, to radically modify the cyclotron to make it work. The cyclotron was already capable of producing an 8 Mev proton, an achievements matched by only a few in the world.[148]

Nishina opted for the latter, although his experimenters preferred doing experiments.[149] The Riken group then started to modify the cyclotron according to the new blueprints.[150] While they were struggling, the war with the United States began, and the materials became even more difficult to procure. When they needed a rubber O-ring for packing, they had to purchase an amount of raw rubber, and then have a manufacturer of rubber products make the O-ring. In particular, the

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147. It seems that this generous act of Lawrence was not advertised widely during the war. See Donald Cooksey's letter in 1943 quoted in Heilbron and Seidel, *Lawrence and His Laboratory*, 320.

148. Yamazaki Fumio's comment in Tomonaga Sin-itiro and others, "Zadan Nishina kenkyûshitsu no ôgonjidai," in *Zadan Nishina kenkyûshitsu no ôgonjidai*, vol. 6 of *Hirakareta kenkyûjo to shidôsha tachi*, reprint, 1978 (Tokyo: Misuzu Shobô, 1982), 154. He does not note the amout of current. Lawrence's 60-inch cylotron was able to create a deuteron beam of 16 Mev and 100µA in October 1940. See Heilbron and Seidel, *Lawrence and His Laboratory*, 196.

149. Tomonaga Sin-itiro and others, "Tomonaga Sin-itiro chosakushû," 154.

150. Shinma Keizô, Yamazaki Fumio, Sugimoto Asao, and Tajima Eizô, "60 inch (ôgata) saikurotoron kensetsu hôkoku," *Kagaku Kenkyûjo Hôkoku* 27 (1951): 156.

special oil used in the newly purchased vacuum pump was not available in Japan, so they had to synthesize it themselves, measuring viscosity and other characteristics of the oil.[151] At the same time, however, the war benefited the Nishina group. The army commissioned to the group to build the atomic bomb. Nishina diverting these funds toward the construction of the 60-inch cyclotron.[152] Nishina and his disciples finally completed the cyclotron in 1944, successfully producing a beam. In April 1945, however, an air raid destroyed the small cyclotron. The large cyclotron survived the war but not the occupation by the Allied Powers.[153] Yamazaki Fumio, one of the members of the experiment subgroup, recalls their primary activity was constructing instruments, rather than conducting experiments.[154]

Nishina's disciples noticed that Nishina's approach to instrument building was different from theirs. Whereas these young experimental physicists were afraid

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151. Yamazaki Fumio, "Nishina kenkyûshitsu ni haitte kara," 231-32.

152. Nishina's wartime research is beyond the scope of this work. I proposed an interepretation of his wartime activities in: Kenji Ito, "Values of 'Pure Science': Nishina Yoshio's Wartime Discourse Between Nationalism and Physics, 1940-1945," *Historical Studies in Physican and Biological Sciences* (in preparation). As for the Ni-go project, see: Walter Grunden, "Science Under the Rising Sun: Weapons Development and the Organization of Scientific Research in World War II Japan," Ph. D. Diss. (University of California Santa Barbara, 1998); Morris F. Low, "Japan's Secret War?: Instant Scientific Manpower and Japan's World War II Atomic Bomb Project," *Annals of Science* 47 (1990): 347-60; John Dower, "'Ni' and 'F': Japan's Wartime Atomic Bomb Research," in *Japan in War & Peace: Selected Essays* (New York: New Press, 1993), 55-100; Keiko Nagase-Reimer, *Forschungen zur Nutzung der Kernenergie in Japan, 1938-1945* (Marburg: Förderverein Marburger Japan-Reihe, forthcoming).

153. For the destruction of the 60-inch cyclotron, see: Shigeru Nakayama, ed., *Occupation Period, 1945-1952*, A Social History of Science and Technology in Postwar Japan (Melbourne: Trans Pasific Press, 2001). Also see: Weiner, "Cylotrons and Internationalism".

154. Yamazaki Fumio, "Nishina kenkyûshitsu ni haitte kara," 232.

of building large instruments, Nishina, originally trained in the department of electrical engineering was bold to scale up the instruments. Yamazaki Fumio said, "An ordinary physicist would not even think of using 1500-ampere current. Physicists did not know that there was such a generator," whereas Nishina was thoroughly familiar with industrial high-voltage electrical engineering.[155]

Nishina was markedly different from, again, Nagaoka Hantarô, the leader of physics in Japan in the previous generation. Nagaoka had not sought to acquire a budget for physics or to build new scientific instruments. Having seen how great discoveries were made with relatively simple instruments, he thought that budget and large machines were not essential for good scientific research. It should be noted, however, that Nagaoka was flexible enough to change his view about physics in general, but not to change his own research style. In the mid-1930s, Nagaoka turned to supporting Nishina and probably Sagane Ryôkichi, a son of Nagaoka's and chief experimentalist of the Nishina group. In an address at a meeting of the trustees of the Japan Society for Promotion of Science, Nagaoka said:

> Since the previous century, it has been claimed that great discoveries appeared not from a well-equipped laboratory, but from relatively simple instruments. Indeed, if one looks at Faraday's fundamental discovery about electricity, it is appropriate to say that he [illuminated] the great laws of nature, by not poor but by no equipment at all, using hand-made machines.[156]

Although Nagaoka did not mention it, he himself had been the most ardent proponent of such a claim. In fact, he richly illustrated this argument for

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155. Tomonaga Sin-itiro and others, "Zadan Nishina sensei wo shinonde," 74.

156. Nagaoka Hantarô, "Sôgôkenkyû no hitsuyô," *Gakujutsu shinkô*, no. 3 (May 1937): 6.

discoveries without equipment with three additional examples of Edison, Pasteur, and Roentgen, unwittingly showing how much thought and credence he had given to this claim. In this address, Nagaoka intended to demonstrate that such a claim was outdated and that successful scientific research would require a generous funding. His point was further illustrated in an another address in January:

> It has been claimed that a scientific discovery was made possible by the ability of the scientist, not by large instruments. It is however, agreed by experts that physicists have already exhausted most of the discoveries possible by a small scale experiment made with sealing wax, nails, and tinplate sheets, and that future discoveries would be difficult to accomplish without a large scale instrument."[157]

Curiously, Tomonaga Sin-itiro, Nishina's closest disciple, later made a comment more sympathetic to Nagaoka before 1930 than to his mentor. In articles written after Nishina's death, Tomonaga questioned Nishina's decision to construct a larger cyclotron in 1937, rather than using the smaller one. Most of the important experiments in nuclear physics at that time were conducted with relatively small instruments, as the examples of Ernest Rutherford, Curie, Bothe, Otto Hahn, Cecil F. Powell, and others demonstrated. Tomonaga claimed it would have been possible to achieve important discoveries with relatively cheap instruments, if one conducted original and careful experiments. At the same time, however, Tomonaga admitted that Nishina was seeking not only to produce experimental results, but also to create and expand an infrastructure of atomic physics.[158]

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157. Nagaoka Hantarô, "Gakkai jitsugyôkai he no yôbô," *Gakujutsu shinkô*, no. 2 (February 1937): 2.

158. Tomonaga Sin-itiro, "Nishina sensei," in *Butsurigaku to watashi*, vol. 2, reprint, 1951, Tomonaga Sin-itiro chosakushû (Tokyo: Misizu Shobô, 1982), 221-2; Tomonaga Sin-itiro and others, "Zadan Nishina sensei to kakubutsuri no hattatsu," in *Hirakareta kenkyûjo to shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakushû*, reprint, 1961 (Tokyo: Misuzu Shobô, 1982), 117-18.

In his scientific research, Nishina applied engineering, constructing large machines. He increasingly relied on larger and better experimental instruments, rather than on ingenuity or skills of experimenters. Nishina's move from the ingenuity-based approach toward an instrument-centered approach of experimental physics did not emerge from scientific necessity. It came from Nishina's conviction that better equipment would bring better scientific results. This approach corresponded withNishina's entrepreneurial approach to physics and the norm of engineer-entrepreneurialism of the Nishina clan. Since scientific research was conducted as a business enterprise, its success depended on the engineering skills to construct machines and create a better research infrastructure. To achieve entrepreneurial success through the introduction of engineering was an appropriate act in accordance to the engineer-entrepreneurialism of the Nishina clain, as revealed in the work of Nishina Arimoto and Nishina Empei.

3.3. Rebuilding the Japanese Physics Community

Nishina's scientific activities, described so far in this and the preceding chapters, indicate that his motivation was not to accumulate his own scientific capital. Rather, his efforts were centered on constructing the infrastructure of atomic physics in Japan.

The reconstruction of the deteriorating home institution was an appropriate or even imperative act for some of the late 19th century youth, and especially for Nishina Yoshio, as we have already seen. Here I claim that Nishina's scientific activities were focused on the reorganization of Japanese physicists, and thatt a parallel existed between the restoration of the Nishinas and the reorganization of the Japanese physics community. In the next section, I examine Nishina's transition from the House of Nishinas to physics in Japan.

As I discussed in Chapter 3, younger physicists deemed the situation of physics unsatisfactory. They revolted against the physics establishment, but they themselves were unable to create a fruitful research tradition. In this situation, Nishina came back. As I argued in the previous chapter, he created a favorable environment in which good physicists could mature and organized them to produce the maximum results. Nishina was aware that those were the roles that he should play.

Nishina wrote in 1938 that "There is a very subtle interaction between the society and an individual, by which the society shapes history, going through good times and bad times." In this article entitled "Human Being and the Environment," he stressed the importance of the environment in devloping the human intellect. He wrote, "Besides the issue of culture and heredity, it is certain that a person's ability and character is to much extent determined by environments. A certain environment shapes a personality, and then that person changes the environments. He creates certain tendencies in various kinds of societies, large and small, such as a state, a family, or any other organization. Such tendencies eventually produce a great religious thinker, a military leader, or a statesman."[159]

This notion of the interaction between environments and individuals was a persistent one for Nishina. In November 1949, a year and half before his death, when he gave a lecture at a middle school near his birthplace and was asked to write something as a memento, Nishina wrote down, "Individuals make the environment, and the environment shapes individuals."[160] To produce good scientists, therefore, one must create a good environment.

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159. Nishina Yoshio, "Hito to kankyô," *Chûôkôron*, January 1938, 410-12.

160. *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 182.

Since Nishina acquired his own division at the Institute of Physical and Chemical Research, his group grew quickly. The manpower of the Nishina's group increased almost exponentially (Fig. 6.5).[161]

As he trained his disciples, quality of the personnel improved: a young research fellow became a doctor of science, and then a professor. Financial growth in the prewar years was not as impressive, but the war drastically improved the group's economic circumstances (Fig. 6.6).[162]

The topics in which Nishina was involved also multiplied. When he came back to Japan, his research topic was, modestly defined, "quantum theory," meaning its theoretical studies. Soon, experimental atomic physics became a part of his project. Inevitably, construction of cyclotrons started. To supplement still lacking data, Nishina's attention turned to the use of natural high-energy phenomena, the cosmic ray. On the cosmic ray, Nishina wrote extensive popular accounts of the cosmic ray, and succeeded in extracting money from the army air force, which was interested in the meteorological implications of the cosmic ray research.[163]

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161. The statistics are based on *Riken Annai*.

162. Statistics are based on Riken's internal financial documents, *Kenkyûshitsu sho shûnyû, Kenkyûshitsu yosan, Kenkyûshitsu yosan an, Kenkyûshitsu Kessanhyô.* The expenses in 1944 and 1945 are based on my extrapolation, and may be inaccurate large error. Especially, the expense in 1945 was probably much smaller. An army office said that the army paid 2,000,000 yen to Nishina's group for its atomic bomb project (See: Yomiuri Shinbunsha, ed., *Shôwa shi no tennô*, vol. 4 (Tokyo: Yomiuri Shinbunsha, 1968), 205-06) . That money probably went to the nuclear physics laboratory, and the cosmic ray division did not receive as much money as I estimated. In any case, it is clear that the expense during the war dwarfed the expense in prewar years. Here I use expense to estimate the financial scale of Nishina's group, because in Riken, budged did not mean much. The director, Ôkouchi, allowed each group to spend over the budget.

163. Tetsu Hirosige, "Social Conditions for Prewar Japanese Research in Nuclear

Nishina's activity extended even outside Riken. Although universities could not offer him a job, they asked Nishina to give lectures on recent developments in atomic physics. Nishina spent much of his first two years since his homecoming on preparing such lectures and giving them in a few universities in different parts of Japan.[164] In particular, his lecture at Kyoto University in 1929 was important, because there he found Tomonaga Sin-itiro and Yukawa Hideki, highly talented but lonesome students, who were learning quantum mechanics without an adequate mentor. Nishina asked Tomonaga to join his group in Tokyo. Yukawa remained in Kyoto and Osaka, but considered Nishina as his teacher. In return, many of those young physicists trained under Nishina's supervision eventually left Riken, and had a job at a university around Japan, extending Nishina's network, and spreading the style of research they learned in Riken.[165]

It was not necessarily natural that a senior scientist would assume such a position. As I mentioned, Nagaoka Hantarô, for example, kept working with a small number of assistants, although he was view as the boss of the Japanese physics community.[166] Nishina also differed from other physicists trained in Copenhagen. Besides Nishina, eight Japanese physicists stayed in Copenhagen under Bohr's guidance. None of them played an organizing role in Japanese science.

Physics," *Japanese Studies in the History of Science*, no. 2 (1963): 80-93.

164. Nishina, A letter to George Hevesy on April 1, 1929, 6.

165. A physicist in previous generations comparable to Nishina in this respect was Honda Kôtarô, who, trained as an experital physicist, worked on physics of steel and created a strong research school in metalurgy at the University of Tohoku.

166. Itakura, Kimura, and Yagi, *Nagaoka Hantarô den*.

Nishina's school building activity in the 1930s was therefore was an act of reconstructing a community of atomic physicists. He tried to raise money to build machines and extend his laboratory, which were means of running a business. He recruited and networked young physicists, to expand his clan of atomic physicists. Ultimately, he aimed to produce scientific results, and gain for the community of Japanese atomic physicists' scientific prestige. Just as Nishina as a member of the Nishina clan aimed to restore the family fortune in the youth, now as a physicist, he tried to accumulated scientific capital of the Japanese physics community, and build its infrastructure to produce further wealth.

4. From Rebuilding the House to Rebuilding Physics

Norms are by definition situational. Black attire is a norm at funeral, but not necessarily at wedding. Nishina's norms in his personal sphere were not necessarily valid in his scientific sphere unless the given situations validated those norms. I claim that nationalism was the link between these two spheres.

Nationalism was not evident in Nishina Yoshio's letters in his youth. Yet, letters from his brothers indicate that he was aware of it, and his later activities seem to show that it was a part of his normative principles. In particular, Teisaku's letters indicate that his conception of "success" was to do good for the country. In his letter to Yoshio on March 1, 1910, mentioned above, recommending that Yoshio should choose engineering in the higher school, he wrote, "Depending the way you work, you can do many interesting things in engineering. The area of engineering work is vast. Depending the way you do it, you can accomplish a great contribution to the country."[167]

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167. Nishina Teisaku, A letter to Nishina Yoshio, March 1, 1910 in *Nishina*

As we have seen, the "school spirit" of the Sixth Higher was very conducive to nationalism. Besides Mr. Kaneko's militaristic stance, the students themselves were voluntarily nationalistic. The declaration of the resolution in response to the newspaper article included an explicitly nationalistic statement such as, "to become of use to the country."[168]

More important for Nishina Yoshio personally was Teisaku's letter of May 3, 1918. It was a reply to Yoshio's above-mentioned letter of May 8, where he expressed his intention to decline Shibaura Workshop's job offer. Teisaku's reply, although he agreed that Yoshio should go to the graduate school, directed toward a completely different career from what Yoshio had written in his letter:

> I am impressed by your firm will and lofty ideal. Entering a graduate school would benefit your later career advancement, and make it easier for you to study abroad in the future. In particular, in my humble opinion, your calling is not money making, but the pursuit of deepest truth in arts and sciences, and thereby to contribute to the country. Please call up your courage and bend every effort to become a pillar of the state.[169]

We do not have Yoshio's reply to this letter, and there is no direct evidence about how he received this piece of advice from the brother. No matter whether or to what extent Nishina Yoshio embraced nationalist sentiment, this letter at least provided Yoshio an assurance from his fatherly figure and rhetoric to justify pursuing his scientific interesting. Since Yoshio had an obligation to rebuild the house, his personal interest would not allow him to pursue a scientific career. Yet,

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Yoshio hakase shokanshû: Shônen jidai hen (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 21.

168. "Kakukumi iinkai hôkoku," 139-40.

169. Nishina Teisaku, A letter to Nishina Yoshio, May 3, 1918 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 141-42.

this obligation could be overridden by a higher cause, namely to serve the country. If pursuing a scientific career could contribute to the country, his action to do so could be justified, as far as he would do to the country what he was originally obliged to do his family. Thus, the appropriate conducts in his familial sphere were translated into his scientific spheres.

Teisaku's permission, however, did not immediately let Nishina Yoshio consider leaving family as appropriate. It is not clear exactly when Nishina decided to pursue an academic career, rather than to be a successful entrepreneur. As I mentioned, even during the years in Europe, Nishina wrote that physics was not enough to devote one's entire life. He contemplated to become a manufacturer of scientific toys, while he was in Germany.[170] Contradictory evidence in these years show Nishina's ambivalence.

Nishina's attitude became more inclined toward physics when his mother Tsune died in October 1922. Nishina was in Germany (very probably in Göttingen), and deeply regreted that he could not see his mother before she died.[171] In his diary, Nishina wrote: "Half of my wishes in my life are gone." He later told his sons that "After your grandmother died, I changed my mind. I began

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170. Nishina Kôjirô, "Chichi Yoshio no ryûgaku seikatsu," 268-70.

171. Nishina Teisaku, A letter to Nishina Yoshio, October 3, 1922 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 152; Nishina Yoshio, A letter to Nishina Toku, on December 6, 1922 in *Nishina Yoshio hakase shokanshû: Shônen jidai hen* (Satoshô: Kagaku Shinkô Nishina Zaidan, 1993), 153-54; Nishina Yoshio, A letter to Uchida Kanae, October 7, 1922 in *Oriori no tayori* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 41; Nishina Yoshio, A letter to Uchida Kanae, October 25, 1922 in *Oriori no tayori* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 42; Nishina Yoshio, A letter to Uchida Kanae, November 13, 1922 in *Oriori no tayori* (Satoshô: Kagakushinkô Nishina Zaidan, 1993), 43.

to think there was no need to go back to Japan in a hurry."[172] Nishina's obligation to his family was not simply his filiality toward his mother. Nor did it originate his love to his mother. It was a social and ethical obligation to the institution of house (*ie*). Yet, it was also probably the case that Tsune constituted a strong psychological bond between Nishina and his clan. Now that this bond was broken, Nishina was even freer than before from the family obligations (Fig. 6.7)

Released from the obligations to the family, fist by Teisaku's letter when he graduated and second by his mother's death, Nishina was able to make his group in Riken his family. He spent most of his time for Riken. His late return to home made his wife suspicious. By her insistence, Nishina allowed her to attend one of his seminars, asking instead to bring fruits as tuition, which made his young disciples happy. When Nishina died, he was not buried in the family cemetery in Hamanaka, but in Tama Cemetery in Tokyo. To complete Nishina's relocation from his conventional family to the scientific clan, his best disciple, Tomonaga Sin-itiro, was buried beside his tomb. (Fig. 6.8)

5. Conclusion

The House of Nishina was declining, and Nishina Yoshio, a child prodigy of the Nishina clan, could have become its savior. He had developed a few norms in his family environment. Partially, his legendary grandfather and his brothers set those norms. Paritly, he had developed then during his schooldays at the conservative Sixth Higher School or in his reading of biographies. His successful achievements at school, his desire to turn to electrical chemistry, his shift of interest to physics at the graduate school, and his chance to study abroad, led Nishina to a considerably different path. In the process, he moved away from the

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172. Nishina Kôjirô, "Chichi Yoshio no ryûgaku seikatsu," 266-68.

Nishina clan, and the members of the Nishina clan began to tolerate Nishina's freedom. His eldest brother Teisaku, the head of the branch Yoshio belonged to, acknowledged that Yoshio's exceptional talent should be directed toward a national good, rather than the restoration of the Nishina clan. Nishina's mother's death further facilitated his shift from the family to physics. In physics, however, Nishina brought in the norms that he cultivated in his familial career. In stead of rebuilding the House of Nishina, he attemped to build up Japan's physics community. As he would have attempted to succeed in the secular world, Nishina brought in entrepreneurial style of scientific research into his group. As his grandfather Arimoto and his brother Empei were trying, Nishina attempted to succeed through his engineering skills, by building better machines. What was appropriate in the familal sphere was not necessarily appropriate in the scientific sphere. Yet, in Nishina's case, he had to justify his scientific enterprise to himself and to his family. For that purpose, Nishina appropriately set it as his goal to rebuild Japan's physics. Since it was a national matter, it could legitimately replace his earlier goal of restoring the Nishina clan.

At the beginning of this chapter, I raised a question whether in Nishina's scientific activities there was a conflict between traditionally Japanese and Western values. The above inquiry might not conclusively answer to this question, because it sought to see only positive connections between Nishina's native norms and his scientific activities. Yet, it does show that the relation between them was at least not a simple conflict. The scientific style that Nishina established at Riken fit well in the norms with which he was familiar in his youth. Those norms were rooted in Japan's rural society, and conditioned by the time and place when Japan was rapidly industrializing the country, by introducing Western technology. They were politically and ideologically loaded in the sense that those norms were constrained by the local household system that bound individuals and the ethos of elite students who aspired to be of use to the country.

Nishina Yoshio, therefore, came from a culture completely different from that of his disciples. It was a combined culture of a progressive but declining rural landlord and an engineer-entrepreneur. This culture of the Nishina clan makes a strong contrast with the rebellious student cultures, in which Nishina Yoshio's disciples were immersed. Their different relations to Kaneko Sentarô, in particular, indicate an abysmal difference between them. As I have written, the difference was both generational and geographical. Moreover, Nishina's study abroad might have helped him to keep the same cultural inclination, by keeping him away from the modernist cultural trends in the late 1920s.

More striking is the success of the cohabitation of different cultures in the school of Nishina. As we have seen in this and the previous chapters, collaboration between Nishina and young physicists worked very well. Nishina gave young physicists what they lacked: scientific leadership, organization, institutional and moral support, and visions of future directions of research. The young physicists provided Nishina with manpower, their theoretical or experimental skills, and, above all, their enthusiasm in the new physics, all of which were essential to realize the kind of physics research that Nishina seems to have envisioned.

- Arimoto
  - Ariyoshi — Ariyuki — Katsumi
    - Yasushi
    - Tamotsu
    - Tadayuki
  - Arihito — Tôtarô — Akira
  - Ariyoshi
  - Arimasa ‖ Tsune
    - Teisaku (1870-1934) — Kajio
    - Empei (1872-1933)
    - Kiyo
    - Riku
    - Toyo
    - Yasuo (1884-1949(
    - Toku
    - Yoshio (1890-1951)
    - Masamichi

Fig. 6.1 Family Tree of the Nishina Clan

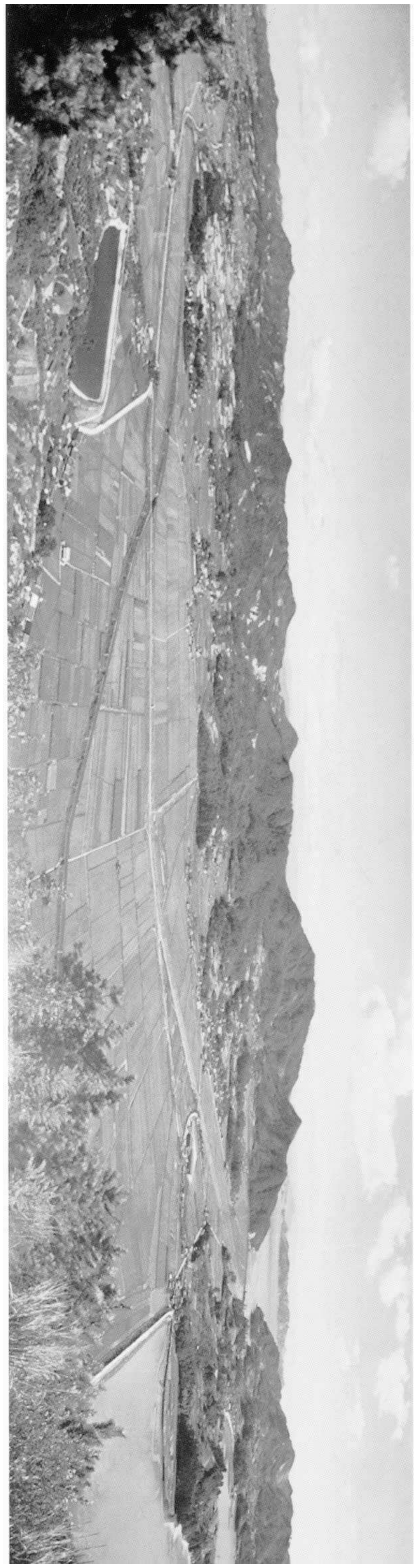

Fig 6.2 Picture of Satosho in the 1950s (Courtesy of Nishina Foundation, Satosho)

Fig. 6.3 The Hamanaka Cemetery (copyright by Kenji Ito)

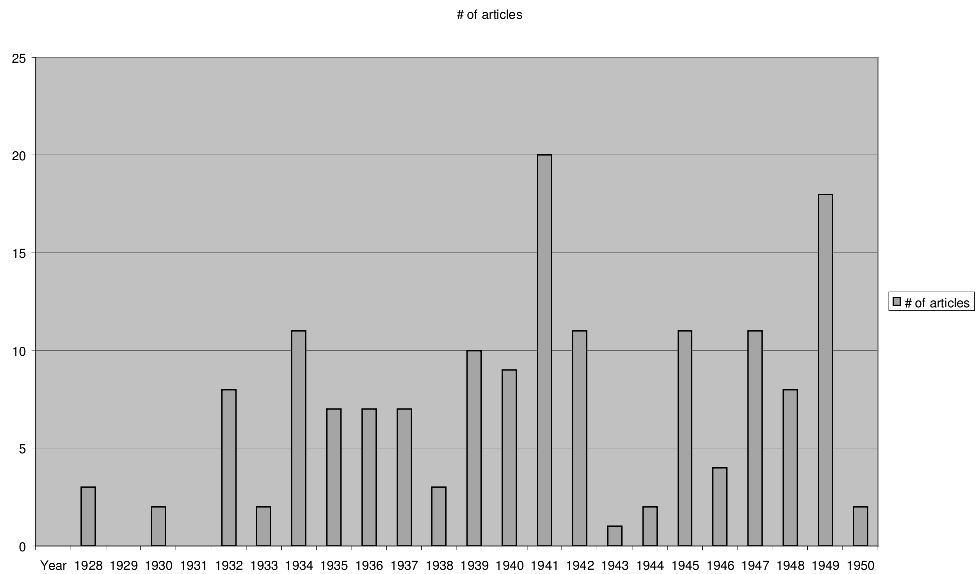

Fig. 6.4 Graph of Nishina's Popular Articles

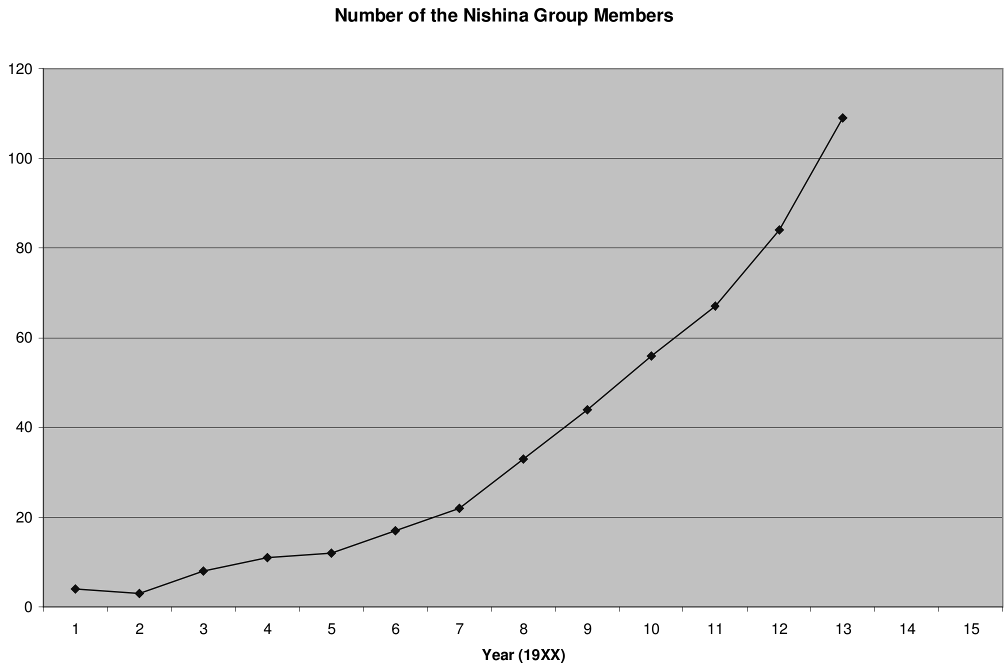

Fig. 6.5 Graph of the Number of Nishina Group Members

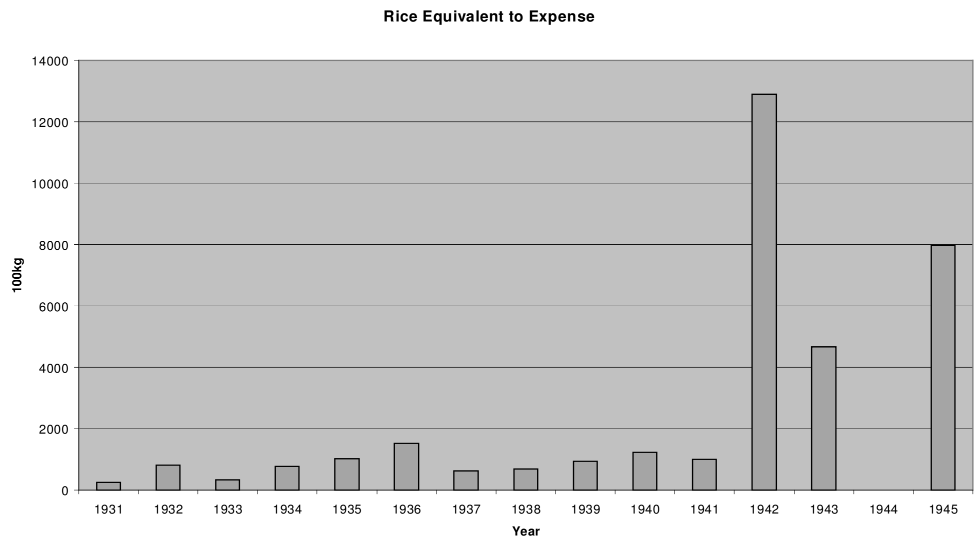

Fig. 6.6 Expense of the Nishina Group
(The prices in year 1941 and 1942 are interpolations. The official rice price in 1944 is dubiously low, and expense in that year cannot be determined)


Fig. 6.7 Nishina Tsune (Courtesy of Nishina Foundation, Satosho)

Fig. 6.8 Nishina's Tomb (Courtesy of Inoue Izumi)
The small stone next to Nishina's tomb is Tomonaga's

Chapter 7
Complementarity in the "Far East":
The Philosophy of Quantum Physics and Japanese Intellectuals around the 1930s

1. Is Quantum Mechanics Akin to Eastern Thought?

Leon Rosenfeld, Niels Bohr's long-time collaborator, once asked Yukawa Hideki, "whether the Japanese physicists had experienced the same difficulty as their Western colleagues in assimilating the idea of complementarity and in adapting themselves to it. He answered, "No, Bohr's argumentation has always appeared quite evident to us.'" Rosenfeld continued, "[A]s I expressed surprise, he added, with his aristocratic smile, 'You see, we in Japan have not been corrupted by Aristotle'." [1]

Yukawa was wrong. His statement that Bohr's complementarity was obvious to Japanese does not do justice to what actually happened when Japanese physicists and intellectuals first confronted this idea in the 1930s. As I discuss later in this chapter, some Japanese felt that complementarity was "profound," or "interesting"; some regarded it as "Machian" and "idealistic." Many physicists and intellectuals paid little attention to complementarity until Bohr's visit to Japan in 1937, gave it publicity. None of them, however, found complementarity "obvious."

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1. Leon Rosenfeld, "Niels Bohr's Contribution to Epistemology," *Physics Today* 16 (1960): 47-54. For the arguments on the relation between complementarity and "Eastern thought," see: D. S. Kothari, "The Complementarity Principle and Eastern Philosophy," in *Niels Bohr: A Centenary Volume*, edited by A. P. French and P. J. Kennedy (Cambridge: Harvard University Press, 1985), 325-31; Ellen Katz, "Niels Bohr: Philosopher-Physicist," Ph. D. Diss. (New York University, 1986). Also, see: Gerald Holton, "The Roots of Complementarity," in *Thematic Origins of Scientific Thought: Kepler to Einstein*, rev. ed. (Cambridge: Harvard University Press, 1973), 99-146.

Apparently Yukawa's perception of complementarity differed considerably from his fellow physicists and other intellectuals.

Yukawa's mistake was not only factual. He made two general assumptions about the culture of physics in Japan, assumptions which I consider fundamentally flawed. First, Yukawa's observation presupposes that there was a single monolithic culture shared by Japanese physicists. Referring to "Japanese physicists" with the first person plural, Yukawa neglected the diversity among them, characterizing them as if they had the same cultural background and the same degree of understanding of Bohr's concept of complementarity.

Second, by imposing such a monolithic view of Japanese physicists, Yukawa's statement tacitly presupposed and reinforced a dichotomous perception of "Eastern" and "Western" cultures. According to Yukawa, there was a definite cultural gap between "Western" culture, which was dominated by Aristotelianism, and Japanese culture, which was not.

By examining how Japanese physicists and other intellectuals from the early 1920s to the late 1940s understood and responded to issues of the interpretation of quantum mechanics, this chapter shows the contrary. First, it shows that the discussion of complementarity in Japan reveals the diversity of the cultures of Japanese physicists and other intellectuals involved in this issue. I can identify at least five different subcultures which gave their specific interpretive frameworks to understand complementarity: (1) research and teaching of physics; (2) science journalism; (3) scientific essay (*zuihitsu*) writing; (4) Marxist activism; and (5) Kyoto School philosophy.

Second, the historical contexts in which Japanese intellectuals discussed quantum mechanics had relatively little connection with traditional "Eastern" thought. Contrary to what Yukawa's statement might suggest, most Japanese intellectuals involved in the philosophical discussions of quantum mechanics were much more familiar with thoughts and ideas from the "West" (whether German idealist philosophy, dialectic materialism, or modern physics itself), than with traditional Japanese or "Eastern" thoughts. At the same time, the discussion of quantum mechanics was embedded in the hybrid intellectual environment of Japan, shaped by the cultural and social conditions of modern Japan.

This chapter aims at more than a critique of Yukawa's remarks. By using the Japanese response to complementarity, it seeks to capture how various cultures in and around the science of prewar Japan interacted with one another. It shows that discussions of scientific issues, such as complementarity, occupied an important place in the cultural sphere of interwar Japan. Not only scientists, but also a wide range of educated Japanese discussed and read about scientific issues. Issues such as complementarity and uncertainty relations drew broad attention, if not deep understanding. Various popular science magazines served the role both of catalysts to stimulate ideas of various intellectuals, and of vehicles to convey new scientific ideas. Numerous scientists regularly wrote popular accounts of science. Philosophers eagerly learned and discussed new scientific discoveries, as if there were no distinction between "two cultures."

The stake are in fact, even higher. Cultural essentialism, so beautifully represented by Yukawa, is not a singular phenomenon. It is ubiquitous both in Japan and in the West. Cultural essentialists believe that cultures in Japan are particular to Japan. In other words, hey believe inan essential" Japaneseness" inherent to Japanese cultures. In science studies, cultural essentialists try to see "Japaneseness" in all the scientific practices. This chapter shows how such an essentialist endeavor fails in the case of complementarity.

At the same time, this chapter will demonstrate the central theme of this volume, by illustrating how differently historical figures in different cultures interpreted the idea of complementality. Not only did the meaning of quantum mechanics differ in Japan from its meaning in Europe, but also one of its principal philosophical ideas evoked different interpretations among different people in Japan.

The chapter begins with Niels Bohr's lecture at the Como conference in 1927, where Bohr presented his idea of complementarity for the first time. A Japanese physicist, Nishina Yoshio, helped Bohr to translate the paper into English.

With Nishina's homecoming, the stage moves to Japan. In the first phase of the introduction of the philosophy of quantum mechanics, a few physicists attempted to promulgate the idea of complementarity, but failed. While Nishina successfully developed a research school of atomic physics, his disciples paid little attention to foundational issues in quantum mechanics in this early period. Sakai Takuzô, who taught quantum mechanics at Tokyo University, gave a substantial account of complementarity in his textbook, but no evidence shows that it attracted much attention. During the second phase, from the late 1920s to the mid-1930s, issues of quantum mechanics gained broader attention among Japanese intellectuals. However, it was not complementarity, but the concepts of uncertainty relations and acausality that interested them. Well-developed science journalism in Japan played the central role in bringing philosophical issues of quantum mechanics within the reach of a broader audience. Japanese intellectuals were ready to respond to the news conveyed by scientific journalists. Philosophers of the Kyoto School and Marxists competed to dominate the Japanese intellectual scene, and such a fundamental issue as causality easily attracted their attention.

Around 1937, when Niels Bohr visited Japan, the situation changed. The mere news that Bohr was coming was enough to induce some to write about Bohr. Only then did many Japanese intellectuals begin paying serious attention to Bohr's complementarity. Their understanding varied. While some philosophers resorted to Hegelian dialectics or neo-Kantianism, Marxists regarded Bohr's philosophy as a form of subjectivism. The way they understood complementarity reflected the contemporary intellectual situation of Japan, where Japanese intellectuals were struggling to assimilate Western ideas, rather than the traditional Japanese thought.

2. The Como lecture and Nishina Yoshio

Niels Bohr presented his idea of complementarity for the first time in public at the meeting held near Como Lake on September 16, 1927. We do not know exactly what he said at the meeting, but a typescript dated October 12 and 13 1927 is supposed to be the closest to Bohr's talk.[2] According to this typescript, Bohr's concern was a fundamental limitation of classical physical concpets when they were applied to atomic phenomena. He argued against the idea of discarding classical concepts even if they might appear inadequate to describe the situations in atomic physics. He argued that, since our interpretation of experimental materials rests upon classical ideas, we have to retain these ideas. On the other hand, he admited, the quantum postulate states that any atomic process involves an essential discontinuity, or "individuality as Bohr put it, symbolized by Planck's quantum of action. This implies that the causal space-time coordination of atomic processes is impossible. The postulate implies that no observation of atomic phenomena is possible without disturbance. If you make an observation of space-time, causality

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2. Jørgen Kalckar, "Introduction," in *Niels Bohr Collected Works*, vol. 6, edited by Jørgen Kalckar (Amsterdam: North-Holland, 1985), 29.

does not hold. If you do not do measurement, you can expect that causal relations, such as conservation laws, are applicable, but you do not know the space-time coordination of the phenomena. Therefore, Bohr claimed, "The very nature of the quantum theory thus forces us to regard the space-time coordination and the claim of causality, the union of which characterizes the classical theories, as complementary features of the description of experience."[3]

After the lecture, an intense discussion with Wolfgang Pauli followed. Bohr and Pauli stayed in a villa near the lake for a week, and apparently finished a draft of the paper in German. In his characteristic way, Bohr repeatedly revised it.[4]

In December, Bohr asked Oskar Klein and Nishina Yoshio to translate his paper into English.[5] As I mentioned in Chapter 4, Nishina stayed in Hamburg and learned quantum mechanics from October 1927 to February 1928 under Wolfgang Pauli's tutelage. Nishina wrote his first theoretical work with Isidor I. Rabi, who moved together with him from Copenhagen.[6] When Nishina came back to Copenhagen, in a collaboration with Klein, he was able to make a fairly important theoretical contribution to the newly developing field of relativistic quantum mechanics.[7]

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3. Niels Bohr, "The Quantum Postulate and the Recent Development of Atomic Theory," in *Niels Bohr Collected Works*, vol. 8, edited by Jorgen Kalckar, reprint, 1927 (Amsterdam: North-Holand, 1985), 91.

4. Kalckar, "Introduction," 29-30.

5. Tamaki Hidehiko, "Nishina Yoshio no yôroppa ryûgaku kôhan (1926-1928) no riron kenkyû ni kansuru shiryô," *Butsurigaku shi nôto*, no. 1 (1991): 18-23.

6. Yoshio Nishina and Isidore I. Rabi, "Der Wahre Absorptionskoeffizient der Röntgenstrahlen Nach der Quantentheorie," *Verhandlungen der Deutschen Physikalischen Gesellschaft* 9 (1928): 6-9.

7. Oskar Klein and Yoshio Nishina, "Über die Streuung von Strahlung durch freie

In Hamburg, Nishina participated in Pauli's seminar, where one of the central themes was conceptual issues concerning quantum mechanics, in particular, Heisenberg's uncertainty relations and Bohr's complementarity. Besides Bohr and Heisenberg, Pauli, who was in close contact with Heisenberg and Bohr, was most deeply involved in the recent developments of the interpretation of quantum mechanics. The entry of Nishina's seminar notes for November 8 reads, "Question of determinism." According to this note, Pauli derived an uncertainty relation of frequency and time for a Gaussian wave packet. In a week, he moved on to discuss the question concerning the measurement of position and momentum, using the gamma-ray microscope. Then he followed Bohr's argument, and concluded that space-time description and causal description were complementary.[8]

Around December 20, Nishina returned to Copenhagen where he spent the Christmas holiday.[9] Bohr asked Nishina and Klein to translate his paper probably because other physicists, especially English speaking physicists, were back in their home countries, and unavailable. Entrusted with the work of translation, Nishina and Klein discussed Bohr's idea of complementarity. Nishina produced 18-page reading note based on the German version of the complementarity paper. Sheets of papers entitled "Discussion with Klein" dated December 21 and December 30 show that Nishina and Klein spent long Scandinavian nights in late December

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Electronen nach der neuen relativistischen Quantendynamik von Dirac," *Zeitschrift für Physik* 52 (1929): 853-68.

8. Yoshio Nishina, "Pauli Seminar," Nishina Yoshio's notes at Pauli's seminar, Sangôkan shiryô, Riken (Wakôshi, Japan, 1927).

9. Nishina's notes of Pauli's lecutre show that he was in Hamburg until December 19, and a note of Nishina's entitled "Discussion with Klein" was dated December 21. Nishina returned to Hamburg by January 9, when his lecture notes of 1928 started.

discussing conceptual issues of quantum mechanics.[10]

Through this experience, Nishina was impressed by and interested in Bohr's idea of complementarity. In his letter to Nagaoka Hantarô, a physicist and former teacher of Nishina, he wrote from Hamburg in 1928 that:

> Bohr's new theory is extremely profound. It shows that particle theory and wave theory of radiation and matter are not contradictory but complementary, and it emphasizes that each of them is only an abstract theory that represents just one side of the matter.[11]

3. Theoretical Physics in 1920s Japan and the Introduction of Quantum Mechanics

3-1. Nishina Yoshio and Research Physicists' Reactions to Complementarity

In spite of his earlier interest and involvements in Bohr's philosophy of quantum mechanics, Nishina did not talk much about the philosophy of quantum mechanics after he came back to Japan. Once Nishina was given a chance to talk about Bohr's theory of measurement at the colloquium of Riken, probably in 1933.[12] He prepared for his talk by reading Bohr's article with his young disciples,

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10. Yoshio Nishina, "Discussion with Klein," manuscript, Sangôkan Shiryô, Kinen Shiryôshitsu, Riken (Wakôshi, Japan, 1927).

11. Yoshio Nishina, letter to Nagaoka Hantarô, January 28 (1928), Nagaoka Hantarô Collection, National Science Museum, Tokyo.

12. It was probably the paper by Bohr and Rosenfeld on field measurement: Niels Bohr and Leon Rosenfeld, "Zur Frage der Messbarkeit der elektromagnetischen Feldgrössen," *Det kongelige Danske Videnskabernes Selskabs, Mathematisk-fysiske Meddelser, series 12, no. 8* (1933): 65; The English translation is: Niels Bohr and Leon Rosenfeld, "On the Question of the Measurability of Electromagnetic Field Quantities," in *Selected Papers by Leon Rosenfeld*, edited by Robert. S. Cohen and John J. Stachel, translated by Aage Petersen (Dordrecht: North-Holland, 1933), 357-400. As for the historical significance of this paper, see: Olivier Darrigal, "Cohérence et complétude de la mécanique quantique: l'example de Bohr-Rosenfeld," *Revue d'histoire des Science* 154 (1991): 137-79.

such as Tomonaga Sin-itiro and Tamaki Hidehiko. They, however, found Bohr's article extremely boring and had a hard time keeping themselves awake, partially because of Nishina's presentation style (he just read the German text to his students). Tamaki Hidehiko, one of Nishina's early disciples, confessed that he always fell asleep, and the only thing he could remember about Nishina's lecture was "the pronunciation of *Zustand* sounded like "chûshutanto." Similarly, Tomonaga felt too drowsy to focus his eyesight, and lines of the book appeared to be doubled.[13]

Nishina also delivered a lecture on Bohr's ideas at a few meetings outside the institute, such as meetings of electrical engineers. His talk there was based on Bohr's Como lecture, discussing the necessity of classical concepts, wave-particle duality, the derivation of the uncertainty relation, and the gamma-ray experiment. Nishina never used the word "complementarity" explicitly, but obviously he had Bohr's complementarity in mind when he explained wave-particle duality as follows: "There is a definite boundary between [particle and wave natures], and by complementing each other, these two constitute a complete system . . ."[14]

However, these lectures and their publications attracted little attention, in contrast to the enthusiastic responses to complementarity in the late 1930s. A meeting of electrical engineers was obviously not a good place to talk about such an issue. Similarly, his article on wave-particle duality and complementarity

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13. Tomonaga Sin-itiro, et al, "Zadan Nishina sensei wo shinonde," in *Hirakareta kenkyûjo to sono shidôsha tachi*, vol. 6 of *Tomonaga Sin-itiro chosakushû*, reprint, 1951 (Tokyo: Misuzu Shobô, 1982), 61.

14. Nishina Yoshio, "Ryôshiron to ingasei ni tsuite," *Denki Gakkai Zasshi* 50 (1929): 133-45. Another lecture by Nishina related complementarity was: Nishina Yoshio, "Hikari to busshitsu no sôji to sôi (1)," *Rika kyôiku*, no. 4 (April 1931): 18-26; Nishina Yoshio, "Hikari to busshitsu no sôji to sôi (2)," *Rika kyôiku*, no. 5 (May 1931): 22-31.

appeared in the journal *Rika kyôiku* (Science Education), a journal for science teachers, which did not prove to be a particularly good place for reaching and stimulating intellectuals and scientists.

3-2. Sakai Takuzô and Complementarity in Textbooks

Probably the first Japanese word for "complementarity" appeared in 1930 in a textbook, *Ryôshiron* (Quantum Theory), written by a young physicist, Sakai Takuzô.[15] Since 1928, Sakai was teaching quantum mechanics at Tokyo University as an associate professor. He graduated from the Department of Physics at Tokyo University with a specialty of electromagnetism and thermodynamics. Although he was not doing any research in quantum mechanics, to fill in the gap caused by Nagaoka Hantarô's retirement, Sakai had to teach it.

Sakai's book was the first textbook of quantum mechanics in Japan, and one of the earliest anywhere. Due to the lack of any reliable textbook (in any language) on quantum mechanics,[16] Sakai had to base his writing mostly on primary sources. He devoted the last section of his book to a treatment of the interpretation of quantum mechanics, discussing both uncertainty relations and

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15. Sakai Takuzô, *Ryôshiron*, Iwanami kôza butsuri oyobi kagaku (Tokyo: Iwanami Shoten, 1930).

16. By the time this text book was published, Sakai was able to refer to the following books: Max Born and Pascual Jordan, *Elementare Quantenmechanik* (Berlin: Springer, 1930); Iakov Il'ich Frenkel,' *Einführung in die Wellenmechanik* (Berlin: Springer, 1929); Arnold Sommerfeld, *Atombau und Spektrallinien, wellenmechanischer Erganzungsband* (Braunschweig: Friedrich Vieweg und Sohn, 1929); Hermann Weyl, *Gruppentheorie und Quantenmechanik* (Leipzig: S. Hirzel, 1928); Werner Heisenberg, *Die physikalischen Prinzipien der Quantentheorie* (Leipzig: S. Hirzel, 1930); Paul Adrian Maurice Dirac, *The Principles of Quantum Mechanics* (Oxford: Clarendon Press, 1930). Besides Bohr's Como Lecture, Sakai seems to have used Heisenberg's book when he wrote the part on interpretation of quantum mechanics.

complementarity. His translation of complementarity as *hosoku kankei* or *hosokusei*, was generally followed, with only slight variations, until 1938. His explanation of complementarity was obviously based on Bohr's Como Lecture. Sakai wrote:

> Our experiment can determine various quantities only within the limits shown by uncertainty relations at the same time. This is the fundamental idea of quantum theory.
> Reflecting on these matters, Bohr stated the following. First, our measurement is fundamentally connected to the framework of space-time. If measurement does not disturb the object to be measured, and, hence, there is no room for arbitrariness, we will always have the same state and can give the same definition to all the physical quantities. Hence, a system from the same initial state will reach the same final state, and we can find a causal relation between them. This was the idea in the old theory.
>
> In quantum theory however, . . . we cannot neglect the effect of measurement. In other words, when we try to define the system spatio-temporally, there is always room for arbitrariness. On the other hand, if we try to retain causality, then the system should remain closed, unaffected by outside influence. In that case, however, we cannot know anything about such a system by observation (this is complementarity [*hosokusei*] of spatio-temporal description and causality).[17]

Complementarity and uncertainty caught Sakai's attention, not because he was particularly oriented to the philosophical discussion of quantum mechanics, but because, as a teacher, Sakai had to explain what all these unfamiliar symbols in quantum mechanics meant. He had to seek ways to make this new theory understandable to students (and probably to himself), and in order to do so, he naturally relied on the most orthodox source, in this case, the so-called Copenhagen interpretation of quantum mechanics. Thus, the pedagogical setting provided one of the earliest loci for conceptual problems of quantum mechanics.

3-3. Failed Dissemination

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17. Sakai Takuzô, *Ryôshiron*, 179-80.

Some Japanese physicists, therefore, from the very beginning, had considerable familiarity with complementarity. Both Nishina and Sakai showed fair understanding of complementarity. As a translator of the quintessential text of complementarity, Nishina was more familiar with Bohr's idea. Sakai was, at least, able to locate some of Bohrs most important ideas. Both Nishina and Sakai occupied an important position in physics. One was about to lead atomic physics research at the most prominent research center in Japan, Institute of Physical Chemical Research. The other was teaching the quantum mechanics course at Japan's most prestigious pedagogical institution, Tokyo University, where the majority of research physicists received their undergraduate education.

Yet, at this point, Nishina's and Sakai's works and teaching seems to have induced none of their students to pay any serious attention to complementarity. As we saw above, Nishina's disciples did not show any interest in the foundational problems of quantum mechanics.[18] Sakai's students rarely recalled his lecture on quantum mechanics, much less quoted from his textbook. As we see in the next section, complementarity became a major issue among Japanese intellectuals only after the mid-1930s. This suggests that, except for someone like Nishina who studied under Bohr, or Sakai, who needed to consult Bohr's writing for his lecture and textbook, Japanese intellectuals in general were not particularly receptive to the idea of complementarity. In other words, there was nothing among the Japanese that made them intrinsically congenial to complementarity.

Nishina and Sakai lacked an adequate audience and context when they discussed complementarity. The pedagogical setting of an authoritarian university

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18. This does not mean that none of Nishina's disciples ever showed any interest in philosophical issues related to quantum mechanics. Later, Sakata Shôichi, one of Nishina's early disciples, wrote a book on the methodology of physics. As we ill see, Taketani Mituo showed strong interests in philosophical problems. These,

stripped Bohr's idea of intellectual and philosophical appeal. In Riken, scientists were too busy to catch up with the newest scientific developments. These were not suitable contexts in which people could conduct philosophical discussions of quantum mechanics. In different places in Japan, suitable media and receptive audience existed (as we will see in the next section), yet there was no institutional context that made these available to Nishina and Sakai at this point.

4. Causality and Dialectic Materialism, 1927---1937

4-1. Causality and science journalism

One of the most salient features of quantum mechanics was its acausal nature. The notion of probability was introduced into quantum theory by Albert Einstein in 1916, when he derived Planck's distribution elegantly by considering transition probabilities between different energy states.[19] In 1918, Niels Bohr used Einstein's idea of transition probabilities in his atomic model, and developed his correspondence principle.[20] They were not clear whether their probabilities were merely statistical, or essentially acausal, but in 1924, Niels Bohr, with Hendrik Kramers and John Slater, introduced an essential probability in the so-called BKS theory.[21] Early works on what we call matrix mechanics, such as Werner Heisenberg's first paper of quantum mechanics in 1925 or the so-called *Drei*

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however, happened later, and in a very different context.

19. Albert Einstein, "Zur Quantentheorie der Strahlung," *Physikalische Gesellschaft Zürich, Mitteilungen* 18 (1916): 47-62.

20. Niels Bohr, "On the Quantum Theory of Line-Spectra," *D. Kgl. Danske Vidensk Selsk. Skrifter, Naturvidensk. Og Mathem. Afd. 8. Raekke, IV, 1, 1-3* (1918).

21. Niels Bohr, H. Kramers, and J. Slater, "The Quantum Theory of Radiation," *Philosophical Magazine* 47 (1924): 785-867.

Männer Arbeit by Heisenberg, Pascual Jordan, and Max Born, inherited the notion of transition probabilities from Bohr's correspondence principle. But these authors were not yet explicit as to whether these probabilities were essential or apparent.[22] The first person who explicitly stated that the new quantum mechanics was indeterministic was Max Born. In his work on collision, Born interpreted Schrödinger's wave functions as representing probabilities and claimed that deterministic descriptions were impossible (he was, however, explicitly neutral about whether there would be a deterministic theory in future).[23] Being infuriated by Born's betrayal to the matrix (or "quantum") mechanics camp, Heisenberg countered Born by showing that in fluctuation phenomena his "quantum mechanics" could incorporate a probabilistic interpretation.[24] P. A. M. Dirac and Jordan generalized Heisenberg's theory in their transformation theory, incorporating probabilistic ideas in it.[25] Extending Dirac and Jordan's transformation theory and adding his own gamma-ray microscope thought experiment, Heisenberg derived his famous uncertainty relations. It was probably the most serious blow to determinism, by undermining the premise of determinism

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22. Werner Heisenberg, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen," *Zeitschrift für Physik* 33 (1925): 879-93; Max Born, Werner Heisenberg, and Pascual Jordan, "Zur Quantenmechanik II," *Zeitschrift für Physik* 35 (1926): 557-615.

23. Max Born, "Zur Quantenmechanik der Stossvorgänge," *Zeitschrift fûr Physik* 37 (1926): 863-67; Max Born, "Quantenmechanik der Stossvorgänge," *Zeitschrift fûr Physik* 38 (1926): 803-27.

24. Heisenberg, "Schwankungserscheinungen und Quantenmechanik," *Zeitschrift für Physik* 40 (1927): 501-06.

25. Paul A. M. Dirac, "The Physical Interpretation of the Quantum Dynamics," *Proceedings of the Royal Society of London, Series A* 113 (1927): 621-41; Pascual Jordan, "Über eine neue Begründung der Quantenmechanik," *Zeitschrift für Physik* 40 (1927): 809-38.

(or at least that was what Heisenberg contended).[26]

Japanese physicists had, of course, access to many of those works. By their exposure to those developments, and Born and Heisenberg's discussions on causality and determinism, it was then natural that during the earliest discussions concerning the philosophical problems of quantum mechanics in Japan acausality was front and center.

Already in September 1927, Kurihara Kaname discussed acausality in his "Recent Physics and Causality," published in *Tôyô gakugei zasshi*(Eastern Journal of Arts and Sciences). Kurihara was a young physicist who graduated the Department of Theoretical Physics at Tokyo University in 1923. He became a professor of the University of Mercantile Marine and later of the First Higher School.[27] Mentioning Pascual Jordan's "Philosophical Foundations of Quantum Theory,"[28] Kurihara characterizes quantum theory as probabilistic. He, however, refused to posit essential indeterminacy as a scientific postulate. He claimed that one probability in quantum theory did not indicate indeterminacy, but a different kind of determinedness than in macroscopic physics. "Wtih Max Planck," he declared, "I would like to believe in *Gesetzlichkeit* of nature." He suggested that the "synthesis of lawfulness and probability" would be the problem to be solved, and that "after its solution, a new and lofty world view will perhaps emerge."[29]

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26. Werner Heisenberg, "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Dynamik," *Zeitschrift für Physik* 43 (1927): 172-98.

27. Kagaku Bunka Shimbunsha, ed., *Gendai Nihon kagaku gijutsusha meikan (Japanese Men of Science: Short Biography)* (Tokyo: Kagaku Bunka Shuppansha, 1949), 40.

28. Pascual Jordan, "Philosophical Foundations of Quantum Theory," *Nature* 119 (1927): 566-69, translated by Robert Oppenheimer.

29. Kurihara Kaname, "Saikin no butsurigaku to ingaritsu," *Tôyô gakugei zasshi* 43, no. 533 (1927): 501-06.

In the following year, another young physicist, Ochiai Kiichirô, a former classmate of Kurihara, mentioned the statistical interpretation of quantum mechanics and Heisenberg's uncertainty relations. It was part of a review of recent developments in atomic physics published in *Rika kyoiku* (Science education), a journal for science teachers of secondary education. Here, Ochiai claimed that although for an individual electron causality would not hold, for the statistical expectation of many electrons, which, he said, was what was really observed), causality remained valid.[30]

During the 1930s, Japanese intellectuals and readers began paying more attention to the issue of causality in quantum mechanics, following, in this respect, European trends. Some of the popular science writings by European scientists, such as Arthur Eddington, James Jeans, or Pascual Jordan were translated and well read.[31]

For example, Eddington, who was not sympathetic to determinism even

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30. Ochiai Kiichirô, "Shin genshi rikigaku," *Rika kyôiku* 11, no. 6 (June 1928): 19-25.

31. Arthur Eddington, "Ketteiron no chôraku," translated and abridged by Jun Ishiwara, *Kagaku* 3 (1932): 231-34, 276-80 translated from Arthur Eddington, "Decline of Determinism," *Nature* 129 (1932): 233-40. James H. Jeans, *Shin butsurigaku no uchûzô*, translated by Yamamura Kiyoshi (Tokyo: Kôseisha, 1932); James H. Jeans, *Shimpi Na Uchû*, translated by Suzuki Takanobu (Tokyo: Iwanami Shoten, 1938) both translated from James H. Jeans, *The Mysterious Universe* (Cambridge: Cambridge University Press, 1930); James H. Jeans, *Kagaku no shin haikei*, translated by Kagawa Toyohiko and Nakamura Shishio (1934) translated from James H. Jeans, *New Background of Science* (Cambridge: Cambridge University Press, 1933); Pascual Jordan, "Ryôshirikigaku to seibutsugaku oyobi shinrigaku no konpon mondai," translated and abridged Jun Ishiwara, *Kagaku* 3 (1933): 9-11, translated from Pascual Jordan, "Quantenmechanik und Grundprobleme der Biologie und Psychologie," *Die Naturwissenschaften* 20 (1932): 815-21).

before quantum mechanics,[32] now happily declared, "Determinism has faded out of theoretical physics." Whereas wave mechanics did not differ much from classical hydrodynamics, the difference was that "in the older formulae every symbol was theoretically determinable by observation, in the present theory there occur symbols the values of which are not assignable by observation."[33] In other words, even if we had a definite solution for Schrödinger's equation, because of the "Principle of Uncertainty," the solution would contain indeterminable symbols. From this physical indeterminism, Eddington moved to "Mental Indeterminism," claiming that "[i]f the atom has indeterminacy, surely the human mind will have an equal indeterminacy."[34]

Whereas Eddington admitted that the indeterminacy of human movements might be quantitatively insignificant, Pascual Jordan came up with an idea to explain free will. Jordan was a distinguished theoretical physicist, a collaborator of Max Born and Werner Heisenberg, as well as a self-avowed positivist. He argued that there was an "amplifier mechanism" in an organism, which could amplify the quantum mechanical uncertainty, combined with the "amplifier mechanism." As a result, an organism could create a macroscopic uncertainty, which would explain the freedom of will. In addition, he argued that the intermediary ontological status of wave functions suggested the possibility of telepathy.[35]

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32. Paul Forman, "The Reception of an Acausal Quantum Mechanics in Germany and Britain," in *The Reception of Unconventional Science*, Seymour. H. Mauskopf (Boulder: Westview Press, 1979), 32.

33. Eddington, "Decline of Determinism," 238.

34. Ibid., 240.

35. Pascual Jordan, *Anschauliche Quantentheorie: Eine Einführung in die moderne Auffassung der Quantenerscheinungen* (Berlin: Springer, 1936); M. Norton Wise, "Pascual Jordan: Quantum Mechanics, Psychology, National

Other than translations of these articles by Eddington and Jordan, science magazines in Japan carried numerous articles on the breakdown of causality in quantum mechanics.[36] These accounts were mostly based on Heisenberg's uncertainty relations, which became so well known that by then people referred to uncertain relation as "*that* well-known uncertainty relation" (rei no fukakuteisei-kankei).

The rise of science journalism enabled a wide range of Japanese intellectuals to participate in the discussion of quantum mechanics as accompanying uncertainty and complementarity. The earliest semi-popular scientific journal, *Tôyô gakugei zasshi* had started in 1871. Science journalism aimed to report recent developments of science to a broad range of readership. Japanese scientists took on the task of spreading the newest scientific knowledge seriously. Even Nagaoka Hantarô, one of the most research-oriented scientists, took this task seriously. He published extensive popular accounts of various topics

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Socialism," in *Science, Technology and National Socialism*, edited by Mark Walker and Monika Renneberg (Cambridge: Cambridge University Press, 1993), 224-54; Richard Beyler, "From Positivism to Organicism: Pascual Jordan's Interpretation of Modern Physics in Cultural Context," Ph. D. Diss. (Cambridge: Harvard University, 1996); Richard Beyler, "Targeting the Organism: The Scientific and Cultural Context of Pascual Jordan's Quantum Biology, 1932-1947," *Isis* 87 (1996): 248-73.

36. Ishiwara Jun, "Fukakuteisei genri nitsuite," *Kagaku* 1 (1931): 313-15; Takeuchi Tokio, "Arashi no nakanaru shin butsurigaku," *Kagaku chishiki* 12, no. 1 (January 1932): 54-56; Hoda Sakae, "Ingaritsu ni kansuru ichi kôsatsu," *Nihon gakujutsu kyôkai hôkoku* 7, no. 1 (March 1932): 7-11; N. S., "Ingaritsu to ryôshirikigaku," *Tetsugaku zasshi*, no. 539 (January 1932); Ishiwara Jun, "Ingaritsu no mondai," *Kagaku* 3 (1932): 231-34, 276-80; Max von Laue, "Ingaritsu ni kansuru setsumei ni tsuite," excerpt in Japanese, *Kagaku* 3 (1933): 102; Eddington, "Ketteiron no chôraku"; Takeuchi Tokio, "Shizen kagaku no hijôji," *Kaizô* 15, no. 1 (January 1933): 246-50; Ishiwara Jun, "Haizenberuku no fukakuteisei kankei," in *Kagaku tokubetsu daimoku*, Iwanami kôza butsuri oyobi kagaku (Tokyo: Iwanami Shoten, 1933), 631-46; Sugai Jun'ichi, "Ingaritsu ni kansuru sho mondai," *Risô*, no. 46 (March 1934): 68-79.

in physics, touching on topics easily accessible to non-physicists, such as biographies of famous physicists and recent discoveries in physics.

From the 1910s to the 1930s, science journalism developed steadily in Japan. In addition to well-established journals, such as *Tôyô gakugei zasshi* in 1861 and *Rigakukai* (The World of Science, founded in 1904), new scientific magazines appeared: *Gendai no kagaku* (Contemporary Science, 1912), *Kagaku to bungei* (Science and Literature, 1914), *Rika kyôiku* (Science Education, 1917), *Kdomo to kagaku* (The Youth and Science, 1917), *Shonen kagaku* (Science for Boys, 1917), *Kagaku gahô* (Illustrated Reports of Science1919), *Kagaku zasshi* (Magazine of Science, 1920), *Kagaku chishiki* (Scientific Knowledge, 1921), *Kagaku gahô* (Illustrated Report of Science, 1923), *Kodomo no kagaku* (Science for the Youth, 1924), *Shizen kagaku* (Natural Science, 1926), *Butsuri kagaku no shinpo* (Progress of Physical Sciences 1926), *Kagaku* (Science, 1931), *Sôgô kagaku* (General Science, 1935), and *Kagaku pen* (Science Pen, 1936). Other journals dealing with broader topics, especially philosophical journals, quite often carried articles on the natural sciences. These journals included: *Tetsugaku kenkyû* (Philosophy Studies, 1917), *Kaizô*(Rebuilding, 1918), *Warera* (We, 1918), *Shisô* (Thought, 1921), *Yuibutsurron kenkyû* (Materialism Studies, 1933), *Sekai bunka* (World Culture, 1935), and *Chisei* (Intellect, 1938). These journals provided Japanese intellectuals with forums where they could discuss a wide range of topics including issues of quantum mechanics, and debate with people from various backgrounds.[37]

A German-trained ex-physicist, Ishiwara Jun, held the first rank among Japanese scientific journalists. He had once been a leading theoretical physicist in

37. On science magazines in prewar Japan, see: Takata Seiji, "Kagaku zasshi no senzen to sengo," *Butsuri* 51 (1996): 189-93.

Japan. As I mentioned in Chapter 2, he produced first-rate works in the field of early quantum theory and relativity. In 1921, however, he lost his professorship at Tôhoku University. He had an affair with a beautiful poetess Hara Asao. Madly in love with Hara, Ishiwara left his wife and childrenhis relation with Hara public. This, in turn, became a well-publicized scandal, leading to his resignation and premature retirement from the scientific community.[38] After retirement, Ishiwara focused his activities on the popularization of science. When Einstein visited Japan in 1922, Ishiwara worked as the interpreter for his lectures.[39] In 1931, he became the editor-in-chief of *Kagaku* (Science), one of the major scientific journals, published by Japan's leading academic publisher, Iwanami Shoten. Since then, he played an essential role in the science journalism of the prewar Japan.

Although no longer a member of the scientific community proper, Ishiwara's science journalism was held in high esteem. Scientists generally despised scientific journalists who wrote inaccurate accounts on science and made money from them.[40] Since Ishiwara's scientific works were among the best in Japan, he was certainly not the kind of journalist who would sell unreliable articles on science to newspapers and magazines. Indeed, Ishiwara's authority was enough to make other scientific journalists to address him as *sensei* (literary, "My teacher"), an honorific, which journalists did not tend to use among themselves.[41]

Ishiwara also played a central role in discussions about causality in quantum mechanics. As early as 1927, in his "Essence of Quantum Theory"

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38. Ôhara Tomie, *Hara Asao* (Tokyo: Kôdansha, 1996).

39. Kaneko Tsutomu, *Ainshutain shokku* (Tokyo: Kawade Shobô, 1981).

40. For example, both Terada, and Nagaoka complained that Newspaper wrote lies about science. See:

(*Ryôshiron no honshitsu*),[42] Ishiwara mentioned the issue of acausality. His 1931 paper, "On the Uncertainty Principle" (*Fukakuteisei genri ni tsuite*) was not only his major work on acausality in quantum mechanics, but also one of the few articles by Ishiwara that, implicitly, referred to Bohr's idea of complementarity.[43] After an explanation of wave-particle duality, he wrote:

> Now, we can give an answer to this problem today, thanks to the new development of quantum mechanics. Mostly Heisenberg and Bohr clarified this. According to their interpretation, the aforementioned duality is not **contradictory**, but **complementary**. The nature of physical objects, such as matter, electrons, or light, is investigated by various experiments. Certain experimental methods reveal particulate nature, others, wave nature, and no method can ever allow us to see them both at the same time [emphases are Ishiwara's].[44]

However, Ishiwara's main concerns were the uncertainty relations and causality rather than complementarity. The uncertainty principle was, Ishiwara said, "loudly" asserted as forcing us to reject causality. Although causality did not hold for electrons, nonetheless, Ishiwara claimed, it remained valid in the physical laws in the domain of everyday phenomena.

> Certainly, causality in the old sense is no longer valid. Yet, as far as physical laws that we ordinarily experience are concerned, even if they can be analyzed into electronic phenomena with uncertainty, hence, and are probabilistic phenomena, it seems quite natural to regard them as exactly

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41. For example, Nishina Yoshio, et al., "Zadankai: kagaku oyobi kagaku bunmei wo kataru," *Nihonhyôron*, May 1937, 191-223

42. Ishiwara Jun, "Ryôshiron no honshitsu," *Taiyô* 3, no. 11 (September 1927): 69-86.

43. Ishiwara Jun, "Fukakuteisei genri nitsuite," *Kagaku* 1, no. 7 (October 1931): 313-15.

44. Ibid., 313.

valid, and to save causality, because the probability that a phenomenon contrary to these laws happens is extremely small.[45]

Sugai Jun'ichi, a physicist, science writer, and later technocrat, stated a similar view in 1934.[46] Sugai admitted that uncertainty relations would imply the rejection of mechanical causality, but he claimed that they included the old causality as a special cause, hence that quantum mechanics posed a "causality of higher order." This higher order, Sugai claimed, encompassed the two initially contradictory physical laws (that is, causality and uncertainty).[47]

Takeuchi Tokio was another important science journalist. He graduated from the department of experimental physics at Tokyo University in 1918, and after serving as an engineer at Mitsubishi Nagasaki Shipyard, he became a professor at Tokyo Technical Higher School (now Tokyo Institute of Technology). Unlike Ishiwara, Takeuchi's works did not include any original contribution to physics, but he produced many short articles in English, and wrote popular accounts of physics. In particular, it is noteworthy that his book published in 1927 (*Shin ryôshi rikigaku oyobi shin hadô rikigaku ronsô*) was one of the earliest introductions of quantum mechanics into Japan.[48] This book, a collection of popular accounts by Heisenberg, de Broglie, Schrödinger and others, does not indicate to what extent the translator understood what he was translating. In spite of all the shortcomings, the fact that he realized the importance of quantum mechanics as early as 1927 indicates his ability as a science journalist.

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45. Ibid., 314.

46. Sugai Jun'ichi, "Ingaritsu ni kansuru sho mondai."

47. For a similar view, see: Hoda Sakae, "Ingaritsu ni kansuru ichi kôsatsu."

48. Takeuchi Tokio, *Shin ryôshi rikigaku oyobi hadô rikigaku ronsô* (Tokyo:

In the early 1930s, Takeuchi was quick to jump on the issue of acausality, and successfully made sensational news out of it. A 1932 article, entitled "Physics in a Storm," for example, was a hodgepodge of ideas from various people, including Heisenberg, Planck, Bohr, and Schrödinger. Here, he claimed that "Today physics has entered the period of *Sturm und Drang*. Once we overcome this crisis, wonderful new phenomena will be discovered, and the deepest secret of our theoretical knowledge will be found."[49] More explicitly, in an article written the following year, he claimed that natural science was in an "emergency," because physics, which was, according to him, the "monarch of all the natural sciences" was undergoing a vast conceptual change. The prime reason for that change was the denial of a strict causality.[50] When a radium atom decays, we only know its probability. Takeuchi explained that it was not due to a lack of knowledge, but because the process was essentially probabilistic. Takeuchi, then, gave a short account of Heisenberg's uncertainty relations, including his gamma-ray microscope experiment, and went on to claim that the issue of acausality in physics illuminated the problem of free will, roughly repeating Pascual Jordan's argument.[51]

Acausality was a double-edged sword for scientific journalists such as Ishiwara. On the one hand, they welcomed this issue; scientific journalists were always thirsty for big events to write about. The breakdown of causality had in itself tremendous "news value." Since this topic addressed mysterious issues such as free will or telepathy, it could attract a large general readership. Moreover, scientific journalists fashioned themselves as popularizers of science, not critics.

Daitôkaku, 1927).

49. Takeuchi Tokio, "Arashi no nakanaru shin butsurigaku," 56.

50. Takeuchi Tokio, "Shizen kagaku no hijôji," 246.

51. Ibid., 249.

This implied that they could not contradict venerable European physicists, such as Arthur Eddington. If in Europe physicists thought that causality no longer worked, the job of scientific journalists was to convey this view as a fact.

On the other hand, there was a danger that a total rejection of causality would undermine their position as scientific journalists. Causality was the linchpin of scientific rationality and its rigor. Science, especially physics, could boast of its special status as a privileged form of human knowledge, partly because of the precision of its predictions. The authority of scientific journalists hinged upon the authority of science itself. Hence, I claim, their option was to reject causality dutifully, following European physicists, but create a substitute immediately (such as, a "causality of higher order" proposed by Sugai).

In later years, Niels Bohr presented his complementarity as a "wider framework," which should take the place of causality.[52] Japanese intellectuals were in search of a new framework, a substitute of causality, but did not realize that complementarity could provide what they wanted, and paid little attention to this idea at this point. Science journalists probably did not see much news value in Bohr's complementarity. As was the case with most of his papers, Bohr's paper on complementarity was written in ambiguous language. It must have been difficult to see any sensational aspects in it. It could be easily seen as just another way of talking about uncertainty relations or wave-particle duality.

In the 1920s, therefore, there existed strong science journalism in Japan, and it played a dual role. On the one hand, it served as a vehicle to carry new scientific ideas. On the other hand, it employed its own interpretive framework. Since science journalism looked at scientific events in terms of news values,

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52. Niels Bohr, "Quantum Physics and Philosophy: Causality and Complementarity," in *Essays 1958-1962 on Atomic Physics and Human Knowledge* (New York: Wiley & Sons, 1963), 7.

complementarity did not attain prominence, especially because it had to compete directly with acausality and uncertainty relations.

4-2. Dialectical Materialism and Quantum Mechanics: Marxist intellectuals, Kyoto School philosophers and scientific journalists

The two major streams of intellectuals in prewar Japan, as far as the philosophy of science was concerned, were the Kyoto School philosophers (in a broad sense) and the Marxists. These two intellectual movements were in many ways antithetical, yet some aspects of both were products of the same social environment of a country that was hastily Westernizing. Nationalist aspects in the Kyoto School philosophy represented an attempt to essentialize and retain Japan's national identity in reaction to forced Westernization. Japanese Marxism was partially a reaction to social and economic problems caused by hasty modernization.

The 1930s were the years when Marxists actively engaged in a broad range of intellectual endeavors. The philosophy of science was no exception. Both Friedrich Engels's *Dialektik der Natur* and Vladimir Lenin's *Materialism and Empirico-criticism* were translated into Japanese around 1930, providing Japanese Marxist philosophers with bases for their philosophy of science.[53] As for the history of science, *Science at the Cross Roads,*[54] a collection of papers by Soviet

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53. Friedrich Engels, *Shizen benshôhô*, edited and translated by Tadashi Katô and Yujiô Kako (Tokyo: Iwanamisho Shoten, 1929-32); Vladimir Il'ich Lenin, *Yiubutsuron to keikenhihanron*, translated by Fumio Sano (Tokyo: Iwanami Shoten, 1930-31). For a brief account of Engels' and Lenin's philosophy of science, see: Loren R. Graham, *Science, Philosophy, and Human Behavior in the Soviet Union* (New York: Columbia University Press, 1987), 30-35; and Helena Sheehan, *Marxism and the Philosophy of Science: A Critical History* (New Jersey: Humanities Press, 1985), Chapters 1 and 3.

historians and philosophers of science, which included a classic article by Boris Hessen on the social roots of Newtonian mechanics, was translated twice into Japanese right after the publication of the original book.[55] In 1935, a prominent Marxist philosopher, Tosaka Jun, published the first systematic Marxist theory of science by a Japanese author, *Kagakuron* (Theory of science).[56]

Kyoto school philosophers were considered the leading representatives of philosophical thought in prewar Japan. Although there was a leftist faction within the Kyoto school, and those who were sympathetic to Marxism, Kyoto school philosophers were generally politically conservative.[57] Later in the 1940s, some (for example, Kôsaka Masaaki, Kôyama Iwao, and Watsuji Tetsurô) willingly cooperated with the Japanese military government, and gave ideological and theoretical support to its cause.[58] Their political alignment and position in the philosophical community, which was usually idealistic,[59] made them the natural

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54. *Science at the Cross Roads: Papers Presented to the International Congress of the History of Science and Technology Held in London from June 9th to July 3rd, 1931, by the Delegates of the U. S. S. R.*, reprint, 1931 (London: Frank Cass, 1971).

55. *Shinkô shizenkagaku ronshû*, Puroretaria Kagaku Kenkyûjo (Tokyo: Sangyô rôdô chôshasho, 1932); *Kiro ni tatsu shizen kagaku*, Yuibutsuron Kenkyûkai (Tokyo: Ôhata Shoten, 1934).

56. Tosaka Jun, *Kagakuron*, Yuibutsuron Zensho (Tokyo: Mikasa Shobô, 1935).

57. This does not mean that no Marxist existed in Kyoto. Many Marxist intellectuals, such as the members of Yuibutsuron Kenkyûkai (Society of Materialism Studies), were based in Tokyo, but prominent Marxist philosophers of science, such as Tosaka and Taketani Mitsuo were active in Kyoto.

58. Saburô Ienaga, *The Pacific War, 1931-1945: A Critical Perspective on Japan's Role in World War II* (New York: Pantheon Books, 1978), 122.

59. Here I use the term "idealism" to indicate a category of philosophical tradition (such as German idealism), not "idealism" in the colloquial sense.

enemies of Marxist intellectuals, who were usually materialist and anti-government.[60]

The debate between the Marxists and Kyoto School philosophers concerning quantum mechanics began with Tanabe Hajime's article. Tanabe was a former professor of the philosophy of science at Tohoku Imperial University. He moved to Kyoto University, and joined the group of philosophers, led by the most famous philosopher in Japan, Nishida Kitarô. Tanabe was probably the most influential philosopher of science in Japan. While Nishida Kitarô's interest was more in religion than in science, Tanabe, who originally intended to become a mathematician, was more interested in science, especially mathematics and physics.[61] Tanabe started his career as a philosopher with Kantian or neo-Kantian examinations of physics and mathematics. From the mid-1920s, however, Tanabe was increasingly inclined toward Hegelian dialectics.[62]

Tanabe was extremely influential. Many philosophers and scientists, including young Yukawa Hideki and Taketani Mitsuo, read his books and were

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60. There was a wide spectrum of political alignment among the Kyoto School thinkers, and not every was politically conservative or nationalistic.

61. Tanabe wrote extensively on religion and ethics, and, ironically, it is this aspect of Tanabe's work that scholars, both in Japan and in other countries, pay most attention to. This scholarly bias does not reflect the features of Tanabe's philosophical works, but rather, I contend, it reveals the lack of training in physicis and mathematics among current Tanabe scholars. One exception is Tanaka Yutaka. For example, he discusses Tanabe's "philosphy of science" after the war: Tanaka Yutaka, "Kagaku, shûkyô, tetsugaku: Nishida to Tanabe no shisaku wo tebikitoshite" (1997), Http://pweb.cc.sophia.ac.jp/~yutaka-t/process/tetugaku/nittetu1997.html (Last accessed on April 13, 2001); Tanaka Yutaka, "Tanabe Hajime no kagaku tetsugaku to shûkyô tetsugaku," in *Gyakusetsu kara jitsuzai he: Kagaku tetsugaku shûkyôtetsugaku ronkô* (Tokyo: Kôrosha, 1993), 183-212.

62. Nagai Hiroshi, "Tanabe benshôhô to shizenkagaku," in *Tanabe Hajime: Shisô*

greatly inspired. As I mentioned in Chapter 3, elite institutions of higher education, especially higher schools, were dominated by a form of *kyôyôshugi*, or "culturalism." Many Japanese students were absorbed in literary and philosophical works (Descartes, Kant, and Schopenhauer were among their favorites), and indulged in classical music. In such an environment, learning science through Tanabe's seriously philosophical books was a common and favored practice, even among science students. Tanabe was keen on following recent developments of physics in Europe, and quick to introduce new ideas.

Tanabe's "The New Physics and the Dialectics of Nature" (*Shin butsurigaku to shizen benshôhô*),[63] published in 1933, is important here partly because it discussed Bohr's ideas on quantum mechanics. Tanabe, borrowing Bohr's analogy of a stick, wrote:

> When a stick is grasped normally, we sense and feel it as an object. When we hold it tightly, and use it to touch things, our sense of feeling is located at the point where the stick touches those things; hence the stick now belongs to the subject. Similarly, [in the gamma ray experiment], although the radiation of the ray is an object, it comes to belong to the subject when one uses it as a means of measurement. This duality causes the uncertainty. . . This reciprocity [of subject and object] requires us to revise the view of classical mechanics, in which the means of measurement was idealized, and it causes reciprocal uncertainty.

This "reciprocity" (*kôgosei*) was the term Bohr proposed as a better word for complementarity in the article published in 1929 (although Bohr withdrew it later).[64]

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to kaisô, edited by Takeuchi Yoshinori, Mutô Kazuo, and Tsujimura Kôichi (Tokyo: Chikuma Shobô, 1991), 18-47.

63. Tanabe Hajime, "Shin butsurigaku to shizen benshôhô," *Kaizô* 15, no. 4 (1933): 80-97.

Tanabe further argued in this paper that the emergence of new physical theories, such as relativity theory and quantum mechanics, contradicted the (Marxist) dialectics of nature (*shizen benshôhô*). Tanabe regarded the reciprocity of subject and object in the measurement a dialectical process, in which subject and object were synthesized in a higher dimension. He called this "nature's dialectics" (*shizen no benshôhô*). Since the Marxist dialectics of nature stood on materialism, it did not accommodate such a synthesis of subject and object as demanded by nature's dialectics. Therefore, Tanabe concluded, the Marxist dialectics of nature was wrong in light of the new physics.

Tanabe's argument was a serious attack on Marxist philosophy of science. Since Marxists took, with a small number of exceptions, the position of scientism (the idea that natural science was the ideal form of knowledge), they could hardly tolerate criticism that their philosophy was scientifically obsolete. Their response was swift. Nagai Kazuo, a member of the Marxist intellectual circle, *Yuibutsuron kenkyûkai* (Society for Materialism Studies), countered Tanabe's argument against natural dialectics in a paper published under his pseudonym, "Gô Hajime." Nagai wrote:

> Whenever an epoch-making advance in physics occurs, there are always physicists who draw idealistic conclusions from it, as well as philosophers who use it to concoct philosophical idealism. This is unavoidable considering their class origin. On the other hand, although the correct view of nature, namely natural dialectics, was discovered, bourgeois scholars have been greeting it with conscious or unconscious antipathy and cold silence because of the class nature of this philosophy. Hence idealism persists in physics. Yet, unlike physicists, conscientious bourgeois philosophers cannot help having some interest in natural dialectics. Still, limited by their class origins, they cannot understand it correctly. Given a social situation where class conflict is radicalizing, they become actively reactionary in this genre of ideology, too, and end up playing a social role

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64. Niels Bohr, "The Quantum of Action and the Description of Nature," in *Atomic Theory and the Description of Nature*, reprint, 1929 (Woodbridge: Ox Bow Press, 1987), 95.

> as a part of the reactionary idealist faction existing in all fields of culture. Dr. Tanabe's "New Physics and Dialectics of Nature," which appeared this year, is a typical phenomenon of this kind of reactionary theory in this country.[65]

While Tanabe argued that the interaction between the subject and the object caused indeterminacy, Nagai insisted that the duality of electron and light was an objective quality of the electron itself, independent of human cognition. Similarly, Nagai argued that uncertainty relations were objective laws of nature, not caused by anything. While criticizing Tanabe, Nagai also attacked Bohr and Heisenberg for their "subjectivist" interpretation of quantum mechanics, chiding Tanabe for following their "idealistic explanation." Nagai concluded that Tanabe's "nature's dialectics" was a "thought style" that isolated and exaggerated only one side of dialectics, a thought style, Nagai said, common among all kinds of idealism.[66]

Another Marxist intellectual, Taketani Mitsuo, who was also a physicist and philosopher, responded to Tanabe. He became a very influential figure in postwar Japan, and his three-stage theory of science had many adherents both among scientists and non-scientists. In 1935, Taketani was serving as an unpaid assistant at Kyoto Imperial University, two years after his graduation from the department of physics there. During the late 1930s, he was developing his ideas on the three-stage theory, although publication of its systematic presentation had to wait until 1941.[67] While Taketani was a student, Tanabe's books on quantum

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65. Gô Hajime, pseud., "Shin butsurigaku to shizen benshôhô: Tanabe hakase no dôdai ronbun no hihan," *Yuibutsuron Kenkyû* 12 (1933): 33.

66. Ibid., 57.

67. Taketani Mituo, "Nyûton rikigaku no keisei ni tsuite," in *Benshôhô no shomondai* (Tokyo: Keisô Shobô, 1968), 68-72 . For an English translation, see:

mechanics fascinated him, though he later concluded that Tanabe's ideas were "irrelevant and rather misconceived." Very disappointed, according to Taketani, he started his quest for a "philosophy useful for quantum mechanics." When left-wing students and young scholars in Kyoto founded a new cultural journal, *Sekai bunka* (World Culture), Taketani joined them and published many articles there on problems related to modern science, using his pen name "Tani Kazuo." He did so, partly because "fascist mysticism tried to deceive people by using quantum mechanics."[68]

Taketani's view of quantum mechanics with his criticism against Tanabe appeared in a paper in 1936: "Nature's Dialectics: On quantum mechanics" (*Shizen no benshôhô: ryôshirikigaku nitsuite*).[69] Taketani argued that in quantum mechanics, the concept of "state" was essential. It unified two conflicting forms of phenomena, particle and wave. He wrote:

> So-called acausal reduction of states by measurement does not imply "agency of subject" or "denial of causality." Rather, measurement is based

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Mituo Taketani, "On Formation of the Newton [Sic] Mechanics," *Progress of Theoretical Physics, Supplement*, no. 50 (1971): 53-64.

68. Taketani Mituo, "Hashigaki," in *Benshôhô no shomondai*, reprint, 1946 (Tokyo: Keisô Shobô, 1968), 3-8; Needless to say, these are Taketani's later recollections, and therefore do not necessarily reflect the facts. However, they are relatively reliable sources to fathom Taketani's perceptions. By fascist mysticism, he meant Tanabe's philosophy. Although Pascual Jordan, a physicist in Nazi Germany, who used quantum mechanics to argue for organicism and telepathy, appears to fit Taketani's description, there is no evidence that Taketani was referring to him. On Jordan, see: Beyler, "Targeting the Organism"; Beyler, "From Positivism to Organicism"; Wise, "Pascual Jordan".

69. Tani Kazuo, pseud., "Shizen no benshôhô: Ryôshirikigaku ni tsuite," *Sekai Bunka* 2, no. 15 (1936): 2-11. For a translation, see: Mituo Taketani, "Dialectics of Nature: On Quantum Mechanics," *Progress of Theoretical Physics, Supplement*, no. 50 (1971): 27-36. I use my own translation from the original Japanese.

> on material laws, namely the dialectics of quantum mechanical superposition laws. There is no ground for the view that the action of the subject causes the uncertainty principle.[70]

An aspect of complementarity attracted Kyoto School philosophers, such as Tanabe and, later, Nishida Kitarô, who interpreted complementarity as an idea suggesting interactions between subject and object, and their synthesis.[71] This appeared to give a clue to one of the prime goals of their philosophical project, to "overcome" subject-object duality, which was the basis of a modern Western subjectivity since Descartes. Kyoto School philosophers' interest in complementarity invited the attention of their enemies, Marxists. Marxist intellectuals, especially Taketani, resisting any "subjectivist" interpretation of quantum mechanics, attacked Tanabe, criticized "idealistic" elements of Bohr's theories and began to establish their own philosophy of science to counter the Kyoto School philosophy. Through the exchange between the Kyoto School and Marxists, complementarity began to acquire some visibility among Japanese intellectuals.

Both Kyoto school philosophers and Marxists were appropriating complementarity from their philosophical or ideological perspectives. They, however, did not necessarily try to distort it to fit their purpose. Rather, complementarity addressed the issues of concern to them, and it was ambivalent enough to allow them to draw their own interpretations.

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70. Tani Kazuo, "Shizen no benshôhô," 9.

71. Nishinda Kitarô seems to have been well informed of the recent developments in physics from his son, Nishida Sotohiko. As we saw in Chapter 3, Nishida Sotohiko was a graduate of the physics department at Kyoto University, where he studied quantum mechanics with Tamua Matsuhei. It was, however, in the 1940s that Nishida Kitarô began writing about his views on quantum mechanics. See: Nishida Kitarô, "Chishiki no kyakkansei ni tsuite (1)," *Shisô*, no. 248 (January

4-3. Japanese Responses to the EPR paper

A simultaneous development of controversies regarding quantum mechanics in Europe gave further incentives to the debate among Japanese intellectuals. Albert Einstein never endorsed quantum mechanics (or more precisely, he never accepted Bohr's interpretation of quantum mechanics). Earlier debates took place at the fifth and sixth meetings of the Solvay Congress in 1927 and in 1930.[72] On these occasions, Einstein attempted to undermine the validity of the uncertainty relations.[73] These debates were, however, witnessed by a small number of physicists, and were not very well-publicized. The proceedings of the Solvay Congress contained only a small portion of the debates, and most of the debates were carried out in informal exchanges during the meetings. Detailed descriptions of the debates by Bohr appeared much later.[74] Philipp Frank, for example, knew Einstein's opposition to quantum mechanics only in 1929.[75] There

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1943): 1-43; Nishida Kitarô, "Chishiki no kyakkansei ni tsuite (2)," *Shisô*, no. 248 (February 1943): 1-50.

72. *Electrons et photons: Rapports et discussions cinquième conseil de physique tenue à Bruxelles du 24 au 29 Octobre 1927 sous les auspices de l'Institut International de Physique Solvay* (Paris: Gauthier-Villars, 1928); *Le magnêtisme: Rapports et discussions du sixième conseil de physique sous les auspices de l'Institut International de Physique Solvay* (Paris: Gauthier-Villars, 1932).

73. For a short description of their debates, see, for example: Max Jammer, *Philosophy of Quantum Mechanics* (New York: Wiley & Sons, 1974), 109-36; Dugald Murdoch, *Niels Bohr's Philosophy of Physics* (Cambridge: Cambridge University Press, 1987), 155-61.

74. Niels Bohr, "Discussion with Einstein on Epistemological Problems in Atomic Physics," in *Albert Einstein: Philosopher-Scientist*, P. A. Schilpp (La Salle: Open Court, 1949), 199-241.

75. Philipp Frank, *Einstein: His Life and Times* (New York: Knopf, 1947), 215.

is no indication that anyone in Japan knew Einstein's stance toward quantum mechanics and his debates with Bohr until 1935.

In 1935, still dissatisfied with the current form of quantum mechanics, Einstein once again launched a fierce attack on it. Working with Boris Podolsky, a Russian physicist visiting Princeton, and Nathan Rosen, a recent Ph. D. from MIT, who had just begun working at Princeton,[76] this time Einstein focused his criticism on the completeness of quantum mechanics, rather than physical results, about which he had no objection. In their argument, Einstein, Podolsky, and Rosen claimed that quantum theory did not have a way to represent all the "elements of reality," and therefore its description was incomplete. Here, they defined "physical reality" as follows: "if, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality, corresponding to this physical quantity." Examining a thought experiment of two physical systems that had once interacted and then were separated from each other by an arbitrary distance, they pointed out that one could measure the position and the momentum of one of the systems without disturbing it. Due to the laws of conservation, the measurement of the position or the momentum of one system determines the position or the momentum of the other system. Therefore, by measuring the momentum of the first system, one could predict the momentum of the second system with certainty. Similarly, one could predict the position of the second system with certainty by measuring the position of the first system. In both cases, there would be no disturbance by measurement, because one could separate the two systems by an arbitrary distance. Therefore, they claimed that according to the definition of "physical reality," the position and the momentum of the other system had

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76. Jammer, *Philosophy of Quantum Mechanics*, 167, 180.

elements of physical reality. However, quantum mechanics could not tell the exact values of the position and momentum, because of uncertainty relations. Therefore, they concluded that this theory must be considered as incomplete.[77]

Niels Bohr quickly responded to Einstein and his co-authors. He argued that the definition of reality by Einstein, Podolsky, and Rosen was arbitrary. According to Bohr, once two systems were in interaction, even if they were then separated and there could be no physical influence, there still was an influence on the "conditions of measurement." Einstein and others claimed that they could measure either position or momentum of one system, and since in each case their measurement would determine position or momentum of the other system, the position and the momentum of the latter was determined from the beginning. Bohr argued, however, that this argument was erroneous. Until they actually measured the position or momentum of one system, the position or the momentum of the other system would not be determined. Einstein and others erred when they assumed that a physical system had, from the beginning, definite values for positions and momenta, which was not the case in quantum mechanics. Bohr's claim implied that it was not inappropriate to say quantum mechanics was incomplete because of its failure to fulfill an unrealistic demand set by such an arbitrary definition of reality. For Bohr, quantum mechanics was complete in the sense that it gave the most exhaustive *possible* description of reality.[78]

This historic exchange was the climax of the so-called Bohr-Einstein debate, which dated back to their debate about light-quanta in the early 1920s.

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77. Albert Einstein, Boris Podolsky, and Nathen Rosen, "Can Quantum Mechanical Description of the Reality Be Considered Complete?" *Physical Review* 47 (1935): 777-80.

78. Niels Bohr, "Can Quantum Mechanical Description of the Reality Be Considered Complete?" *Physical Review* 48 (1935): 797-802.

This "battle of titans," as David Kaiser has sarcastically dubbed it,[79] appeared in the widely read *Physical Review* and could not—and did not—fail to attract attention among Japanese intellectuals. For scientific journalists, this debate was big news, and therefore had to be covered.

Ishiwara, among others, quickly responded to this debate, and reported it in his "Probability Theory and Natural Sciences" (*Gûzenron to shizen kagaku*). However, curiously, he did not show much interest in the apparent main issue of this debate, the question of the completeness of quantum mechanics. After having outlined the debate, although admitting that it might be worth physicists' consideration whether a theory was complete in Einstein's sense or not, he wrote,

> [W]e have a much more important and interesting problem, namely, whether we can recognize causal relations in quantum phenomena in general. Completeness of the theory may only be related to the definition of reality given by Einstein and others.[80]

It was of course reasonable to argue that completeness of the theory depended on the definition of reality. Yet, this was exactly what Bohr pointed out, and the main point of the debate was whether such a definition was legitimate or not. For Ishiwara, the problem of causality was the central issue of quantum mechanics, and he was much less receptive to other problems.

A more intense interest arose from among Marxists. For a Marxist scientist like Taketani, the exchange between EPR and Bohr marked a memorable occasion,

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79. David Kaiser, "Bringing the Human Actors Back on Stage: The Personal Context of the Einstein-Bohr Debate," *British Journal for the History of Science* 27 (1994): 130.

80. Ishiwara Jun, "Gûzenron to shizen kagaku," *Nihon Hyôron* 10, no. 10 (1935): 42-54. For another article by Ishiwara concerning the problem of EPR, see: Ishiwara Jun, "Gendai kagakukai no saikô ronsô: butsuriteki jitsuzai no honshitsu," *Kagaku Chishiki* 15 (1935): 559-61.

when "Bohr taught Einstein" (*Bôa Ainshutain wo oshiu*).[81] At this point, for Taketani, Bohr was the person who "accomplished brilliant achievements by introducing quantum theory into the atom, and later contributed greatly to the development of atomic physics, and educated many excellent physicists." Einstein, one the other hand, was a "former Machian," then a "mechanical materialist," who was "no longer able to keep up with the development of physics."[82] Yet Taketani made some reservations in his support of Bohr. In an article published the next year, he admitted that it was fair to criticize Bohr for his subjectivism and "confusion" of subject and object.[83] The problem, according to Taketani, was Bohr's use of words, which was different from that of "philosophers." Taketani suggested that it would be necessary to reformulate Bohr's ideas in the more accurate language of philosophy.

Taketani's ambivalence about Bohr lasted even after the phase of the EPR debate. In 1937, in the introduction to his translation of the EPR paper and Bohr's paper replying to EPR. He wrote:

> This paper not only explains extremely masterfully and intelligibly the esoteric measurement problem, but also is a precious paper in its original contribution to the interpretation of quantum theory.[84]

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81. Tani Kazuo, pseud., "Bôa Ainshutain wo oshiu," *Sekai Bunka* 2, no. 15 (1935): 53-54.

82. Tani Kazuo, pseud., "Butsurigakkai no wadai," *Sekai Bunka* 1, no. 11 (1935): 24-28.

83. Tani Kazuo, "Bôa Ainshutain wo oshiu."

84. Niels Bohr, "Genshiron ni okeru ingaritsu: Butsuriteki jitsuzai no ryôshirikigakueki kijutsu wa kanzen to kangae rareruka?" *Tetsugaku Kenkyû* 22, no. 257 (August 1937): 808-19, translated by Mituo Taketani. Taketani also translated the EPR paper: Albert Einstein, et al., "Ryôshirikigaku ni okeru kansoku ni tsuite," *Tetsugaku Kenkyû* 22, no. 251 (February 1937): 168-88, translated by Mituo Taketani.

Taketani's evaluation of Bohr was inconsistent. He took Bohr's side only in opposition to Einstein. Taketani himself was a quantum physicist, deeply committed to what people perceived Einstein was attacking. His close friend and intellectual ally, Sakata Shôichi, working under Nishina, who was one of Bohr's disciples. Taketani himself was working with physicists in Osaka and Kyoto, and was soon going to contribute to the development of meson theory. This attitude toward Bohr was encouraged by his scientism. It was not easy to criticize one of the "heroes" of modern science without undermining science itself. On the other hand, Taketani naturally criticized Bohr's "subjective" or "idealistic" interpretation because of Teketani's ideological standpoint as a Marxist.

The issue, then, was not about a vision of physics, as was essentially the case in the Bohr-Einstein debate. Marxist intellectuals had their more pressing problems. An increasingly oppressive Japanese authority gave few options even to originally moderate Marxists like Taketani: either silence or extreme radicalism. Taketani, although he never resorted to physical violence, radicalized his intellectual activities, attacking those he perceived as reactionaries. When Taketani talked about "fascist mysticism," he was alluding to Tanabe, who was, in fact, a relatively liberal nationalist.[85] In the case of a physicist like Taketani, there was an alternative: to escape into the realm of science. By doing so, he was able to avoid the fate of other Marxist intellectuals, such as Tosaka Jun or Miki Kiyoshi, who died in jail. Eventually Taketani was able to find a relatively safe asylum from

85. Around the end of the war, Tanabe began to "repent." For an account in Englishof Tanabe's *Philosophy as Metanoetics*, see: John Dower, *Embracing Defeat: Japan in the Wake of World War II* (New York: Norton New Press, 1999), 496-501.

political persecution: The *Ni-go* Project (the Japanese atomic bomb project) under Nishina Yoshio.[86]

The debate between Einstein and Bohr in 1935 concerning the EPR argument was different from earlier debates, because it was carried out in a well-circulated scientific journal. Science journalists in Japan began noticing their debates, and renewed the interest in philosophical issues related to quantum mechanics. In particular, they began to throw more light on one of the principal debaters, Niels Bohr, and his philosophical ideas (rather than his atomic model).

It is clear that the renewed publicity did not come from interest in a newly formulated problem, such as the EPR argument. Ishiwara, still bound by his earlier concern with acausality, could not recognize newly emerging aspects of the controversy in the EPR paper and Bohr's response to it. While the contenders were debating over the completeness of quantum mechanics, Ishiwara still insisted that the issue of causality was more important.

Taketani's response to the Einstein-Bohr debate shows his dilemma of being a Marxist and a physicist. On the one hand, being a physicist trained in the field of atomic physics, he had to defend the mainstream physics, represented by Bohr, against Einstein's attack. On the other hand, being a Marxist, he had to oppose any form of idealism. Taketani's ambivalence shows that he was living in and moving between two different subcultures, namely the culture of atomic physicists affiliated with Nishina Yoshio and the culture of Marxists.

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86. Taketani's recollections on the atomic bomb can be seen in Yomiuri Shinbunsha, ed., *Shôwa shi no tennô*, vol. 4 (Tokyo: Yomiuri Shinbunsha, 1968). For Taketani's autobiographical account, see: Taketani Mituo, *Shisô wo oru* (Tokyo: Asahi Shimbunsha, 1985). As for the Ni-go project, see references in Chapter 6.

5. Niels Bohr's Visit to Japan in 1937 and After

5-1. Amplification of the Bohr Shock Through Science Journalism

In the late 1930s, a broader readership began paying attention to conceptual questions concerning quantum mechanics. The incentive was Bohr's visit to Japan in 1937.

When Nishina Yoshio wrote the letter about complementarity to Nagaoka in 1928, he already insisted that they should invite Bohr to Japan sometime.[87] After his return to Japan, Bohr, his mentor, was obviously the top of the list of scientists to be invited to Japan. Nishina made a good start by successfully inviting Werner Heisenberg and P. A. M. Dirac to Japan in 1929. Bohr, however, had more commitments and responsibility, especially to his institute, than those younger physicists. The correspondence between Nishina and the Bohrs from 1929 to the early 1930s reveal that the trip was repeatedly postponed. In 1929, Bohr was completely occupied, and proposed to visit Japan and America in 1930, but he wrote he would prefer 1931.[88] In 1930, Bohr found that he had "various unsuspected University duties" and therefore unable to leave Copenhagen in 1931.[89] After repeated delays, it appears that Bohr, with his wife Margarethe and son Christian, could visit Japan in 1935. In a long letter to Bohr on March 21, 1934, Nishina excitedly proposed a travel plan, and explained financial

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87. Nishina, letter to Nagaoka Hantarô.

88. Niels Bohr, A letter to Nishina Yoshio, December 26, 1929 in *Y. Nishina's Correspondence with N. Bohr and Copenhageners, 1928-1949*, NKZ Publication (Tokyo: Nishina Kinen Zaidan, 1984), 16.

89. Niels Bohr, A letter to Nishina Yoshio, August 4, 1930 in *Y. Nishina's Correspondence with N. Bohr and Copenhageners, 1928-1949*, NKZ Publication (Tokyo: Nishina Kinen Zaidan, 1984), 17-18.

arrangements.[90] In July, however, Nishina was informed by Betty Schultz, Bohr's secretary, that Christian had died, drowned on a sailing trip.[91] The Bohrs naturally canceled the trip. It was only in 1937 that Bohr's visit to Japan was finally realized.

Bohr's visit was fairly covered by mass media. Unfortunately for Bohr and complementarity, the Asama Maru, the luxuay steamer the Bohr family took, carried a far more famous figure aboard: Helen Keller. Major newspapers extensively covered her voyage to and activities in Japan. Hellen Keller's presence easily over-shadowed a modest report on Bohr's arrival.[92] Moreover, Bohr's scientific achievements, atomic theory and complementarity, did not attract general interest as much as the relativity theory of Einstein, whose visit to Japan in 1922 was a sensational success.[93] Unlike relativity theory, quantum mechanics was beyond laymen's understanding and imagination. Besides, Bohr was not as photogenic a figure as Einstein. A reporter from Asahi Newspaper, who obviously expected to see someone like Einstein, reported, "Professor Bohr has a mediocre appearance, and it is difficult to imagine that he is a world renowned authority of quantum mechanics and atomic theory."[94]

However, within the academic world, Bohr's visit had a considerable impact. *Teikoiku Daigaku shimbun* (Imperial University Newspaper), a weekly

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90. Yoshio Nishina, A letter to Niels Bohr, March 21, 1934 in *Y. Nishina's Correspondence with N. Bohr and Copenhageners, 1928-1949*, NKZ Publication (Tokyo: Nishina Kinen Zaidan, 1984), 33-38.

91. Betty Schultz, A letter to Nishina Yoshio, July 5, 1934 in *Y. Nishina's Correspondence with N. Bohr and Copenhageners, 1928-1949*, NKZ Publication (Tokyo: Nishina Kinen Zaidan, 1984), 38-39.

92. *Asahi Shinbun,* morning edition, April 16, 1937, p. 11.

93. Kaneko Tsutomu, *Ainshutain Shokku*.

94. *Asahi Shimbun,* morning edition, April 16, 1937, p. 11.

newspaper published at Tokyo University, carried articles about Bohr in every issue while he was in Japan, telling readers who he was, where he visited, and what he did. Within the Japanese scientific community, his visit was a big event. Many scientific journals covered stories about Bohr's achievement, his trip in Japan, and especially his lectures.

Bohr delivered lectures on the subjects that concerned him at that time: issues on the foundation of quantum mechanics and those on nuclear physics. As for the former subject, he talked about complementarity, uncertainty relation, and his debate with Einstein, including the *Gedankenexperiment* of the photon box and EPR's argument. Several scientific journals and one newspaper printed Bohr's lectures. Fujioka Yoshio published in *Kagaku* a summary of the whole lecture series at Tokyo University.[95] Part of this lecture series was also reported by Takeuchi Tokio and Q. L. Z (pseudonym).[96] Nishina translated a lecture at Kagaku Chishiki Fukyû Kyôkai (Association of the Promulgation of Scientific Knowledge) and published in a magazine *Kagaku chishiki* (Scientific knowledge).[97] There was no record for the lectures in Kyoto, but according to Taketani, the contents of the Kyoto lectures were almost the same as Bohr's reply to Einstein, Podolsky, and Rosen's paper.

Bohr's visit and his lectures enhanced the visibility of complementarity in Japan, overshadowing other rival interpretive ideas of quantum mechanics, and made a sea change in the context in which Japanese intellectuals discussed

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95. Fujioka Yoshio, "Bôa Kyôju No Kôen," *Kagaku* 7 (1937): 278-91, 323-27.

96. Takeuchi Tokio, "Bôa hakase no kôen," *Tokyo Butsuri Gakkaishi* 46 (1937): 301-08; Q. L. Z., pseud., "Nîrusu Bôa kyôju no kôen," *Tokyo Butsuri Gakkai Zasshi* 46 (1937): 301-08.

97. Nishina Yoshio, "Nîrusu Bôa kyôju no raichô ni saishite," *Kagaku* 7 (1937): 207-10.

philosophical issues of quantum mechanics. Nishina was familiar with complementarity from the beginning. Now he began writing about complementarity more seriously and extensively. The organizer of Bohr's visit, Nishina began talking about complementarity even before the Asama Maru reached the Japanese shore, When a journalist asked about this Danish physicist who was coming to Japan, Nishina said that complementarity would exert as much influence on philosophy as relativity theory did.[98] In November 1938, *Kagaku chishiki* had a special issue on "the theory of complementarity."[99] Nishina edited this issue, and contributed an article with the same title. In his article, Nishina contentedly declared, "Today complementarity receives wide attention in science and philosophy in general, which is, I suppose, a matter of course."[100]

The sudden rise of interest in complementarity among Japanese intellectuals was, therefore, not motivated by some natural interest in, or cultural affinity with Bohr's idea. As the previous sections show, it was partially prepared by some Japanese intellectuals' interest in philosophical issues of quantum mechanics. More immediately, however, it was triggered by Bohr's visit to Japan, and the timing of Bohr's visit to Japan in 1937 was due to various events, such as Bohr's administrative chores and the accidental death of his son—events that were entirely contingent.

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98. Nishina Yoshio, et al., "Kagaku oyobi kagaku bunmei wo kataru."

99. Articles on complementarity included: Nishina Yoshio, "Sôhoseiriron," *Kagaku chishiki* 18, no. 11 (1938): 14-17; Hayashi Takashi, "Seirigaku no sôhosei," *Kagaku chishiki* 18, no. 11 (1938): 18-21; Saigusa Hiroto, "Tetsugaku no sôhosei," *Kagaku chishiki* 18, no. 11 (1938): 22-26; Kagawa Toyohiko, "Shingaku no sôhosei," *Kagaku chishiki* 18, no. 11 (1938): 28-31; Itagaki Takaho, "Geijutsugaku no ichi tokushitsu: sôhosei ni kanrenshite," *Kagaku chishiki* 18, no. 11 (1938): 32-35.

100. Nishina Yoshio, "Sôhoseiriron," 14.

5-2. "Scientist-Literati" and Complementarity

"Scientist-literati" is my translation of the Japanese expression *"bunjin kagakusha*," meaning those scientists who were very actively involved in literary activities and used scientific subject matter in their literary writings. By this word, I do not refer to sientists, whose practices in physics or medicine were totally independent of their literary work, such as Ishiwara Jun or Saitô Mokichi. Scientists-literati, who saw aesthetic values in science, were also different from scientific journalists, who were interested in science because of its news values.

The most representative of such scientists-literati was Terada Torahiko. Terada was an experimental physicist at the Tokyo Imperial University, and Riken, who worked on various unconventional subjects. He obtained his doctorate for a study on *shakuhachi,* a traditional Japanese woodwind instrument. His investigations ranged across such topics as *konpeit*ô (Japanese traditional sweets with a peculiar shape), cracks, and *senkô hanabi* (tiny traditional fireworks in Japan). At the same time, Terada maintained a strong interest in recent developments in atomic physics, including an early research interest in X-ray diffraction. He was also one of the most supportive professors for younger scholars who were studying quantum mechanics, especially before Nishina's return to Japan, as we have seen in Chapter 3.

Terada was well known for his literary works, including science essays and commentaries on literature, paintings, and movies. He was the earliest disciple of Natsume Sôseki, one of the greatest novelists in Japanese literature, since the time Terada was a student at the Kumamoto Fifth Higher School, and Natsume was an English teacher. Some of the characters in Sôseki's novels, such as Mizushima

Kangetsu in his first novel, *I Am a Cat*, were modeled on Terada.[101] He himself learned haiku from Sôseki, and continuously published his works in the genre of *zuihitsu.* The Japanese *zuihitsu* is probably more similar to prosaic poetry than to English essays. A *zuihitsu* usually has no specific argument. Rather, it is an unorganized collection of impressions, or description of private experiences. It may express a certain opinion, but the way a *zuihitsu* supports an opinion tends to be more intuitive than logical, resorting to literary techniques, such as metaphors and analogies, rather than empirical evidence. The author usually writes from his or her personal perspectives. The writing of *zuihitsu* is supposed to express the personality of the author. The dry and objective style of academic writing was completely alien to this genre.

Terada's scientific "essays" dealt with various topics, including Einstein's relativity theory. In "A Side View of Relativity Theory" (*Sôtaisei riron sokumenkan*),[102] Terada did not describe what relativity theory was like, as a scientific journalist would have done. Rather, he discussed what it meant to understand relativity theory. He wrote that when we learned Newtonian mechanics, we thought we understood it, but

> It is of course insufficient for us to have knowledge of science in order to evaluate scientific knowledge. As you do not really know your home country until you live overseas, science cannot be "understood" unless it is critically evaluated in relation to every non-science, especially metaphysics and epistemology. Aside from these general issues, as for Newton's laws, we are led to the paradox that Newton himself did not understand his laws, because only after the advent of relativity theory did it become possible to understand what Newton's laws were. According to the same argument, perhaps Einstein cannot yet understand relativity theory.

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101. Sôseki Natsume, *I Am a Cat*, translated by Aiko Ito and Graeme Wilson (Rutland: C. E. Tuttle Co., 1972-86).

102. Terada Torahiko, "Sôtaiseiriron sokumenkan," in *Terada Torahiko zenshû*, vol. 10 (Tokyo: Iwanami Shoten, 1950), 288-302.

On the other hand, however difficult it was to understand, so far as relativity theory was a physical theory, Terada claimed, to explain it for lay people was still possible.

> At least, just as we laymen can enjoy Beethoven's music, it is not impossible for anyone to have a taste of relativity theory, and I suppose it is not so bad to taste it to that extent.[103]

For Terada, it was only natural to bring into science aesthetic values and attitudes and to discuss the nature of science from the viewpoint of an artist. More often his essays came from his observations of everyday phenomena, blended with his scientific insights as an experimental physicist. His "Evolution of Monsters"(*Bakemono no shinka*) is characteristic.[104] Terada claimed that "Of all the inventions made in the advancement of human culture, the 'monster' is one of the most brilliant master pieces." According to Terada, monsters were "legitimate sons" of man's interaction with nature, just like religion and science were. Ancient people explained various natural phenomena as acts of monsters. For example, Japanese folklore had ascribed the phenomenon to the mischievous play of ogres wearing tiger skin pants. Terada continued, now people explained thunder in terms of another monster, called atmospheric electricity. Yet, its nature was yet to be investigated. Natural sciences, Terada claimed, did not resolve mysteries, but deepened them. To call thunder and lightening "atmospheric electricity" was not a

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103. Ibid., 296.

104. Terada Torahiko, "Bakemono no shinka," in *Terada Torahiko zenshû*, vol. 3, reprint, 1929 (Tokyo: Iwanami Shoten, 1950), 8-25.

solution of the problem, but just a formulation. Unsolved mysteries of nature would remain forever in different forms, and under different names.

> To think there is no such a thing as a monster is actually a real superstition. The universe is eternally full of monsters and marvels. All the volumes of science are just like picture books of hundreds of monsters. When people forget to be frightened by those monsters, science dies. Personally, I sometimes think it is perhaps scientists who most often enter the world of the mysterious.[105]

Then, Terada mentioned Niels Bohr:

> Some say that Niels Bohr in Denmark, the foremost authority of modern physics, when discussing the fundamental contradiction inherent in modern physics, said that the human mind might not be advanced enough to resolve that contradiction. This modest remark by a respected authority seems to grant a place for the existence of my "monsters." If this is the case, the monsters, after a long exclusion, can now openly wander about. Or, maybe this is just my paranoiac interpretation of Bohr's remark.[106]

In the Japanese intellectual scene, Terada appeared, not as a paranoia, but as a most respectable literary figure and creative physicist. Every educated person read Natsume Sôseki's works, especially *I Am a Cat,* and *Sanshirô*, where characters modelled on Terada appeared.[107] Virtually all the scientists spent their youth at a higher school, where they received intensive liberal arts education, and many of them learned to value literature. Many of them came to admire Terada greatly. New physics students were thrilled at the thought of attending Terada's lectures. Some younger physicists strove to emulate him.

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105. Ibid., 23-24.

106. Ibid., 24-25.

107. *Sanshirô* is a novel about a student of Tokyo Univeristy, and one of the main characters, Mr. Nonomiya, is a physicist working at the university, apparently

Terada died in 1935, but the trend that he represented survived him, and existed in the late 1930s. As I mentioned in Chapter 3, young physicists in the "rebellious youth" cultures were closely attached to Terada's tradition. Fujioka Yoshio was arguably in this tradition. Fujioka appeared in Chapter 3 as one of the organizers of the Physics Reading Group, the splinter group of young physicists who initiated the studies of quantum mechanics in Japan. After Bohr's visit to Japan, Fujioka, now a professor at Tokyo Bunrika University, actively wrote about complementarity. In an essay, called "Evil Presence"(*Yôki*), Fujioka attempted to apply the idea of complementarity to understand apparently supernatural phenomena.[108] When Fujioka's mother was taken ill, a physicist friend of Fujioka, N (Nakaya Ukichiro, the closest disciple of Terada and Fujioka's future brother-in-law, who was also one of the organizers of the physics reading group in Chapter 3) visited his family. Seeing the sick old woman, N urged Fujioka to let a famous physician, T, diagnose her. As it turned out, Fujioka's mother's illness was a serious one, and only after she received extensive treatment in a university hospital, did she recover. Later N told Fujioka,

> Actually, when I saw your mother the other day, I felt an evil presence [*yô ki*]in her sick bed, and had an intuition that it was a serious disease. That was why I recommended Dr. T. Now, I am relieved, since I feel no such evil presence around her. I felt this evil presence when I visited Professor Terada [Torahiko] just before he died.[109]

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modeled on Terada. See: Sôseki Natsume, *Sanshirô: A Novel*, Jay Rubin, reprint, 1977 (New York: Putnam, 1982).

108. Fujioka Yoshio, *Gendai no butsurigaku* (Tokyo: Iwanami Shoten, 1938); Fujioka Yoshio, "Yôki," *Shisô*, no. 139 (1939): 95-101.

109. Fujioka Yoshio, "Yôki," 96.

In the article, Fujioka asked how one could interpret this "evil presence," assuming it existed (since such a well-known physicist like N talked about it seriously). Probably, he reasoned, there were several "unnatural" characteristics to a seriously sick person, such as fever, smell, expressions, and other subtle differences. A person with sharp sensitivity could grasp these differences intuitively and synthetically and judge how serious the patient's disease was.

Fujioka proceeded to discuss complementarity (or what he called the complementarity principle), which he felt would illuminate the question of "evil presence." Certainly, Fujioka wrote, all natural phenomena, including biological phenomena, such as "evil presence," should follow physical and chemical laws. Yet, (Fujioka explained Bohr's idea):

> In order to investigate a part of, or the whole of an organism with physical or chemical methods, one must apply some kind of external force to it. This inevitably kills that organism, and annihilates the characteristics of biological phenomena. . . . This shows that physical and chemical methodology is in a complementary relation to biological phenomena.[110]

As is often the case with the genre of *zuihitsu*, this essay did not show an explicit logical structure. What Fujioka was probably implying was that the "evil presence" was a biological phenomenon, which could not be captured by physical and chemical methods, and that the existence of such phenomena was allowed, or even guaranteed by Bohr's idea of complementarity. The idea of complementarity, Fujioka thought, allowed a room for N's "evil presence," just as Terada thought Bohr's remark made a room for his "monsters,"

5-3. The Kyoto School's Response to Bohr

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110. Ibid., 100-01.

While Nishina did not go farther than just explaining Bohr's ideas at this point, Tanabe, who was quick to respond to Bohr's visit, freely applied the idea of complementarity to problems of his own concern. Just before Bohr reached Japan, Tanabe had already written an article on complementarity, titled "The World View and World Picture" (*Sekaikan to sekaizô*),[111] relying on Pascual Jordan's understanding of complementarity and his application of this concept to the problem of free will.[112] Here he translated "complementarity," as "*haitateki sôgo hosokusei,*" which meant "exclusive mutual complementarity," and discussed his favorite topic, inseparability of subject and object. Tanabe further extended the idea of complementarity and utilized it in his own *Staatslehre.* He wrote:

> Only the unification of a state, which is based on an actual historical national society and realized by way of the practical subjectification of individuals, can rationalize the establishment of concrete inseparability between the totality and the individuality. However, such unification of opposites must go beyond mere so-called exclusive mutual complementarity shown by the new physics. It must be concretely carried out by the practice of the subject.[113]

Tanabe's direct response to Bohr's visit and his talk in Japan appeared in his paper entitled "Philosophical Significance of Quantum Theory" (*Ryôshiron no tetsugakuteki imi*), published in July 1937.[114] Here Tanabe was much less audacious in appropriating and mystifying Bohr's ideas. He tried to discuss the ideas of correspondence principle and complementarity. Bohr's *Atomic Theory and*

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111. Tanabe Hajime, "Sekaikan to sekaizô," *Kagaku* 7 (1937): 181-86.

112. Jordan, *Anschauliche Quantentheorie*, Chapter 5.

113. Tanabe Hajime, "Sekaikan to sekaizô," 183.

114. Tanabe Hajime, "Ryôshiron no tetsugakuteki imi," *Shisô*, no. 181 (1937): 1-29.

the Description of Nature,[115] and Bohr's lecture in Kyoto, which Tanabe attended, constituted the main sources of Tanabe's understanding.[116] Tanabe filled his article with admiration for Bohr's thought as well as complaints about its conceptual difficulty. He described Bohr's argumentation on complementarity and the correspondence principle as "concise but deep, and hard to understand." Tanabe confessed that, although he thought he was able to have some idea of what Bohr meant by attending Bohr's recent lecture, his understanding was still unsatisfactory, and he could by no means grasp correctly Bohr's "profound" thought. In other words, Bohr's arguments were far from obvious to him.

Tanabe's paper was also filled with many unfamiliar terms, which he coined, one of which was *sôhosei*, now the standard translation of "complementarity." Many other terms were taken from the vocabulary of Hegelian dialectics, within which he tried to grasp complementarity and the correspondence principle. Indeed, the main point of this paper was to understand complementarity in terms of dialectics. Tanabe argued:

> Therefore, it is doubtless that the concept of complementarity, which represents the result of this [pragmatic] synthesis, must mean a unification of dialectic opposites. Two complementary things can be mutually exclusive only because they are contradictory and antithetical. Such dialectic unification of two mutually exclusive things is carried out in so-called complementarity. *Mutually exclusive complementarity is, indeed, nothing but the unification of dialectical opposites.* [emphasis is mine][117]

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115. Niels Bohr, *Atomic Theory and the Development of Nature* (Cambridge: Cambridge University Press, 1934).

116. Uchida Yôichi, a physicist in Kyoto, witnessed Tanabe at Bohr's lecture for physicists on May 11 in the physics library. See: Uchida Yôichi, "Kyôto no jitsujô," *Butsuri* 44 (1990): 760.

117. Tanabe Hajime, "Ryôshiron no tetsugakuteki imi," 19.

Tanabe was not the only one who tried to understand complementarity within the framework of dialectics. In fact, it was probably the easiest way of reducing complementarity to a familiar philosophical theory. Saigusa Hiroto, a philosopher and historian of science, for example, stated that there was no other way to find the problem of complementarity in philosophy than to look for it in Hegel's "unmatched" theory.[118]

Tanabe's responses to Bohr's visit indicate how inadequate Yukawa's observation was. First of all, it was not easy for Tanabe to understand complementarity. Second, Tanabe resorted to Hegel's philosophy rather than Eastern thoughts to understand complementarity. Supporters of Yukawa could still claim that Tanabe could not understand complementarity because of his familiarity with the Western philosophy (Tanabe was, one might say, "corrupted" by Aristotle). Such an argument, though logically consistent, would not reflect what actually happened in relation to complementarity.

5-4. Objections to Complementarity: Marxists and Scientists

Not all Japanese intellectuals readily accepted complementarity. Taketani was the most critical of Bohr's philosophical viewpoint. He argued that complementarity was not a physical or a philosophical concept, and that it was a baseless, and merely phenomenological word, which Bohr used in order to concoct his own interpretation of quantum mechanics.[119] According to Taketani, Bohr's argument could not but fall into the debris of classical theory and phenomenological theories, because he did not have a correct methodology. He concluded, "Seeing this, we keenly realize how powerful the dialectics of nature

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118. Saigusa Hiroto, "Tetsugaku no sôhosei."

119. Tani Kazuo, pseud., "Nîrusu Bôa kyôju no shô gyôseki ni tsuite," 39.

is." Evidently, Taketani implied that the "correct methodology" was natural dialectics, and his own three-stage theory, derived, according to Taketani, from a dialectics of nature. "Phenomenological" is only the initial stage of the development of scientific theory according to Taketani's three-stage theory.

Not all objections were ideologically motivated. A physicist, Tomiyama Kotarô, criticized complementarity. He argued that, contrary to what Bohr says, it was not necessary to retain classical concepts, such as position and momentum. In 1939, he published a paper, "Classical elements in quantum theory" (*Ryôshiron ni okeru kotentekinaru mono*), the first of his critical responses to Bohr's interpretation of quantum mechanics. He believed that a new physics should have its own suitable language, so that its new contents could be most adequately expressed. Since quantum mechanics could be most simply expressed by wave functions and operators, Tomiyama claimed, not classical concepts, but "wave functions" and "operators" were the building blocks of an adequate language of quantum mechanics. Tomiyama's criticism was made from the viewpoint of a physicist, who, having been trained to deal with a highly formalized theory of quantum mechanics, no longer had to worry about its philosophical problems. If one learned quantum mechanics through mathematical formalism, the elements in the formalism, such as wave functions, operators, and commutation relations appeared as real as position and momentum in classical physics.[120]

It seems probable that many physicists shared Tomiyama's view but did not bother to express it. As we have already seen, most of Nishina's disciples were not interested in issues concerning the foundation of quantum mechanics. Yukawa was one of the few Japanese physicists who were engaged with the problem of

120. Tomiyama Kotarô, "Ryôshiron ni okeru kotenteki naru mono," *Kagaku* 9 (1939): 156-58.

measurement in quantum mechanics, but he did not publish more than a series of popular accounts.[121]

6. Conclusion: Scientific Cultures and Philosophy of Quantum Mechanics

By looking at the discussion of complementarity in the 1930s, one can detect two features in the cultures surrounding science in interwar Japan: diversity and hybridity.

First, there was never a homogeneous Japanese scientific culture. One can see diversity and multiplicity in the cultural contexts in which the discussion of philosophical issues of quantum mechanics took place. We can now identify five subcultures or types of practices of Japanese intellectuals: (1) research and teaching of physics; (2) science journalism; (3) scientist-literati; (4) Marxist activism; and (5) Kyoto School philosophy. They each reacted to the philosophical issues of quantum mechanics in their own way. For physics teachers, complementarity and uncertainty were convenient pedagogical tools, which were meant to give physical meaning to the formal theory of quantum mechanics. For science journalism, the philosophical issues of quantum mechanics had news value, because of their grand philosophical implications, dramatic debates, and some peculiar interpretations (for example, by Eddington and Jordan). Complementarity could be a good subject for a scientific *zuihitsu,* because it could be connected to suitable subjects, such as "yô ki." While Marxism was antithetical to what Marxists perceived as idealistic aspects of complementarity, the idea of complementarity suited well the ambition of the Kyoto school philosophers to "overcome" Western modern thought. Overcoming Western thought did not mean returning to the

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121. Yukawa Hideki, "Kansoku no riron," *Shizen* Special issue (1971): 84-107, reprint, 1947-08.

Japanese tradition. They were tackling modern, not traditional, problems. They mobilized both Japanese, especially Buddhist, thoughts as well as Western thinkers, such as Hegel, for their purpose.

Second, these subcultures were, more or less, hybrids of Japanese and Western cultures. The systems of ideas to which these Japanese intellectuals resorted, or cultural resources which they used to discuss complementarity, did not necessarily have to do with "traditional" Eastern thought, as was suggested by Yukawa's remark. They certainly belonged to some cultures in Japan, but they were cultures at a specific time in Japan, and they were hybrids of Western philosophical traditions and Japanese thoughts, made possible in the specific intellectual and social environment of prewar Japan.

These subcultures interacted with each other in various ways. The relation between the Kyoto School philosophers and Marxists was antagonistic, yet they were still able to discuss such issues as materialism and dialectics, and they often did. Moreover, some Marxists, such as Taketani, read writings by the Kyoto school philosophers ardently, before they seriously turned to Marxism. Tosaka Jun, another Marxist philosopher of science, was even a former student of Tanabe. At the same time, it was usually the case that intellectuals from different backgrounds could share common cultural resources. For example, German philosophy was a lingua franca for a wide range of Japanese intellectuals. As I have stressed, most of Japanese intellectuals graduated from "higher schools," where they spent three years in liberal arts education. In such an environment, it was natural for many of higher school students to become familiar with European literary and philosophical works.[122]

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122. See Section 2.

Science journalism provided a central locus for the discussion of philosophical issues surrounding quantum mechanics, and became a place where intellectuals from various fields could interact. In addition to professional scientific journalists, some active or retired research scientists actively engaged in science journalism, publishing semi-popular writings on science, or working as consultants or editors of scientific magazines. The same was the case with Marxists and the Kyoto School philosophers. Many of Tanabe's writings reported on new scientific knowledge, with his own philosophical interpretations. One of his books was entitled *Saikin no shizen kagaku* (Recent Natural Sciences).[123] The activities of Marxist intellectuals, too, consisted of publishing articles in Marxist or other periodicals. It was not unusual for both a Marxist and a Kyoto school philosopher to publish articles in the same journal. For example, *Kaizô* was one of the most popular magazines in Japan. Its publisher was responsible for Einstein's visit to Japan, but Einstein complained about its commercialism. Marxists would call it a "bourgeois capitalist" journal, yet this very same publisher published a Japanese version of the collected works of Marx and Engels.[124] As long as they could sell books, they did not care much whether the books were leftist or not.

Historical actors conducted multiple activities other than journalism. For example, a scientist could be at the same time a Marxist activist, as was the case with Taketani and Tamaki Hidehiko, both of whom had arrest records because of their political activities. The affiliation with the publishing world is even stronger in the case of scientist-literati. Terada's writings were distinctly different from science journalism, because he did not intend to report new developments in physics.

123. Tanabe Hajime, *Saikin no shizen kagaku* (Tokyo: Iwanami Shoten, 1915).

124. Karl Marx and Friedrich Engels, *Marukusu Engerusu zenshû* (Tokyo: Kaizôsha, 1928-35).

These diverse subcultures of Japanese intellectuals indicate the place of science in prewar Japan. The social and intellectual environment surrounding the discussion of complementarity and uncertainty relations was partly shaped by contingencies, such as Bohr's visit to Japan, which was delayed by the accidental death of one of Bohr's sons. Yet, it was also situated in the context of a modernizing state. On the one hand, the state needed science as a tool for industrialization. The rapid industrialization, on the other hand, produced new technological objects, added them to the material culture of urban life, and stimulated the curiosity of the Japanese public. People sought science to satisfy their curiosity, and such popular demand for science enabled science journalism to flourish. Science journalism, in turn, allowed Japanese intellectuals to be involved in science, and scientific journalists to treat scientific knowledge as a cultural commodity which they could turn into capital. Against this background, Japanese intellectuals saw science not simply as useful knowledge, but as something suggesting philosophical ideas and new world views, about which they could write articles for non-scientists.

A rapid modernization created various contradictions. A mixture of modernity and (genuine and newly invented) tradition encouraged both the Kyoto school of philosophy and Marxism in opposite directions. The former aimed to "overcome modernity," and the latter was a clear revolt against the invented political tradition, the modern emperor system.[125]

Whether Japanese physicists were "corrupted by Aristotle" or not is difficult to prove or to refute. If the founder of western logical thought,

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125. As for the invented nature of the Japanese monarchy, see: Takashi Fujitani, *Splendid Monarchy: Power and Pageantry in Modern Japan* (Berkeley: University of California Press, 1996); On the modernity of the Japanese emperor system, see: Carol Gluck, *Japan's Modern Myths : Ideology in the Late Meiji*

particularly the categorical distinction of substance and phenomenon, is Aristotle, and if Bohr's complementarity is a revolt against this particular logical tradition, Yukawa's claim, logically, makes sense. One might argue that Kyoto school philosophers, particularly Nishida if not Tanabe, were resorting to "Eastern" traditional thoughts, such as Buddhist philosophy. Yet such a generalization by Yukawa obviously does not do justice to the complexity of the actual historical context in which Japanese intellectuals who participated in the discussion of complementarity, worked and lived, especially when that context was so remarkably rich and diverse.

The rise of interest in philosophical issues of quantum mechanics, not only invited some physicists to participate in the discussion, but also induced some young physicists to engage seriously in the historical and philosophical studies of science. The discipline of the history of science in Japan has many roots, but the debates concerning complementarity was one of its important sources, at least in the history of physics. Amano Kiyoshi graduated from the department of physics of Tokyo University in 1932, and worked for most of his short life, for the Central Laboratory of Metrology (now National Research Laboratory of Metrology, the Japanese equivalent of the Bureau of Standards). Since his student years, however, he had become interested in philosophical and historical studies of physics. Stimulated by ongoing discussions on complmentarity, he wrote a series of articles on interpretations of quantum mechanics in the 1930s.[126] Complementarity had been one of his main interests since then. In his last and uncompleted book,

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Period (Princeton: Princeton University Press, 1985).

126. Amano Kiyoshi, "Ryôshiron kaishaku no hensen to sono bunken," *Nihon sûgaku butsuri gakkai shi* 10 (1936): 445-55; Amano Kiyoshi, "Ryôshiron kaishaku no hensen to sono bunken (2)," *Nihon sûgaku butsuri gakkai shi* 11 (1937): 148-64.

History of Quantum Mechanics mostly concerned philosophical issues of quantum mechanics, such as uncertainty relations and complementarity. Extremely well-versed in Western philosophy, he gave here an interpretation of complementarity in terms of Kantian philosophy.[127] In his study of the history of blackbody radiation published in 1943, he sought the roots of this research in Germany's industrial interests, in particular its steel and electric industries, pointing out the importance of the *Physikalische Technische Reichsanstalt*.[128] Unfortunately for the history of science in Japan, Amano died during the war at the age of 38.[129] His works, however, eloquently testify to the quality and intensity of historical and philosophical investigations of physics by prewar Japanese intellectuals.

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127. Amano Kiyoshi, *Ryôshirikigaku shi* (Tokyo: Nihon kagakusha, 1948).

128. Amano Kiyoshi, *Netsu fukusharon to ryôshiron no kigen* (Tokyo: Dainihonshuppan, 1943). Its important part has been translated: Kiyoshi Amano, "Thermal Radiation Studies That Led to the Genesis of Quantum Theory (I)," *Historia Scientiarum* 10, no. 2 (2000): 185-210, translated by Seiji Takata and Shin-ichi Hyodo; Kiyoshi Amano, "Thermal Radiation Studies That Led to the Genesis of Quantum Theory (II)," *Historia Scientiarum* 10, no. 3 (2001): 255-80, translated by Seiji Takata and Shin-ichi Hyodo.

129. On Amano Kiyoshi's life, see: Takata Seiji, "Kagakushika Amano Kiyoshi no shisô to tassei," *Journal of Seishu University*, no. 3 (1996): 7-14; Seiji Takata, "Amano Kiyoshi, the 'Scientific' Historian of Science," *Historia Scientiarum* 2, no. 1 (1992): 1-10.

Chapter 8
Conclusion:
The Cultural History of Science
Between Scientific and Cultural Essentialism

Locality of Scientific Practices and Two Pitfalls of the History of Physics

This work mainly concerns how place matters to science. The question is not whether place matters, but in what ways and to what extent. To illustrate this point, I present two extreme views and try to locate my position between (or, I would like to say, above) them.

Some might claim that there is a certain "essence" that makes science "science," or quantum mechanics "quantum mechanics." I call such a view "scientific essentialism." According to this view, since the essence of "science" or "quantum mechanics" is the same everywhere in the universe, doing science or practicing quantum mechanics is "essentially" same everywhere in the world, and whatever differences exist are, of course, "unessential." According to this view, learning quantum mechanics is simply learning that essence of quantum mechanics. Anyone who does not grasp or who understands differently the essence of quantum mechanics simply does not understand it. This view holds that there should be no intricate problems concerning the transmission of scientific knowledge.

Historians of science who endorse scientific essentialism might be called "internalists." They emphasize "contents and texts" rather than "contexts." For them, the history of science solely concerns tracing scientific ideas as written in scientific texts. They are often Whiggish because they are more interested in "important" scientific works (important for the development of science), and they are not interested in failures and misunderstandings of science. Unlike the days when historians of science were mostly ex-scientists, today it is rare to find this kind of historians. Yet, there are still historians of science, whose primary concerns are "contents and texts."

A historical example of scientific essentialism is Taketani Mituo's work on the history of quantum physics.[1] With the first volume published in the 1940s, it is one of the earliest works on the history of science in Japan (and the world), along with Amano Kiyoshi's work mentioned in Chapter 7. In a Marxist fashion, Taketani examined the "dialectic logic" of the development of quantum mechanics, applying his famous "Three-Stage Theory" mentioned in Chapter 7. The scope and thoroughness with which Taketani and his collaborator analyzed scientific papers in this work are truly impressive. Yet, the analysis was centered on the "logic" of the development of scientific ideas, often rigidly applying the Three-Stage Theory, and neglecting social and cultural circumstances.

Others might claim that there is something unique in the Japanese culture that is essentially different from other, in particular "Western," cultures, and that there are certain unique ways of doing science in Japan that are determined by the uniqueness of Japanese cultures. I call such a view cultural essentialism.

Cultural essentialism about Japanese culture in general often takes the form of *Nihonjinron* (Study of Japaneseness), vast literature mostly developed by the Japanese about the uniqueness of their culture. For many prominent Japanese

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1. Mituo Taketani and Nagano Masayuki, *Ryôshi rikigaku no keisei to ronri* (Tokyo: Keisô Shobô, 1972-93). The first volume of this colossal work was originally published in 1948, whereas the second and third volumes came out only in 1990 and 1993. Recently, an English verison was published: Mitui Taketani and Masayuki Nagasaki, *The Formationand Logic of Quantum Mechanics* (Singapore: World Scientific, 2002).

intellectuals, both in past and present, the uniqueness of the Japanese culture was a major concern. In science, Yukawa's remark that we saw in Chapter 7 is a classical example of cultural essentialism. According to Yukawa, the Japanese had a different way of thinking because they were not "degenerated by Aristotle," and therefore Japanese physicists did not have difficulty understanding Bohr's idea of complementarity, unlike their Western counterparts.

Sympathizers of such a view are not few, even among historians of science.[2] Part of the reason might be the Kuhnian belief in incommensurability between different cultures, a view that has not yet been dispelled completely. The Kuhnian model goes well with cultural essentialism, because in cultural essentialism, the relation between cultures is same as the relation between paradigms. Kuhnians might consider the works of cultural essentialism as supporting their tenets, and vice versa.

In a sense, these two views are extreme opposites. In one view, place does not matter at all. In the other, place controls everything. What we have seen in this work indicates how inadequate such views are.

As opposed to scientific essentialism, this work has shown how local cultural conditions regulated the scientific practices of physicists in interwar Japan. In Chapter 2, we saw the "cultural of calculating" dominated "theoretical physics" in Japan until the mid-1920s. We have seen in Chapter 3 how the rebellious youth culture in the late 1920s enabled young physicists to rebel against the old tradition of the "culture of calculating" and to start learning quantum mechanics. We learned in Chapter 4 how Nishina Yoshio successfully took advantage of his training in engineering culture when he turned to theoretical physics. Then, as we saw in

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2. For example, some historians have shown strongly negative reactions to my account of Yukawa's remark in a version of Chapter 7.

Chapter 5, Nishina replicated the research culture of the Copenhagen school in Japan after his stay there. We saw, in Chapter 6, that Nishina's scientific style was conditioned by the norms with which he was accustomed in his youth. Finally, we learned in Chapter 7 that Japanese physicists and other intellectuals in different subcultures of science understood Bohr's notion of complementarity variously. We also have seen that Nishina, trained in electrical engineering, liked a formulation of quantum mechanics by P. A. M. Dirac, who had also been trained as an electrical engineer, and that Nishina exploited his engineering background to his advantage.

In short, it matters where and who conducts science. Whereas science is by no means a set of arbitrary rules invented by men, the kind of human activities and knowledge that we call science does not exist independent of human scientists, their lives, and their cultures. Cultural settings are "essential" as long as we want to understand precisely how science is practiced.

If our goal is to understand how science is done, it does not matter whether the scientific works in question are of "scientific" importance. Most of the works completed by the Japanese physicists mentioned in this work are not major scientific breakthroughs. The Klein-Nishina formula is certainly an important work, but someone else could have done it sooner or later. On the other hand, it is difficult to imagine that anyone else could have played Nishina's role in Japan's physics. An essentialist approach would miss the many stories that need to be told in order to understand scientific practices.

In opposition to cultural essentialism, this work has shown that the way Japanese physicists understood and practiced quantum mechanics was locally conditioned, but not determined by their "unique Japanese culture." In spite of Yukawa's remarks, these scientific cultures that shaped physicists behaviors, values, motivations, and understanding, cannot always be regarded as uniquely

Japanese. Scientific cultures in Japan were diverse, as we saw in Chapter7. Scientific cultures in prewar Japan's physics made generational changes (from the "culture of calculating" to the "culture of rebellion," then to the "culture of Copenhagen"), each keeping some elements of the previous generation (For example, as I have mentioned in Chapter 2, even if young physicists detested dry manipulations of equations, they were nonetheless well-trained in calculations, and their calculational skills turned out to be extremely useful when young physicists had to carry out lengthy calculations in quantum mechanics). More importantly, they were a mixture of various cultures from various origins.

Restoring Agency

No 400-page work is necessary just to debunk two views so extreme and therefore so easy to criticize, even though advocates of these views are not totally extinct. Once we have confirmed that cultures do not determine science yet are not unrelated to it, we now ask: What exactly is the relation between science and culture?

Scientific and cultural essentialism share one feature in common. In both, the role of historical actors is underestimated. In scientific essentialism, historical figures are merely accidental carriers of scientific ideas. For them, scientific ideas would develop on their own, according to their own logic. Human actors simply provide data, calculate numbers, and give logical reasoning. In cultural essentialism, human actors, bound by their "unique culture," can only think and behave accordingly.

The solution, then, seems to be not just to avoid either of the two extremes, but to bring "the human actors back on stage."[3] This, however, does not mean to return to the psychological analysis of historical actors and to reduce everything to matters of their personal tastes. As we have seen in Chapter 6, such an approach would lead to various methodological problems. For example, accounting for historical figures' behaviors in terms of their personal peculiarities can be universally used and is, therefore, the same as saying nothing. Knowing scientists' personal peculiarities might satisfy our curiosity, but can not help our understanding of science and how it is practiced. What, then, can be done to restore actor's agency without degenerating into psychohistory, while retaining sound historical, social, and cultural analyses? I can see at least two kinds of remedies.

One is to reconsider the relation between human actors and external conditions. For example, there is the Latourian approach to resolving the inside/outside duality. In the Callon-Latour actor network model, there are only actors.[4] Latour's intention was to resolve the natural/social distinction, and the central issue about the actor network theory was, at least for critics, not whether to give agency to human actors, but whether to give it to non-human actors, such as microbes and scallops. More recently, however, Latour, in his reappraisal of Gabriel Tarde's *Monadologie et sociologie,* presents Tarde's vision of sociology, which is of interest here. Tarde, who has been criticized for his "psychologism" and "spiritualism" had an idea of sociology in complete opposition to Emile

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3. David Kaiser, "Bringing the Human Actors Back on Stage: The Personal Context of the Einstein-Bohr Debate'," *British Journal for the History of Science* 27 (1994): 129-52.

4. On the actor network theory, see: Bruno Latour, *Science in Action* (Cambridge: Harvard University Press, 1987). As for a study by Michel Callon, see, for example: Michel Callon, "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay" (1986), 67-83.

Dürkheim's. Whereas Dürkheim attempted to explain individuals' behaviors with the laws that govern society, Tarde proposed that one should explain the whole in terms of individuals. In a monadological way, the relation between macro and micro is inverted. Rather than considering the micro to be a part of the macro, the macro (society) is reflected on the micro (individual). While it is not clear how the Tardian vision of sociology could be realized (especially, if its goal is to explain the whole), such a model seems to be very useful in historical accounts. As Latour mentions, in Stendahl's *The Charterhouse of Parma,* the world of its protagonist Fabrice is much more complex and rich than all the battles of the Napoleonic war. Such a historical account seems to be justified.[5] I tried to use this approach (at least partially) in Chapter 3. In that chapter, I tried to present the reality of the young physicists in terms of their own experiences, instead of putting them inside the student cultures or modernism of late1920s Japan. In this "monadological" model, external settings such as social and cultural conditions are taken into the perspectives of the historical actors. Instead of putting historical actors inside cultural settings, the cultural settings are inside historical figures' perspectives.

Another way to reformulate the relation between cultures and human actors is the cultural resource approach that many cultural historians, in particular Norton Wise, would use.[6] By writing that cultures regulated scientific cultures, I do not imply anything deterministic. It would be absurd to claim that the "gentle

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5. Bruno Latour, "Gabriel Tarde and the End of Social," in *The Social in Question: New Bearing in History and the Social Sciences*, edited by Patrick Joyce (London: Routledge, 2002), 117-32.

6. See, for example: M. Norton Wise and Crosbie Smith, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989).

revolutionary" Yukawa[7] became rebellious because he so often read *Water Margin*, the Chinese classical novel on 108 rebellious heroes.[8] This is what one might call the "influence argument," which has been criticized by, for example, Norton Wise.[9] The fact that Yukawa read this novel does not in any way explain Yukwa's rebelliousness. On the other hand, Yukawa's reading of this novel tells us what it meant to Yukawa to be rebellious, in what way Yukawa was rebellious, and why Yukawa presented himself in such a way. In other words, these cultural resources were there, but it is through historical actors' decisions and actions that these cultural resources were brought up and implemented.

Another way to avoid the above-mentioned two pitfalls is to consider multiple subcultures in a certain cultural setting of science and try to find a middle-level account between a monolithic view of a scientific culture and a total irregularity of individual psychology. In this approach, individuals, or subgroups had their own way of behavior and were no longer slaves of the orchestrated whole. Analyzing the place of science in terms of different subcultures and their negotiation has been carried out and emphasized by Peter L. Galison,[10] and such a perspective is amply used in this work, especially in Chapter 7. In Chapter 7, I described how physicists and other intellectuals in 1930s Japan reacted and interpreted complementarity differently, and their differences can be to some extent accounted for in terms of the subcultures to which they belonged. This is a way to describe personal differences without totally losing sociological accounts.

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7. Laurie M. Brown, "Yukawa in the 1930s: A Gentle Revolutionary," *Historia Scientiarum* 36 (1989): 1-27.

8. See Chapter 3.

9. Oral communication.

A logical extension of this approach is to account for the very existence of different subcultures, which can be done at least in two ways. One is to trace apparently personal differences of individuals or subgroups through their earlier education and training. This pedagogical approach have been strongly put forward by Kathleen Olesko, Andrew Warwick, David Kaiser, and others,[11] although their intentions are not always to account for diversity, and more often to account for community building. This approach was used in Chapters 3, 4, 5, and 6. While Chapter 5 (and to some extent Chapter 3) is more concerned with Nishina's efforts to create an integral scientific community in modern atomic physics, background talk was also useful to account for the disintegration and diversification of the scientific community, as in Chapter 3, 4, and 6. In Chapter 3, for example, the rebellious cultures of the young physicists changed the preceding scientific culture, the "culture of calculating." In Chapter 4 and 6, as I have mentioned above, Nishina brought heterogeneous elements into the scientific culture of physics.

While the pedagogical approach traces scientists through time, the other method is to consider the geographical and disciplinary relocation of cultures and science, which I discuss in the next section.

Transfer of Knowledge and Resonance

As we have seen in Chapter 4 and 5, disciplinary and geographical relocation diversifies a scientific culture. For example, Nishina infused an engineering culture into physics when he moved from electrical engineering to theoretical physics. Then he combined the research culture of the Copenhagen

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10. Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: The University of Chicago Press, 1997).

11. See Chapter 3. I do not repeat the citation here.

school with the scientific cultures in Japan when he went back home and built his own research group there.

As in these cases of Nishina, geographical and disciplinary movements of historical figures bring in different elements into a scientific cultures. Yet, I do not claim that Nishina was "influenced" by various cultures that he had experienced, and that he brought into the scientific culture of Japan's atomic physics those various "influences." Such a description would only make a metaphorical approximation of the actual historical processes.

To analyze such processes, in particular the geographical relocation, the notion of resonance that I have proposed in Chapters 1 and 5 might be useful. The replication of scientific practices is not like moving a certain item from one place to another. It is more like recreating a similar phenomenon in a different place. As the physical phenomenon of resonance, it is realized through various mediations, and does not necessarily occur in exactly the same form. In Chapter 5, I showed that the kind of scientific activities in Nishina's group in Japan were not simply an emulation of Bohr's group in Copenhagen. There were differences in many ways, including the way in which the group leaders directed their disciples, the choice of problems and research directions, the group leaders' personalities and philosophical attitudes, material and political conditions, and so on. Yet Nishina was able to create and maintain research activities in his group.

From such a perspective, historical actors who replicate scientific practices in a different place have a room to be creative (or "re-creative"), since they are not rigidly bound by their former experience. What Nishina did was not exactly the same as what Bohr did. In more general terms, historical actors moving across geographical or disciplinary boundaries have a certain degree of freedom regarding how to create a resonance of scientific practices. Of course, as we have seen in

Chapter 3, those who stay in the same place can also make a choice not to assimilate themselves into the community in a certain circumstances. However, such circumstances do not always exist. Those who move face a situation in which they have to change the way they do science, except for the very unlikely case where one could replicate the entire research environment.

In short, here again "resonace" seems to provide the best model to conceptualize the transmission of scientific practices.

Aftermath: War and Occupation

A few months after Bohr's visit to Japan, a war between Japan and China broke out. While the construction of the cyclotron dragged, Japan opened fire with the United States. The turbulance of the war probably delayed but did not stop the Japanese physicists' research activities. Fortunately for the Japanese scientific community, Tomonaga's health condition was so bad when he was examined for the military service that he was branded as unfit for the draft. Tomonaga was forced to conduct military research, but by working on ultramicrowave and waveguides, and applying to this work Heisenberg's S-matrix theory, about which literature was secretely imported into Japan through a U-boat, he continued working on theoretical physics. This experience turned out to be useful to his later, and most important, work on QED.[12] In addition to Tomonaga, Nishina succeeded in keeping some other young physicists from being sent to the battlefield by working for Japan's atomic power project.[13] Whatever Nishina had in mind, the

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12. Julian Schwinger, *Tomonaga Sin-Itiro: A Memorial. Two Shakers of Physics* (Tokyo: Nishina Memorial Foundation, 1980); Silvan S. Schweber, *QED and the Men Who Made It: Dyson, Schwinger, Feynman, and Tomonaga* (Princeton: Princeton University Press, 1994).

Japanese physics' community was relatively successful in preserving its scientific manpower during the war.

After the war, amidst the ruins made by aerial bombardment, the worst housing situation, constant malnutrition, and economic chaos, Japanese physicists continued working on science. Scientists restored international communication in 1948, and the tie with the United States became much closer than before the war.[14] Around the early 1950s, in some, f not all fields of theoretical physics, such as elementary particle theory, Japanese theoretical physicists surpassed those in European countries, and could rival the physicists of their military conquerors.

This rise of theoretical physics might be considered as even more specutacular than that in the 1930s, considering the social conditions of the time. Yet, this could not have happened without the research traditions and cultures established by Nishina before the war. Nishian himself was burdened with administrative functions for Riken's postwar successor, and for the governmental committees, working for the reconstruction of science, not jus physics, in postwar Japan. The postwar science was directed mostly by Nishina's disciples, in particular, Tomonaga and Sakata. The foundation and the tradition was set by Nishina, and inherited by the following generations.

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13. On Nishina's wartime activities, see, for example: John Dower, "'Ni' and 'F': Japan's Wartime Atomic Bomb Research," in *Japan in War & Peace: Selected Essays* (New York: New Press, 1993), 55-100; Kenji Ito, "Values of 'Pure Science': Nishina Yoshio's Wartime Discourse Between Nationalism and Physics, 1940-1945," *Historical Studies in Physican and Biological Sciences* (Forthcoming).

14. As for the general conditions of Japanese science during the occupation period, see: Shigeru Nakayama, Kunio Gotô, and Hitoshi Yoshioka, eds., *The Occupation Period, 1945-1952*, vol. 1 of *A Social History of Science and Technology in Contemporary Japan* (Melbourne: Trans Pacific Press, 2001).

These stories about wartime and postwar Japanese physics would merit separate studies. I at least note, nonetheless, that before Nishina Yoshio died on January 10, 1951, he was able to hear the news of Yukawa's Nobel Prize and saw at least the beginning of this new blossom of theoretical physics in Japan.

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