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TECHNICAL REPORT

Science and Technology Research and Development Capacity in Japan

Observations from Leading U.S. Researchers and Scientists

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RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT and CENTER FOR ASIA PACIFIC POLICY

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Preface

To become and remain competitive in the international arena of science and technology, education and research institutions, industries, and government must determine how to distribute the resources available to support research and development across fields of study and how to create the institutional and social structures needed to support innovative scientific work. To some extent, decisionmaking in this area involves international comparisons of the standing of researchers, scientists, research institutions, and research achievements across nations.

This RAND Corporation Technical Report summarizes the views of 52 leading U.S. scientists regarding Japanese science and technology research and development capacity in 25 fields of research in life science, environmental science, information and communication technology, and nanotechnology and materials science. Their responses cover a range of topics, including university-industry research relations in Japan, the caliber of Japanese research scientists, innovation in Japanese research, funding directions, the role of language and cultural issues in the Japanese scientific enterprise, and the internationalization of Japanese research.

This project was conducted for the Mitsubishi Research Institute (MRI), which asked RAND to interview leading U.S. scientists about their observations on scientific research in Japan. The results of this RAND study will assist MRI in preparing a report for the Council for Science and Technology Policy (CSTP), the highest science and technology policymaking body in Japan, which is currently compiling a new basic science and technology plan for Japan for the years 2006 through 2010. In addition, the information presented here may interest scholars in the social and structural analysis of science, as well as individuals interested in developments in science and technology in Japan.

This research was carried out under the joint auspices of RAND Infrastructure, Safety, and Environment (ISE) and the RAND Center for Asia-Pacific Policy (CAPP). The mission of ISE is to improve the development, operation, use, and protection of society's essential built and natural assets; and to enhance the related social assets of safety and security of individuals in transit and in their workplaces and communities. The ISE research portfolio encompasses research and analysis on a broad range of policy areas including homeland security, criminal justice, public safety, occupational safety, the environment, energy, natural resources, climate, agriculture, economic development, transportation, information and telecommunications technologies, space exploration, and other aspects of science and technology policy. CAPP aims to improve public policy by providing decisionmakers and the public with rigorous, objective research on critical policy issues affecting Asia and U.S.-Asia relations. CAPP is part of the RAND National Security Research Division (NSRD). NSRD

conducts research and analysis for a broad range of clients including the U.S. Department of Defense, the intelligence community, allied foreign governments, and foundations.

More information on RAND Infrastructure, Safety, and Environment is at http://www.rand.org/ise. Inquires may be directed to Debra Knopman, Director, by post at RAND, 1200 S. Hayes Street, Arlington, Virginia 22202-5050, by phone at 703.413.1100, extension 5667, and by email at ise@rand.org.

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Summary

To become and remain competitive in the international arena of science and technology, nations and industries must determine how to distribute the resources available to support research and development across fields of study and how to create the institutional and social structures and incentives needed to support innovative work. To some extent, decisionmaking in this area involves international comparisons to gauge the standing of researchers, research institutions, and research achievements across nations.

Purpose of This report

This report characterizes science and technology research and development capacity in Japan from the perspective of researchers and scientists in the United States. RAND was asked by the Mitsubishi Research Institute (MRI) of Japan to interview 50 leading researchers in the United States across 25 scientific fields in life science, environmental science, information and communication technology, and nanotechnology and materials science.

The results of this report are intended to help MRI prepare a report to the Japanese Council for Science and Technology Policy (CSTP). CSTP, a component of the Office of the Prime Minister of Japan, is responsible for shaping science and technology policy in Japan. Results of the MRI report will help CSTP formulate its "Basic Science and Technology Plan for 2006–2010."

Methods

MRI, in consultation with CSTP, defined the 25 fields and placed them in four major categories, as shown in Table S.1. These fields and categories were chosen because they are priorities in the current science and technology basic plan of Japan (2001–2005) and the Japanese government has the explicit goal of improving Japanese world standing in these fields.[1] Findings from this study will influence which priority fields are selected for the next basic science and technology plan (2006–2010). We recognize that the selected fields and categories do not represent a definitive taxonomy of all scientific research and they are not exclusive

[1] Visit the Council for Science and Technology Policy website for an unofficial English translation of the second plan at http://www8.cao.go.jp/cstp/english/basicplan01-05.pdf.

Table S.1
Categories and Fields Included in Survey

Life Science	Environmental Science	Information and Communication Technology	Nanotechnology and Materials Science
Agricultural science	Environment/ecology	Computer science—basic	Chemical—basic
Biology and biochemistry	Energy engineering	Computer science—applied	Chemical—applied
Clinical medicine	Geoscience	Electrical and electronics engineering	Materials science—metals
Immunology		Mechanical engineering	Materials science—polymers
Microbiology		Mathematics	Materials science—ceramics
Molecular biology and genetics			Materials science—semiconductors
Neuroscience and behavior			Physics—basic
Pharmacology and toxicology			Physics—applied
Plant and animal science			

of one another. The boundaries of science and technology fields are always fuzzy, and increasingly so as research becomes more interdisciplinary.

MRI and CSTP also asked RAND to conduct only two interviews for each field. We recognize that the viewpoints of two researchers provide only a limited perspective on an entire field or even on more specific research areas. Nevertheless, within each of the four major categories, these interviews provide sufficient information to highlight important issues relevant to the quality, structure, dynamics, and visibility of the Japanese scientific enterprise.

RAND was asked by MRI and CSTP to focus on four topics that would be presented as open-ended questions in our interviews:

- important and interesting accomplishments of Japanese institutions observed by respondents in their field of expertise
- evaluation of the level of research conducted at Japanese institutions in the respondent's field of expertise, with a particular emphasis on Japan's performance compared to that of other countries considered the best in the field
- evaluation of the performance of Japanese institutions over time
- examples that show Japan as an important research player in the respondent's field of expertise.

We identified interviewees through a five-step process designed to create a pool of respondents who were, themselves, top-flight researchers and scientists. The main criteria used were the number and amount of federal research grants potential respondents had received in FY1998 through FY2002, major scientific merit awards they had received in the same pe-

riod, and number of publications and citations to their publications. In addition, we asked for nominations by experts and also received recommendations from the researchers we contacted.

In contacting researchers and scientists for interviews, RAND-approved human subject protection protocols were used. The overwhelming majority of our respondents (50 out of 52) were university researchers and scientists; only two were from industry, and the comments we collected focused heavily on research at Japanese universities. Respondents did not find the distinction between basic and applied research helpful in defining their work. These distinctions, specifically for computer science, chemistry, and physics, were defined for the project by MRI and CSTP in the 25 fields selected. Respondents reported that researchers and scientists rarely do only pure basic or applied research and that the lines further blur as interdisciplinary research increases.

Finally, we also gave respondents an opportunity to provide additional comments that they felt were pertinent to considerations about science and technology research and development capacity in Japan but were not covered by the four interview questions.

Major Findings by Topic, Category, and Field

Responses to the four interview questions are organized in this summary by the main topic, category, and field. Additional comments from respondents that tie to the four topics addressed in the interview questions are incorporated here also.

On the whole, Japan was seen to be on par with the United States in many specific research areas within fields of study and leading the world in some areas. Japan was also perceived to excel, in particular, in areas closely associated with problems significant to health and safety in Japan or closely tied to Japan's industrial competitiveness and policy priorities. Japanese research was regarded as solid and high-quality and Japanese researchers and scientists as committed and careful in their work. However, respondents observed a lack of depth in Japanese science and technology research and development capacity and a shortage of original and high-risk research. The best Japanese research was frequently regarded as comparable to the best in the world, but the disparity between the best and the rest within Japan was seen as a hindrance to improving Japan's competitive position in global science and technology.

Accomplishments of Japanese Scientific Institutions

Respondents were asked to comment on important accomplishments observed in their field of expertise in the past 5 to 10 years. With rare exceptions, respondents spoke about Japanese capacity within a specific research area within a field. In most cases, Japan was considered on par with the United States and Europe.

Japan was seen as an important actor in life science, in general, and was described as having made significant contributions in many research areas. However, respondents did not think that Japan had produced groundbreaking discoveries. Japanese research was considered solid, but not exceptional. Japanese efforts in environmental science were regarded as consistently good and much advancement in capacity was observed in recent years. Respondents thought highly of Japanese applied research and said that Japan was making important scientific contributions. Japanese scientists in information and communication technology (ICT)

were seen as doing solid, high-quality research and making important contributions in a wide range of areas, but Japanese research on the whole was not characterized as groundbreaking. Japanese research in nanotechnology and materials science was seen to be of consistently high quality and to excel in many fields, including world leadership in some areas. However, the lack of depth in capacity in general was observed as well.

Quality of Japanese Research

Respondents were asked to compare the quality of research in Japan with that of the best countries in their fields. Japan's best research in life science compared favorably with that in the United States and Europe but, taken as a whole, Japan's published research was seen to be more limited in scope and volume. Japan's best research in agricultural science, microbiology, neuroscience and behavior studies, and plant and animal research was regarded as on par with that in the United States and Europe. One respondent thought that Japan was equal to the United States in biology and biochemistry; the other thought that Japan was behind the United States. The same opposite views were reported for molecular genetics. One respondent thought that Japan was ahead of the United States in pharmacology and toxicology; the other thought that Japan was on par with the United States. One respondent thought that Japanese capacity in clinical medicine had slipped over time.

Japan was viewed as still lagging behind the leading countries in environmental science but improvements were observed in fundamental research, in particular. However, the scope of research and truly original work were more restricted than in leading countries such as the United States. Japan was regarded as on par or ahead of the United States in energy engineering (both respondents spoke about hybrid automotive engines). Significant improvement was noted in ecology, although Japan is still thought to be behind the United States. In geoscience, the Earth Simulator was regarded as a major achievement, putting Japan on par with the United States.

Japan was seen as a leader in several research areas in ICT. Japanese ability to insert technology into products was underscored as a significant strength, but fundamental research capacity and high-risk research were both lacking. Japan was seen as on par with the United States in computer science and electrical and electronics engineering, and ahead of the United States in mechanical engineering (where construction research is concerned). However, Japan was seen as being behind the United States in math. More important, Japanese capacity in math was seen to have declined over time.

Japan was seen as on par with the United States and Europe in most areas of nanotechnology and materials science. The clearest example of Japanese success and world leadership is in carbon nanotube development, which was cited by several respondents. Other areas of world leadership were high-energy physics and high-pressure physics. Improvement was observed in metals research and Japan was seen as being on equal footing with the United States in chemistry and semiconductors research. Only in polymers research and physical chemistry was Japan regarded as being behind the United States.

Longitudinal Trends in Performance of Japanese Scientific Institutions

Respondents reported slow and steady growth in capabilities in life science, including agricultural science and pharmacology and toxicology, but they also saw decline in a few areas such as biology and biochemistry and clinical medicine. Overall improvement was also observed in environmental science. Respondents saw innovation and a good balance between

basic and applied research. In ICT, greater progress was observed in academia than in industry and world leadership was emerging in some areas, but poor physical infrastructure was still noted as a significant problem. In nanotechnology and materials science, there was overall improvement across the fields covered and dramatic improvement in some such as neutrino physics, in which Japan was observed to have come from behind to become the world leader in 15 years. Also, greater progress was reported in universities than in industry or the national laboratories.

Importance of Japanese Research Institutions in the International Arena

The general opinion was that Japan is an important actor in life science, environmental science, and ICT, but not in the same league as the United States and Europe. Japan has shown itself able to produce high-quality and sometimes innovative scientific research. However, Japanese research has not become more innovative on the whole and capacity has not grown in breadth or depth. So, although the top Japanese researchers do world-class research, Japan is not quite a world leader yet. Respondents also saw institutional and cultural barriers as hindrances to more high-risk research, which have potentially bigger payoffs for Japan if it aims to become a world leader in science. In nanotechnology and materials science, Japan's excellence was seen primarily in the applied areas. Japan's lesser strength in basic research was a main reason for the view that Japan does not represent a major actor in the international arena.

CHAPTER ONE

Introduction

To become and remain competitive in the international arena of science and technology research and development, educators, research institutions, industries, and government must determine how to distribute the resources available to support science and technology research and development across fields of study and how to create the institutional and social structures needed to support innovative scientific work. To some extent, decisionmaking in this area involves international comparisons of the standing of nations' researchers, research institutions, and research achievements.

In highly technical fields, those best positioned to make such comparisons are likely to be other researchers and scientists because of their specialized knowledge, which enables them to evaluate the scientific achievements of other researchers and research institutions. Their assessments can help to inform the development of science and technology policies and the resource allocation decisions that follow from those policies. In the study reported here, we examine the views of outstanding U.S. researchers and scientists regarding scientific work in a wide array of scientific disciplines in Japan. Our goal is to provide information that can be used to inform Japanese policies regarding support for science and technology research and development.

The Mitsubishi Research Institute (MRI) of Japan asked RAND to interview leading U.S. researchers and scientists in 25 fields (distinguishing between basic and applied research in three fields) to determine their views on research and development in their fields in Japan. Two interviews were to be conducted in each field.

The results of these interviews will help MRI prepare a report to the Japanese Council for Science and Technology Policy (CSTP). CSTP, located in the Office of the Prime Minister of Japan, is responsible for shaping Japanese science and technology policy. Results of the MRI report will help CSTP formulate the Third Basic Science and Technology Plan for 2006–2010.

MRI, in consultation with CSTP, defined the 25 fields and placed them in four major categories, as shown in Table 1.1. These fields and categories were chosen because they are priorities in the current Japanese science and technology basic plan (2001–2005) and because the Japanese government wants to know how well Japan is doing in these areas. Improving Japanese world standing in these fields is an explicit goal of the current plan, and findings from this study will influence selection of fields to be chosen in the Third Basic Science and Technology Plan for 2006–2010.[1]

[1] Visit the Council for Science and Technology Policy website for an unofficial English translation of the second plan at http://www8.cao.go.jp/cstp/english/basicplan01-05.pdf.

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Categories and Fields Included in Survey

Life Science	Environmental Science	Information and Communication Technology	Nanotechnology and Materials Science
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Microbiology		Mathematics	Materials science—ceramics
Molecular biology and genetics			Materials science—semiconductors
Neuroscience and behavior			Physics—basic
Pharmacology and toxicology			Physics—applied
Plant and animal science			

The 25 areas listed should not be seen as a definitive taxonomy of all scientific research and the fields listed are not necessarily exclusive of one another. The boundaries of scientific fields are always fuzzy, and increasingly so as research becomes more interdisciplinary. The decision to interview two researchers and scientists for each field was made by MRI and CSTP. We recognize that the viewpoints of two researchers and scientists for each field provide only a limited perspective on an entire field or even on more specific research areas. Nevertheless, within each of the four major categories, these interviews provide sufficient information to highlight important issues relevant to the quality, structure, and visibility of the Japanese scientific enterprise.

RAND was asked to focus on four topics, which were presented as open-ended questions in our interviews. They are

- important and interesting accomplishments of Japanese institutions observed by respondents in their field of expertise
- the respondent's assessment of the quality of research conducted at Japanese institutions in the respondent's field of expertise, with a particular emphasis on Japan's performance compared to that of other countries considered the best in the field
- the respondent's assessment of the performance of Japanese institutions over time
- examples that show Japan as an important research player in the respondent's field of expertise.

In August 2004, a team of RAND researchers compiled a list of researchers for these interviews, and, in September 2004, the team completed 52 interviews.[2]

This report has five chapters. Following this introduction, Chapter 2 explains how RAND identified researchers for these interviews, and Chapter 3 presents a discussion of responses by research categories and fields for the four questions. Chapter 4 analyzes and synthesizes the responses. Chapter 5 presents our conclusions.

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[2] We had three respondents each in the fields of neuroscience and behavior study and mathematics. Thus, we spoke with a total of 52 researchers rather than the 50 expected for the 25 fields listed.

CHAPTER TWO

Research Methodology

The 25 fields and the four categories into which they were organized, as well as the decision to interview two researchers for each field covering four major topics, were all made by MRI and CSTP. Within that framework, however, the RAND research team had to decide how to identify leading U.S. researchers and scientists and how best to collect responses from them. In this chapter, we first explain the methods and criteria we used to identify researchers and scientists; we next describe the human subjects protection measures adopted to safeguard data and ensure the anonymity of our respondents and the data they provided; and, finally, we describe how we contacted the respondents for interviews.

Methods and Criteria Used to Identify Researchers and Scientists

We used five steps to identify leading U.S. researchers and scientists in the relevant fields of study. These procedures enabled us to identify individuals who had strong records of receiving federal funding for their research, had won prizes from scientific societies or had earned other professional honors, were widely published and cited, and were recognized by research funding agencies and other researchers and scientists as leaders in their fields. The following paragraphs describe the sequence of activities we undertook to identify top U.S. scientists in the 25 fields.

Step 1. RaDiUS Search

Using the Research and Development in the U.S. (RaDiUS) database, which was developed at RAND, we identified the researchers and scientists who are most active in the relevant fields, as measured by the number and size of federal science and technology research and development (R&D) grants they have received. For each of the 25 fields, search terms were selected to maximize the number of returned hits that would include federal R&D awards within the identified area. The individual searchers were scanned from FY2002, the most recently available information, backward over a five-year time frame. For each category, all identified research awards were analyzed to determine the frequency of mention of each identified principal investigator and the total average fiscal year funding over that time period for each one.

For every broader research area (e.g., agriculture, physics, and chemistry), a very large number of related individual R&D awards were identified, in some cases, more than 10,000. In cases where the number of awards exceeded 10,000, we refined our search to include only those funding agencies that attracted applications for research funds from scientists in a

broad range of fields (e.g., the National Science Foundation). It should be noted that general searches that use very common terms, such as "chemistry," potentially identified nonrelated research awards. However, we assumed that a relevant expert would likely be identified more frequently than an incorrectly identified nonrelevant individual. Therefore, the frequency-based analysis should reduce the chances of incorrectly linking a nonrelated individual to a particular research area. In some cases, the identified search area reflected only a very narrow discipline (e.g., neuroscience and behavior) and produced a much smaller number of relevant awards. This search using RaDiUS produced a total of 618 researcher names, 229 of which were in life science, 100 in environmental science, 114 in information and communication technology (ICT), and 175 in nanotechnology and materials science.

Step 2. Identifying Recipients of Merit Awards

Through Internet searches and consultation with professional societies, we sought the names of the winners of top scientific awards in the 25 fields. Unlike the awards in RaDiUS, which cover grants for R&D activities, we focused on awards that recognize outstanding scientific achievement. Our search covered 15 major scientific merit awards; they include the National Medal of Science, the MacArthur Foundation Fellows, the Albany Medical Center Prize in Medical and Biomedical Research, and other awards given for achievements in specific fields. Our screening process removed all awards associated with associations or societies for graduate students or strictly for funding research. We further refined our search by ensuring that the organization that made the award was a professional association, and we ranked the organizations according to the size of their membership and funding levels. Our search covered a five-year period, from 1998 through 2002. In cases where an award has been given out for fewer than five years preceding 2002, all years of the award granted were searched. We compared these search results with those from the RaDiUS search as a way to further establish the prominence of the researchers and scientists we identified.

Step 3. Bibliographic Search

The list of 618 researcher names for the 25 fields that resulted from the RaDiUS search and the search for winners of scientific awards was subjected to a publication and citation search. For this analysis, we used *SciSearch: A Cited Reference Science Database*, which indexes all significant items from approximately 6,100 international scientific journals. *SciSearch* contains records from agriculture, astronomy, behavioral science, biochemistry, biology, biomedical science, chemistry, computer applications, earth science, mathematics, medicine, meteorology, microbiology, nuclear science, pharmacology, physics, psychiatry, psychology, veterinary medicine, and zoology.

In this search, we focused on identifying the total number of articles and the total number of citations associated with the 618 researchers and scientists. Each name was searched as the publishing (lead) author and then as a cited author. Names in *SciSearch* are entered in the format of "last name, first initial, second initial (if available)" to ensure that authors are associated only with their own work and not with that of others with similar names or initials. In situations where the second initial was not available or when names were identical, we made additional efforts using other library tools to clarify identities. These tools included such databases as Agricola on Online Computer Library Center's First Search and PubMed, and we used the Google search engine for World Wide Web searches. Less than 10

percent of the full list needed additional research, and most identities were resolved. The names that could not be resolved were removed from our list.

Step 4. Nomination by Experts

Next, we asked a number of senior RAND researchers to review the list of researchers and scientists in their respective fields of expertise.[1] We also consulted with experts at the National Institutes of Health and the National Science Foundation, as well as at other well-known organizations that support scientific research, for their views on our list of researcher names. This expert opinion was extremely helpful in highlighting top scientists who might not otherwise have been identified if judged only by the number of research awards and the professional recognition they had received or on the basis of their publications and citations. The additional researchers and scientists suggested to us qualify as leading scientists and engineers because of the quality of their work and their impact on their fields, their appointments to major government and academic panels, and their positions as senior officers in top research organizations and professional societies.

Step 5. Referrals from Selected Respondents

Data from Steps 1 through 4 then helped us to identify a short list of researchers and scientists to contact for interviews. Priority was given to those who have, on balance, received a high number and value in research grants, have won scientific awards, have a high number of publications and citations, and have been pointed out to us by experts as leading researchers. In this manner, the researchers and scientists we selected can be considered the best or among the best in their fields in the United States. However, about a sixth of those we contacted declined to speak with us because they either had no time or were not familiar with research in Japan; instead, they gave us names and contact information for colleagues whom they regarded as knowledgeable about research in Japan. In a few instances, the names provided to us were on our list but were not among those in the top tier selected for interviews. Nevertheless, their familiarity with Japan enabled well-informed observations and they were also generally more eager to share their views with us than those with less or no research contact or interest in Japanese research. As a result, their input added considerable value to this research.

Human Subjects Protection Measures

This project was reviewed by the RAND Human Subjects Protection Committee (HSPC) to ensure compliance with federal regulations for protection of personal data. A data safeguard plan was developed, reviewed, and approved by HSPC. The plan defined how the data collected for this investigation would be stored and for how long, as well as other protocols for data safekeeping and ultimate destruction. All RAND researchers involved in the project signed a data confidentiality agreement, which further detailed the responsibilities involved in data collection, storage, transfer, and use. We also prepared an informed consent form, which provided information on the purpose of this study and on how the data collected were

[1] There are more than 1,000 researchers at RAND; more than two-thirds of them hold the doctorate or another advanced degree.

to be handled and used. The form was approved by the HSPC. It was presented to all respondents, and all respondents were required to give their explicit consent to the terms—in this case, verbal consent was deemed sufficient by the HSPC—*before* RAND researchers could interview them. Finally, HSPC also reviewed and approved our four interview questions (one each for the major topics of interest to MRI and CSTP).

Contacting Respondents for Interviews

Each RAND research team member was assigned responsibility for contacting researchers and scientists and completing interviews for a number of fields, depending on their expertise and research interests. All members were either trained in science, had conducted research on science and technology policy, or both. Respondents were contacted by electronic mail or telephone and asked to participate in the interview.

Before conducting the interviews, all respondents were told about RAND as an organization, the purpose of the interview, the identity of the RAND client for this project, how the data collected would be used, and the presence of data safeguard protocols to protect the anonymity of all respondents and their responses. We also answered any additional questions respondents had about RAND and this project and asked for their explicit verbal consent to use the information they provided under the terms described. Respondents were also told that the questions were open-ended and that they were to answer as they deemed appropriate. Only after completing these steps did we began our interviews.

As described in Chapter 1, we planned to conduct two interviews for each of the 25 chosen fields for a total of 50 interviews. But because we had three respondents each in the fields of neurology and behavior in the life science category and in mathematics in the ICT category, we eventually conducted 52 interviews. Where a third interview was conducted, the researcher we contacted accepted our invitation to speak with us *after* we had already spoken with the first two. We decided to conduct these third interviews because we were interested in these researchers' viewpoints.

Six RAND researchers completed these interviews—all by telephone—in September 2004. On average, the interviews lasted about 30 minutes. Respondents were first asked to state their own research interests within the field and to indicate whether their comments applied to the field in general or only to their specific research areas. We also asked the respondents to state the main sources for their information about Japanese research. We then went through the interview questions with them, allowing them to speak to the questions as they saw fit. We interjected or asked follow-up questions only for clarification and additional details or examples.

Of the 52 respondents, 50 were university-based researchers and scientists; only two worked for private commercial firms. Because of the distinction between basic and applied science in the fields of computer science, chemistry, and physics, we asked respondents in those fields where they place their work. Respondents did not generally find the distinction helpful in describing their research fields. They noted that conventional demarcations between basic and applied research are meaningless when few researchers and scientists engage in pure basic or applied research. The increasing interdisciplinary nature of research further challenges any attempt to box queries regarding the conduct of science into single fields. For

this reason, the summary of responses by category and field does not present separate reporting on basic and applied research in these three fields.

Whatever their sources for information might be, the majority of our respondents demonstrated a great deal of familiarity with Japanese research. Most readily named the Japanese researchers, scientists, and institutions they regarded as the best in Japan. Respondents also commented on how these researchers, scientists, and institutions compared with the best in the world. They were also able to name one or more Japanese scientific accomplishments that they regarded as important in their research areas.

The responses we received covered four types of institutions: universities; government-sponsored research institutions, which are funded but not run by government agencies; national laboratories, in which researchers and scientists are employees of the funding agency; and industry. The information our respondents provided focused primarily on research at universities and government-sponsored research institutions in Japan. Some feedback was also received on industry research.

Few respondents had much to say about research at the national laboratories. We cannot be sure whether our respondents, simply by chance or by choice, have not had much interaction with researchers and scientists from industry and the national laboratories. It might be that they believe that the best research in Japan comes out of the universities and research institutions. Also, the majority of our respondents are university-based researchers and scientists, so their familiarity with academic research in Japan might reflect the institutional environment they operate in; that is, both they and their Japanese counterparts may go to the same professional society conferences and read and write for the same scientific journals.

One final caveat: The answers from our respondents represented their knowledge, experience, and views about research in Japan. With few exceptions, their assessments were within the narrower scope of their specialized research areas rather than the larger fields, such as clinical medicine, mathematics, and physics, or the four categories (life science, environmental science, ICT, and nanotechnology and materials science) under which these fields were organized. Hence, we advise caution in generalizing from our summary and synthesis of responses, respectively, in the next two chapters, or from the individual response reports in the appendix to this document.[2]

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[2] The interview reports in the appendix are arranged in the order and grouping of the four categories and their subordinate fields, as listed in Chapter 1. According to the data safeguard protocols for this project, the names and other personal data of the respondents, such as email addresses and institutional affiliations, were removed. Data that would identify specific individuals and institutions in Japan—conveyed in the responses—were also removed for the same reason.

CHAPTER THREE

Summary of Responses by Topic, Category, and Field

This chapter summarizes responses to the four questions in our interviews. The comments we received from respondents are organized in the four categories of life science, environmental science, ICT, and nanotechnology and materials science identified in this study and the 25 fields under them. We also present here our four interview questions, exactly in the form approved by HSPC and read to our respondents.

Accomplishments of Japanese Scientific Institutions

To obtain our respondents' perspectives on the accomplishments of Japanese scientific institutions in diverse fields, we asked the following question.

> *What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5–10 years)?*

Life Science

Respondents showed broad general knowledge of Japanese scientific undertakings in the fields listed under the category of life science. There was considerable in-depth knowledge of Japanese research activities, the particular researchers and scientists leading them, and their research institutions. Although Japan was seen as an important actor, in general, and was described as having made significant contributions in many research areas, our respondents did not think Japan had made groundbreaking discoveries. Further, Japanese research was considered solid, but not exceptional. The list below provides a brief overview of the accomplishments singled out by our respondents.

- **Agricultural Science.** One respondent thought that Japan has played a major role in advancing plant genomics, pointing in particular to Japanese work on sequencing the rice genome. The second respondent was less impressed by Japanese research in this field, saying that Japanese research is always good, but not groundbreaking by international standards.
- **Biology and Biochemistry.** The first respondent in this research area said that Japan has made very strong contributions in glycobiology; a noteworthy accomplishment was the elucidation of glycan structures, which was reported to have had a major im-

pact on the field. The second respondent had a different opinion. He reported that Japanese researchers and scientists do only initial observational work and typically fail to follow through to develop deeper knowledge. Using stroke research as an example, the respondent stated that Japanese scientists had examined key pathways involved in the occurrence of strokes, but they had stopped short of understanding those mechanisms.

- **Clinical Medicine.** The first respondent in this research area pointed to Japanese research capacity in studying adverse drug effects, but could not name any specific Japanese accomplishments. Our second respondent saw Japan as being behind the world's leaders in research on virology and infectious disease and, more specifically, in research on rotavirus, the influenza virus, enteric viruses, and flavivruses. He recalled there being a number of Japanese researchers and scientists in virology in the past, but indicated that Japan has lost ground in this area in the past 20 years. He added that current research in Japan is less innovative than in the past, and Japanese research in virology and infectious diseases today concentrates on developing assays.
- **Immunology.** Japan was regarded as an influential actor in this field, having produced many important discoveries and outstanding research. Japan was reported to have made seminal contributions to molecular immunology. Japan's success in identifying the AID protein, which plays a central role in somatic mutation, was highlighted.
- **Microbiology.** Japanese microbiologists were described as having made substantial contributions to research on antimicrobial agents and antimicrobial resistance. Further, many pharmaceutical agents developed by Japanese institutions were bought by or licensed to U.S. drug companies. Japanese researchers and scientists were also reported to have an excellent basic understanding of microbial processes important to environmental issues—most notably in the area of anaerobes, which are important to waste treatment. Japan was said to have been involved in this field for a long time, originally focusing primarily on commercial applications and shifting more recently to environmental applications.
- **Molecular Biology and Genetics.** Japan's production of a great deal of cDNA data related to gene sequences was noted as an important accomplishment. Within the field of molecular biology, however, the respondent said that Japan is not a major player. Japan was also said to have an active role in the genome research center and to be contributing significantly to sequencing parts of specific chromosomes. The respondent also noted that Japan has been a leader in cloning full-length copies of genes.
- **Neuroscience and Behavior.** On the whole, Japan was not seen as producing groundbreaking research, although it was seen as contributing to the sum of knowledge in this field. However, there was observation of significant improvement, producing superb work following the Japanese government's decision to make a major commitment to the neuroscience field. Japanese research on primate neurophysiology and the brain basis for perception was singled out as an example of excellent research.
- **Pharmacology and Toxicology.** Japan was reported to be doing critical work on arylhydrocarbon receptor (AhR). Japan's strength in toxicology was highlighted. Japan's basic research in the 1970s on ideas such as carcinogens in burned foods was cited as a major contribution to the field. International work on drug toxicity was also

thought to have benefited from Japanese research in molecular biology events involving GstP (glutathione S-transferasediseas).

- **Plant and Animal Science.** Japan was regarded as a strong player in this area, particularly in basic research. One Japanese team was described as being at the forefront of using technology to make plant genome data widely available via a publicly accessible database. Other Japanese teams did good or excellent work in a variety of areas, including plant hormone signaling, functional genomics, the molecular genetics of rice, cell biology, and plant developmental biology. Japan was also said to produce great models for this field. Japan was reported to be consistently strong in basic plant physiology, and its most notable accomplishment to be in light signaling and responses in plants. Japanese scientists were said to have made many major accomplishments in research on light receptor molecules, such as phytochrome and kryptochrome, and Japan's construction of a large spectrograph was seen as critical to advancing the field.

Environmental Science

Compared to Japanese efforts in other categories and fields investigated in this study, efforts in environmental science were regarded by respondents as consistently good. Japanese research capacity appeared to have advanced significantly in recent years. Respondents generally found Japan to be doing excellent work in applied research and making clearly important scientific contributions. However, several respondents pointed out that better international communication would probably improve Japan's standing in fields in this category. The following list provides a brief overview of Japanese accomplishments in environmental science that were highlighted by our respondents:

- **Ecology.** Japanese researchers and scientists were reported to be doing interesting work on the effects of disturbances such as windstorms on temperate forests, fairly good work on understanding hurricane effects on forest systems, and very good research on the origin of life and its molecular basis. Good work was also beginning to emerge in wetland restoration, but major accomplishments have yet to emerge in ecology studies of deep-sea thermal vents.
- **Energy Engineering.** Japan was noted for its excellence in advancing fuel-efficient vehicles, specifically hybrid cars, which were described as an extraordinarily bold and visionary move. Cutting-edge work produced by Japanese researchers and scientists has enabled the development of crucial control algorithms for these vehicles. Hybrid car technology was seen as changing the entire automotive industry and guaranteeing Japan's leadership in fuel-efficient vehicles in the foreseeable future.
- **Geoscience.** Construction of the Earth Simulator was regarded as one of the most important Japanese accomplishments. The Earth Simulator was described as providing truly cutting-edge simulation of weather and climate change and an amazing technical feat for reaching computational speeds 10 times greater than the best available in any other country. Japan was also seen as having made important strides in using Global Positioning System (GPS) receivers for meteorology and climate change research. Japan was regarded as at the forefront of this research area having made important contributions in tropical cyclone research. Another important Japanese application of GPS was in fine motion detection, which is vital to understanding plate tec-

tonics. In addition, one respondent noted that Japan has done pioneering work using GPS receivers to develop atmospheric moisture profiles, and Japan, at one point, was far ahead of the United States in regional spectral modeling. Finally, Japanese researchers and scientists were reported as being very strong in data simulation, particularly variational data simulation.

Information and Communication Technology

Feedback from our respondents reflected broad general knowledge of Japanese scientific undertakings in ICT. Japanese scientists were seen as doing solid, high-quality research and making important contributions in a wide range of research areas, but Japanese research on the whole was not characterized as groundbreaking. Respondents thought that one reason international perception of Japanese research was not more favorable was that many breakthroughs are not communicated to the larger international scientific community. The list below presents the Japanese accomplishments in ICT cited by our respondents.

- **Computer Science.** A major accomplishment in computer science was the development of Internet Protocol Version 6 (IP V.6), which is critical to broadening Internet mobility. Japan was also regarded as having done excellent work on Internet-enabled consumer electronics. Docomo's I-mode phone was singled out for its advantages over similar European applications using the Wireless Application Protocol. Japanese research in distributed systems and highly dependable systems, though not groundbreaking, was regarded as competitive with the best in the world. Japanese researchers and scientists were seen as best known within this arena for their strength in hardware manufacturing. Japan was not seen as having made any truly important or interesting accomplishments in the area of formal verification but was described as working very hard in speech processing and producing fairly good work.
- **Electrical and Electronics Engineering.** Japan was regarded as having done excellent work in developing future semiconductor devices that are at the limit of sizing in nanoelectronics, as well as in producing top-quality single-electron devices, particularly silicon-based devices. Japanese researchers and scientists were regarded as having done good work in the emerging field of spintronics and are on the cutting edge in mesoscopic physics. A major Japanese accomplishment cited was development of space-based assets for weather and disaster prediction. For example, the space-based weather radar developed in collaboration with the United States has allowed researchers and scientists to study and monitor large-scale weather systems, such as hurricanes, with the aid of detailed, high-quality pictures of entire hurricane systems.
- **Mathematics.** Japan's strength across diverse research areas in mathematics was found to vary considerably. Japanese leadership in developing quantum groups theory was reported as one of its most notable accomplishments. Japanese research was also reported to have contributed to the Boltzman equation, waterwaves, and general theorems for hyperbolic waves, and also to advancements in calculus, mathematical physics, factorization methods, and stochastic differential equations and processes. Japan was not considered particularly strong in the area of nonlinear partial differential equations (PDE).
- **Mechanical Engineering.** Japan's capacity in this arena was evident in the responses we collected. Examples of major accomplishments named included automation of

fabrication and building processes, new welding processes, and new steel material development. Japanese steel companies, in particular, were seen as leaders in steel development and implementation. Japanese technology in thermal and mechanical processing of steel, which improves the quality of steel for infrastructure use, has been used in Japan for decades but only recently introduced to the United States. Japanese research was also said to have been instrumental in developing international building standards, a movement led by Japan in the 1980s. Japan was ahead of everyone else in applying composite materials to civil engineering structures and is a leader in smart composite materials and high-temperature applications for composite materials, such as in rocket and jet engines. Japanese research on carbon fibers reinforcing polymeric substances was regarded as the best in the world. Its work was said to have pushed forward research in this area internationally.

Nanotechnology and Materials Science

Compared with efforts in the other categories and fields investigated in this study, Japanese efforts in nanotechnology and materials sciences were notable for their consistent high quality. The lack of depth in research was noted but, on the whole, Japan was regarded as the best in many specialty areas and comparable to the best in the world in most other areas. Japan was described as having made some fundamental discoveries from the 1950s to the 1970s and its important accomplishments have continued over time in many areas.

- **Ceramics.** Japan was regarded as excellent in making new or improved ceramics products based on breakthroughs made elsewhere, but Japanese research was not seen as innovative. More specifically, in the electrical ceramics area, Japan's success in "reduction to practice" was underscored. Japanese universities and commercial firms were reported to produce excellent ceramic sensors, actuators, and transducers. Today, Japan was said to control about 90 percent of the world market for electroceramics—a significant change from 30 years ago when Japan did not produce a single multilayer capacitor.
- **Chemistry.** Japan was credited with much of the early work on developing carbon nanotubes. Japanese accomplishments noted in the area of physical chemistry were the application of lasers to the study of ultrafast spectroscopy and the development of methods to understand complex molecular dynamics.
- **Metals Research.** Japan was noted as one of the world leaders in thermal electro-oxides, molecular beam epitaxy (MBE), and high-temperature superconductor superlattices. Japanese researchers and scientists were also thought to have done very innovative work on Van der Walls epitaxy and titanium oxide, as well as in materials synthesis in superconductor and magnetics research. Japanese efforts in applied synthesis of new materials and fabricating world-class samples were described as being 10 times greater than efforts in the United States.
- **Physics.** Japan was described as having no equals in high-energy physics and neutrino physics, and its capacity continues to grow. The Super-Kamiokande, which detects solar and supernova neutrinos, was regarded as a world-class facility, and the KamLAND experiment to study the fundamental property of neutrinos was cited as a world-class project. Japan's work in fundamental physics was regarded as worthy of a Nobel Prize. Japan was also reported to be doing extraordinary work in carbon sci-

ence, and one respondent noted that Japanese carbon companies were far ahead of everyone else in applied research. Other areas of strength noted were Japanese research on lithium ion batteries, boron doping, and small nanostructure components. Japan was reported as having been a leader in high-pressure physics for the past two to three decades. Its early work in the area was described as revolutionary, and world-class work is being done today at Japanese universities in applying high-pressure physics to understand the earth's deep interior. Important research was also observed in seismological topography with application to earth science. Finally, Japan was also described as having made significant contributions in advanced materials fabrication and nanoscience and as a leader in high-temperature superconductors and carbon nanotube fabrication. Japan was credited with enabling basic understanding of carbon nanotubes.

- **Polymers.** Japan was noted for discovering the blue laser and for its world-class work on protein folding.
- **Semiconductors.** Japan was reported as the original developer of bulk metallic glass. Other areas of significant Japanese contribution reported were superconductors, electro-ceramics, Piezoelectric materials, high-temperature superconductors, rapid solidification of materials, hard magnet design, and powder metallurgy. Japan's discovery of carbon nanotubes, too, was said to have started an entire field of research. Other innovative research noted was the development of fuel cells based on carbon nanotubes.

Quality of Japanese Research

To obtain our respondents' perspectives on the quality of Japanese scientific institutions in their areas of expertise, we asked the following questions.

> *What is your evaluation of the research produced by Japanese institutions in your field of expertise? In particular, how would you compare these institutions and their work with those in other countries (U.S., Europe—the leading scientific countries) that are considered the best in your field?*

Life Science

Japan's best research compared favorably in quality with the best work in the United States and Europe, and Japan was described as being clearly ahead of both in some areas. However, taken as a whole, the Japanese research portfolio was described as having a more limited scope and a smaller quantity of work produced. Japan's best work in agricultural science, microbiology, neuroscience and behavior studies, and plant and animal research was regarded as on par with that of the United States and Europe. Opinions differed on Japan's contributions in other areas. One respondent thought that Japan was equal to the United States in biology and biochemistry; the other thought that Japan was behind the United States. Opposite views were also reported in molecular genetics. One respondent thought that Japan was ahead of the United States in pharmacology and toxicology; the other thought that Japan was only on par with the United States. One respondent thought that Japanese capacity in clinical medicine had slipped over time.

The list below provides a brief overview of how respondents compared Japanese research to that conducted in the United States and Europe.

- **Agricultural Science.** The best Japanese research in agricultural science was considered second only to that in the United States and comparable in quality to the best anywhere in the world, but a lack of depth was noted.
- **Biology and Biochemistry.** Japan's research in biology and biochemistry was said to be strong, and some cutting-edge research was identified. Japanese researchers and scientists were said to be good at starting research in this area, but they do not typically invest further in understanding the mechanistic aspects of the problem. In a similar manner, it was noted that Japanese scientists develop initial approaches but fail to take them further. U.S. researchers and scientists were considered to do a better job of exploiting technologies.
- **Clinical Medicine.** Japanese research in clinical medicine was characterized as being very good. Japanese researchers and scientists were thought to pay better attention to drug safety than their colleagues in the United States. Although Japanese research was considered well done and reliable, it was not seen as innovative or exciting.
- **Immunology.** Japan was seen as a leader in immunology. The best scientists in Japan were regarded as being of the same caliber as the best in the United States, although U.S. immunology research was seen as stronger overall.
- **Microbiology.** Japanese microbiologists were said to be as good as international leading researchers and scientists elsewhere and ahead of the United States and Europe in research on microbial applications to environmental problems.
- **Molecular Biology and Genetics.** We heard conflicting opinions of Japanese research in this area. Our first respondent thought that Japan is not now positioned to make major contributions to the field because of a shortage of trained personnel. Japan was characterized as being where Europe was 10 to 15 years ago. Our second respondent considered Japanese research in this area to be top-notch.
- **Neuroscience and Behavior.** Our respondents differed about the quality of Japanese research in this field. Japan was simultaneously described as first class, the same or better than other countries, and not quite up to expectations for a large, well-educated nation.
- **Pharmacology and Toxicology.** Japan was described as doing top-quality academic work that compares well with basic research in Europe and the United States but was seen as weaker in applied research.
- **Plant and Animal Science.** Japanese research in this area was described as very solid. Japanese researchers and scientists were seen as doing high-quality work, but revolutionary discoveries, such as sequencing whole genomes, were missing. Japan was regarded as being more successful at taking revolutionary work done elsewhere and applying it to real-world problems. Also, Japan's early work on light receptors was regarded as top-notch, but recent work was not seen as equally innovative or influential.

Environmental Science

Comments from our respondents suggested that Japan is still behind other top scientific countries in environmental science, with the possible exception of research in energy engi-

neering. Respondents largely thought that Japanese research was of high quality but not quite yet among the best. They also observed that Japanese research frequently followed developments in the United States and Europe, particularly in fundamental research. Japan was regarded as on par or ahead of the United States in energy engineering (both respondents spoke about hybrid automotive engines). Significant improvement was noted in ecology, although Japan is still behind the United States. In geoscience, the Earth Simulator was regarded a major achievement, putting Japan on par with the United States.

- **Ecology.** Japanese research in ecology was characterized as being of good quality but still a bit behind the best in the world. It was characterized as being influenced by European studies, which use approaches that are less quantitative and not much in fashion in the United States.
- **Energy Engineering.** Japanese research was thought to compare fairly well with that in the United States and Europe. Japan was described as on par with both in academic research in energy engineering, although without the same breadth and depth. Our respondents noted that Japan produces better, cheaper, and more efficient products, but it does not always produce the ideas that lead to those products. Japanese research was seen as benefiting from long-lasting relationships with industry.
- **Geoscience.** Top Japanese geoscientists were described as slightly behind their U.S. counterparts, and truly original research was lacking. The most important mark of Japanese excellence noted was the Earth Simulator, which was described as the best facility of its kind in the world—an order of magnitude better than anything available in the United States or Europe. Japanese researchers and scientists were seen as ahead in computer simulation and computational infrastructure, excelling, in particular, in high-end computing.

Information and Communication Technology

Most respondents thought that Japanese research in ICT was as good as that carried out in the United States and Europe, and Japan was seen as leading the world in a few areas. More specifically, Japan was seen as on par with the United States in computer science and electrical and electronics engineering, and ahead of the United States in mechanical engineering (where construction research is concerned). However, Japan was seen as being behind the United States in math. More important, Japanese capacity in math was seen to have declined over time. Several respondents mentioned that within the region, Japan is facing new competition from other Asian nations. Respondents found Japan lacking in depth of research capacity, as in research in life science.

- **Computer Science.** Japanese research was described as competitive with that of other leading scientific countries, including the United States. Japan's footprint in theoretical research was seen as shrinking, even taking into consideration that Japan's historical strength is in hardware and it has never been strong on the software side. Japan was described as facing increasing competition from Taiwan, South Korea, and China in the hardware domain. Japan was regarded as among the top two nations (the other being the United States) in the world in speech processing research. Japan was regarded as less visible internationally in this area than the United States, but its leadership in organizing a major annual international meeting on speech processing is

raising its international standing. Performance varies across ICT fields and research areas. Japan was reported to excel in optical communications, but it is seen as weak in computer networking research and in manufacturing Internet hardware, such as routers.

- **Electrical and Electronics Engineering.** Japan was said to have risen to the top of this field and was described as among the very best or on par with the United States and Europe. Japan was also described as having invested more in basic research. The quality of Japanese research, in general, was considered comparable to work done in the United States and Europe, but its quantity fell short. Japan was also observed to target excellence in a narrower set of research areas than the United States.
- **Mathematics.** Our respondents stated that the best schools in mathematics are American and French, so that, although Japan was seen as strong in specific basic research areas, it does not have great pockets of strength. Japan was seen as doing well in applied mathematics, but its work was described as significantly lower in quality than work done in the United States and Europe.
- **Mechanical Engineering.** Japanese research in mechanical engineering was regarded as comparable in quality to the best anywhere in the world. Japanese industry was described as more willing to implement new technologies and invest in risky technologies than its counterparts in the United States and Europe. The strength of Japanese research in this field lies in industry, which also conducts its own basic research. Notable, though, is the rise of China and Brazil, which enjoy low fabrication costs.

Nanotechnology and Materials Science

Japan was seen as being on par with the United States and Europe in almost all areas of nanotechnology and materials science and ahead in several fields. Unlike the other three categories in this study, Japan had clearly assumed a more significant leadership role in nanotechnology and materials science and was seen as being the most, or among the most, important actors in these fields. The clearest example of Japanese success and world leadership is in carbon nanotube development, which was cited by several respondents. Other areas of world leadership were high-energy physics and high-pressure physics. Improvement was observed in metals research and Japan was seen as being on equal footing with the United States in chemistry and semiconductors research. Only in polymers research and physical chemistry was Japan regarded as being behind the United States.

- **Ceramics.** One respondent said that Japan has always been ahead in ceramics. Japanese researchers and scientists were regarded as outstanding in the areas related to electro-ceramics; they are definitely leading the world. Japan was also regarded as the leader in multilayer capacitor and substrate industries. However, the quality of education or training in Japan was perceived as poor, which was used to explain Japan's lack of theorists and its focus on manufacturing.
- **Chemistry.** One respondent thought that Japanese research in chemistry was of very high quality, but little of it could be described as high-risk. Japanese research in areas related to nanotechnology was considered first-class and respondents reported a large number of Japanese publications in this area. Japan was also seen as world-class in advanced materials research. One respondent felt that Japan did not compare well with other countries in physical chemistry. Japan was considered as being on par with

the leading countries in basic chemistry. Japan's excellence in this area, according to one respondent, has made Japan a top destination for sabbaticals and research visits by U.S. senior scientists.

- **Metals Research.** Japanese laboratories were considered comparable to those in the United States and Europe. Also, the best Japanese universities were regarded as on par with the best in the United States, but the average level of capacity of researchers and scientists and institutions was considered lower in Japan.
- **Physics.** Japan's rise as a leader in physics was described as spectacular. Japan's work, especially in applied physics, was regarded as very impressive. The quality of work was said to vary considerably: The best work in Japan is on par with work done in the United States, but depth is lacking as reflected in the small number of top research groups in Japan. Japanese research in high-pressure physics was described as comparable or even better than work done in the United States and Europe, but Japanese research in seismological topography has been less consistently good. Japan was considered a leader in advanced materials research, particularly in fabricating novel materials. Japan was thought to be in the top tier in high-temperature superconductors, along with the United States, and perhaps even better than the United States. Japan was also noted for having the best equipment in world.
- **Polymers.** Our respondents thought that the best work in polymers is done in the United States, France, and Germany, and Japan ranks slightly behind these leaders. Nevertheless, the best work in Japan was considered comparable in quality to the best work of U.S. researchers and scientists.
- **Semiconductors.** Japan was considered to stand on equal footing with the United States in the area of bulk metallic glass. Japanese industry research was considered strong, and this strength is reflected in the innovativeness of its products. Japan was noted as being traditionally strong in Piezoelectric materials, ceramics, and electronic materials. Our respondents considered Japanese research as being ahead of the United States in some cases, but lagging behind other leaders in terms of the international visibility of its work in this area.

Longitudinal Trends in Performance of Japanese Scientific Institutions

To obtain our respondents' perspectives on whether and how the performance of Japanese scientific institutions has changed over time, we asked the following question.

> *What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?*

Life Science

When looking at Japanese research over time in the fields listed for the life science category, most respondents indicated that Japan is improving its capabilities (as reflected in the outcomes of research). However, this growth is slow and steady rather than revolutionary, and Japan had also declined in a few areas. In addition, an accurate assessment of Japanese research was seen by some respondents as hindered by Japanese reluctance to release research

results in a timely fashion. Many respondents thought that major cultural and social changes have made it easier to conduct scientific research in Japan, yet it was generally perceived that research freedom in Japan is still inferior to that in the United States and Europe. Respondents saw "brain drain" in some areas, caused by researchers and scientists moving to other countries to conduct research and an aging scientific community because fewer young people are interested in science careers.

Environmental Science

When looking at Japanese research over time across environmental science, respondents found improvement overall. One respondent suggested that this improvement has come about despite a cumbersome bureaucratic system in Japan. Another respondent argued that improved communication with U.S. and European researchers and scientists has led to improved perceptions of Japanese accomplishments over time. One respondent noted that within the energy engineering field, Japanese companies still do very innovative things and take technical risks, which one does not see as much in Western companies. Within the geoscience area, both respondents saw a good deal of balance in Japan's environmental research program even though focuses have shifted over time.

Information and Communication Technology

When looking at Japanese research over time, most respondents reported improvements in capacity and innovation. The most pronounced progress was observed in academia; corporate research had suffered because of the country's economic problems in the past decade. Some of the most important Japanese advances were made in the 1970s and 1980s. Increased university-industry cooperation in recent years raised hopes of important innovations in the future. Some improvement in facilities and equipment was observed (e.g., increased access to personal computers), but major problems persist with poor physical infrastructure. Japan was seen as staying current with the state of the art in many fields but not always advancing its overall standing. Nevertheless, dramatic successes do occur. For example, Japan was described as initially copying U.S. research in the electrical and electronics engineering field, but today U.S. researchers and scientists are copying from Japan. One concern is the shortage of young researchers and scientists to replace aging senior researchers and scientists and lead Japanese science in the future. Finally, more targeted R&D funding in recent years has improved capacity in the areas funded but those with reduced funding have suffered. This shift from a broad-based to a strategic approach to R&D funding in ICT clearly has important ramifications.

Nanotechnology and Materials Science

Respondents thought, on the whole, that Japan has improved and, in some cases, dramatically. Improvement has been particularly evident at the universities, but less progress has been made in industry and the national laboratories. Tremendous nonlinear growth has been observed within the ceramics field in the past 10 to 15 years. Japan has come to be the world leader in neutrino physics in a matter of 15 years.

Importance of Japanese Research Institutions in the International Arena

Our last topic concerned respondents' perceptions of Japan as a scientific power in their research areas. Each respondent was asked to comment on this topic.

> *Comment on and provide examples of whether Japan is an important research player in your field of expertise.*

Life Science

Respondents generally felt that Japan was a major actor in this field of research, but Japanese contributions and achievements were not seen to equal those of the United States and Europe. Many respondents pointed to more Japanese participation at major international conferences and increased international collaboration as evidence of improved standing within the world scientific community; they believed that this was beginning to pay dividends for Japan and raising its status within various research areas. Some respondents indicated that a "muddled" academic system, which does not allow a great deal of academic freedom, meant that Japanese research was not as competitive as that in the top countries in the life science fields. The Japanese were often referred to as "rivals" or "competitors" but were not often thought of as the leading country within a specialized research area.

Environmental Science

Those interviewed for this study generally agreed that Japan is an important contributor in environmental science but not at the same level as the United States and Europe. Japanese research was seen as solid but not the best in the world. A slight exception in energy engineering is the development of hybrid vehicles, which has made Japan the leader in this area. The Earth Simulator was also pointed to as the best facility of its kind in the world. Overall, therefore, Japan is "respected around the world . . . [but] not considered to be at the very top."

Information and Communication Technology

On the whole, our respondents regarded Japan as a major actor in ICT, with seminal contributions that date back several decades. Today, Japan remains a leader in fields ranging from bridge-building to space-based weather radar to carbon fiber development. But its influence in some areas has also declined in the past 10 to 15 years. For example, Japan was a major player a decade ago in mathematics, but not any more. Japan has attempted to take a leadership role in specific research areas, such as bioinformatics, distributed computing, and networking infrastructure. These efforts have met with mixed success. Japan's standing in this area would be helped if more graduate students were sent to study at laboratories in the United States and Europe. As was the case in life science, Japan was regarded as an important player but viewed as being slightly behind the United States and Europe.

Nanotechnology and Materials Science

Responses varied greatly among our respondents. Many thought that Japan was an important actor, but many others did not share this assessment. On the whole, feedback indicated that Japanese research was highly regarded by our respondents but Japan was still seen as being second to the United States. In research areas where there is a clear distinction between basic

and applied research, there was a near universal opinion that Japanese scientists excel primarily in applied areas. Respondents spoke well of Japan's ability to take breakthroughs or products produced in other countries and improve upon them.

CHAPTER FOUR

Analysis and Synthesis of Responses

Our analysis of interview data also highlighted many significant issues about science and technology research and development capacity in Japan. These issues either cut across or were beyond the scope of the four interview questions. Although the issues highlighted here do not represent a comprehensive list of Japanese scientific accomplishments or priorities, or an in-depth analysis of Japanese science, they offer substantial insights about the current state of science and technology research and development capacity in Japan and, in so doing, provide valuable information for future policy decisions.

Main Sources of Information

Our respondents reported several major sources of information on Japanese research. They include scientific journals; professional society newsletters; professional conferences; visits to Japan; research collaborations; visits by Japanese researchers, scientists, and postdoctoral fellows to their laboratories or university departments in the United States; email exchanges; and voluntary or paid service as advisors and reviewers on scientific boards and panels.

Among these sources, conferences and publications were mentioned most frequently. Many respondents said that listening to papers presented at conferences and interaction with fellow participants were the best way to learn about the latest work in Japan. Many respondents reported that they had attended professional meetings in Japan organized by Japanese institutions, as well as meetings organized by international professional bodies. Respondents found these meetings helpful in learning about the latest research and the top researchers and scientists in their fields in Japan. Publications in scientific journals or professional society newsletters were cited by virtually every respondent as being important to informing them about research in Japan. The reporting of Japanese research findings in publications enabled our respondents to learn what research is being done, who is doing it, where it is being done, what methods are being used, and what sorts of instrumentation and data are used in the work.

Their review of literature, however, was limited to English-language publications, mostly those published in the United States and some in Europe—journals that would be regarded as the leading publications in their fields or specialty areas. A few reported that they regularly use English-language scientific journals published in Japan because they thought that Japanese researchers and scientists did some of the best work related to their research interests and reported their work in these publications.

Among those who had spent more considerable periods in Japan, only three respondents reported sabbaticals in Japan (one in plant science, two in computer science), one taught in Japan as a visiting professor, and two spent time in Japan on Japanese government fellowships. On research collaborations, six respondents reported past or current collaborations. One said that his work with a Japanese scientist on carbon nanotubes completely changed his career. The rest were much less enthusiastic, including two who said that the bureaucracy and hierarchical social structure in Japan have dampened their interest in new collaborations with Japanese researchers and scientists. Also, two respondents said that they had done research for Japanese commercial firms: One had sat on Japanese government-sponsored scientific panels, and six reported frequent or regular visits to Japan for research or to attend conferences.

Universities and Industry Research

Research at universities in Japan was described as mainly application-oriented although an increasing amount of basic research was reported at a few universities and selected research areas. In contrast, Japanese industry was reported to conduct a considerable amount of basic research. The quality and creativity of fundamental research in industry were seen by several respondents as being more competitive than university research in Japan. In some fields and specialty areas, industry research scientists, rather than their counterparts in universities, were regarded as the leaders in Japan. Japanese industry laboratories were seen as having excellent facilities and equipment and solid funding.

Quality of Facilities

Infrastructure, facilities, and equipment for success in scientific research were cited as critical issues in the discussions. How well researchers and scientists perform depends on the infrastructure, facilities, and equipment available to them. When asked to evaluate the performance of Japanese institutions over time, a large number of our respondents spoke on this subject. They emphasized that substantial investment in these areas is needed and that it must be sustained over a period of time to support scientific research today and groom the next generations of Japanese scientists. In their view, Japan's successes in science today, such as in nanotechnology, resulted from sustained investment over many years. Indeed, in areas where Japan was described as world-class or comparable to the United States and other countries with strong scientific establishments, Japan's scientific infrastructure, facilities, and equipment were generally described as state of the art.

Many respondents reported that facilities and equipment at university laboratories have improved over time. A few respondents working in what appeared to be areas receiving substantial Japanese government attention and funding, such as brain research, reported the creation of several government-sponsored research centers, along with new buildings and world-class equipment. Interview responses suggested that where improvement was less dramatic, universities at least managed to keep their laboratories from deteriorating. However, on the whole, infrastructure at Japanese universities, even among the best, was not generally

viewed as excellent. In fact, it was described as poor in some cases—even at an imperial university.

Industry, by comparison, was regarded by several respondents, particularly those in the ICT fields, as having better infrastructure, facilities, and equipment than universities. In some cases, university-industry collaboration provided university researchers and scientists access to facilities and equipment that they did not have at their home institutions. Indeed, it appeared from responses across the fields that universities still have some catching up to do, despite an overall improvement in the past decade or more.

University-Industry Relations

Opinions about the quality of university-industry relationships in Japan differ among respondents who commented on this topic. Some respondents described university-based researchers and scientists in their fields or specialty areas, such as carbon science, as having difficult university-industry relations. But, many respondents described very close working relations between universities and industry, and these relationships were seen as greatly facilitating the transfer of research findings, including new technology, from university to industry. Respondents engaged in metals, pharmaceutical, and automotive engineering research, for example, reported positive and dynamic relations between university researchers and scientists and their industry partners.

Successful university-industry relationships were often described as lasting for long periods. One respondent portrayed such relationships as linkages in which industrial enterprises "adopt" universities, making them (or specific departments and research teams) long-term exclusive partners with multiyear grants and contracts. For example, one respondent provided a detailed description of a particular university-industry relationship in which the university received three- to five-year grants from a commercial enterprise.

Innovativeness of Japanese Research

Several respondents characterized the thrust of Japanese research programs by saying some variant of, "When Japan decides to do something, it really goes at it." A few thought that Japanese research in their field or specialty area was ahead of that in the United States, such as in microbial application to the environment, hybrid automotive engineering, civil engineering, cancer research, hepatitis, and seismic research. One respondent thought that in high-temperature superconductors, Japan was first in the world. A couple of respondents praised, in particular, Japan's ability to "reduce [scientific findings] to practice," that is, to move scientific discoveries and technological innovations into applications.

The majority of respondents described Japanese research in their field or specialty areas as "cutting-edge," "world-class," and "on par" with that in the United States and the best in the world. Even when the work was not top quality, Japanese research was described as "solid" and "reliable." However, with few exceptions, respondents emphasized that their view that certain individuals and institutions are excellent was specifically linked to those individuals and institutions and did not reflect an assessment of Japanese science on the whole in

their fields or specialty areas. When evaluating the quality of Japanese research on the whole, the lack of depth, innovation, and creativity were invariably noted.

Responses suggest that research areas in which Japan was perceived to excel were areas that were closely associated with problems significant to safety and health in Japan or closely tied to Japan's industrial competitiveness and policy priorities. Examples included Japanese research in cancer, hepatitis, seismology, environmental technology, and automotive engineering. Resources available from government to support work in these areas had allowed not only the development of individual experts but also some depth reflected in the presence of a considerable number of good researchers and scientists in a larger number of institutions across Japan.

Perceived Changes in Science and Technology Research

Overall, the quality of Japanese research was seen to have improved over the past decade, and change had been particularly dramatic in some areas. Japanese research in some specialty areas was seen as having gone beyond being good—that is, being reliable and making incremental contributions—to being innovative and creative. For example, Japanese theorists in advanced materials and nanoscience were described as extremely creative and innovative. In this instance, one respondent reported seeing increased decentralization and depth as more Japanese researchers and scientists work in this area, many of them outside the top institutions in Tokyo. Another indicator cited was the increased number of Japanese publications in leading scientific journals, such as *Science* and *Nature*.

A number of respondents stated that the structure of science in Japan was changing, from one that involved close relationships between the ministries and universities and government-sponsored institutions to one characterized by greater competition in the allocation of R&D funding. Respondents who spoke on this topic thought it likely that these changes would improve the quality and innovativeness of Japanese research, but they felt that it was too early to assess their impact. It was noted that the effects of these changes might not be apparent until about a decade from now.

Japan's Relationship to the Global Science and Technology Community

Respondents felt that Japan's visibility in the top international scientific journals did not reflect its scientific capacity and accomplishments. Publishing in the Japanese language and presentations in Japanese effectively limit access to Japanese research by researchers and scientists outside Japan. None of our respondents reported reading Japanese-language scientific publications, but many indicated awareness that a vibrant scientific community exists in Japan with its own conferences, publications, and professional societies—all in the Japanese language.

This domestic community provides rich opportunities for Japanese researchers and scientists to publish and present their research findings rather than seeking outlets in the United States or elsewhere. One respondent found it remarkable that Japan still publishes a larger number of scientific journals at home than such nations as Germany and the Netherlands—countries that have sophisticated scientific capabilities but where researchers and sci-

entists strive to publish their work in English. Other respondents thought that an incentive structure that rewards visibility of their work within Japan might be the motivation for Japanese researchers and scientists to publish and present their work within Japan rather than overseas. Hence, some respondents felt that perhaps very innovative work was being done in Japan and reported in Japanese, but the world does not know about it because outsiders judge only by English-language publications and presentations.

Given the presence of this large and dynamic scientific community in Japan, a few respondents indicated that it was hard to tell whether innovative research was not being done or was being done but reported only in Japanese-language journals. In this connection, several respondents said that they observed that innovative work in Japan was usually published first in Japanese, then debated and refined within Japan before the work was published in English in Japan or overseas. Hence, by the time the rest of the world learned about the work, perhaps years later, the work might no longer appear innovative, even though it would have been seen as cutting-edge when it was first reported within Japan.

Rise of China and Korea as Major Scientific Nations

An interesting point brought up by a few respondents was the rise of China and Korea as major scientific nations. One respondent thought that regional politics might make it difficult for Japanese scientists and institutions to collaborate with their Chinese and Korean counterparts. At the same time, China and Korea—nations that are able to do good science at lower cost—might begin to compete with Japan in securing international research partners such as the United States.

Caliber of Japanese Scientists

In general, respondents took the view that the best Japanese scientists in their respective fields or specialty areas compared well with the best in the world, and a few respondents thought that top scientists in their fields or specialty areas in Japan were the best in the world. This Japanese strength in science was clearly not a recent phenomenon. When asked to cite examples of Japanese scientific accomplishments, respondents readily named the top scientists in Japan and the important research they had done from the 1960s and 1970s to the present.

Japanese researchers and scientists were praised for being careful with details, having strong work ethics, and being intensely committed to their research, as well as for their ability to translate scientific discoveries into practical applications. However, "innovative" and "creative" were not words widely used to describe Japanese researchers and scientists and their work.

Respondents also offered observations on other issues that they felt were important to Japan's future scientific capacity. First, regardless of whether Japanese scientists were considered the best or among the best in the world, many respondents felt that there was a clear gap between the best and the rest *within* Japan. Several respondents noted a lack of depth, pointing out that Japan has some very good scientists but not many and that the best researchers and scientists are concentrated in a handful of institutions.

Second, several respondents voiced concern that fewer young people in Japan were enrolling in science at the undergraduate and graduate levels and those who do often end up working in industry rather than in academia. For example, few young Japanese scientists were observed to be involved in molecular biology. (An exception was environmental science; one respondent observed that many young Japanese scientists are entering this field.) Respondents were worried about whether future generations of young Japanese scientists will be available to lead Japanese science in the future. Nevertheless, in general, respondents thought well of young Japanese scientists in their fields and specialty areas, citing improvements in their research skills, their increased willingness to speak out and assert their views, and their greater proficiency in English and cross-cultural communication. Young Japanese researchers and scientists were also said to be doing more innovative research and were active participants in international conferences.

Third, several respondents noted the absence of Japanese women scientists in their fields or specialty areas in Japan. One respondent considered Japanese women an untapped resource to boost Japanese science today and lead it in the future and asserted that ignoring this asset was particularly egregious considering the declining number of young Japanese people going into science. Another respondent indicated awareness that the scientific research environment was not welcoming to Japanese women and cited the example of a Japanese woman scientist, whom he knew, who had come to the United States to further her career.

Training of Japanese Graduate Students

University-based researchers and scientists in Japan were perceived to be less hands-on in guiding their graduate students than were their counterparts in the United States. One respondent surmised that the low level of engagement between students and faculty might be a result of the way Japanese graduate education is financed. In most instances, Japanese graduate students pay their own tuition rather than being supported by research grants received by their professors. Japanese professors thus have less reason to involve graduate students in their research and to monitor their progress, whether to ensure the quality of student work or to comply with requirements to train graduate students under the terms of a research grant.

Capacity of Laboratory Technicians

The presence and capacity of laboratory technicians were important to the performance of researchers and scientists in Japan. We found two divergent examples to underscore this point. In the first instance, the availability of highly skilled laboratory technicians was reported by one respondent as important to successes produced in a Japanese laboratory. In contrast, another respondent observed that the absence of laboratory technicians required that Japanese researcher scientists do the work of technicians, and this affected their ability to focus on research tasks.

Decentralization in the Structure of Science

Many respondents expressed awareness that the structure of science in Japan was changing. They thought that a decentralization of R&D from the capital and a few other major cities to other parts of Japan would help expand scientific capacity and create a more competitive environment that would have a positive effect on the quality of Japanese research. However, they thought that it would take many more years before the results of this change will be known.

Funding for R&D

Whether discussing Japanese scientific accomplishments or the performance of Japanese researchers, scientists, and institutions, respondents offered opinions on R&D funding in Japan. Most said that the Japanese government has taken a strategic approach to R&D investment, resulting in the concentration of R&D resources at elite institutions and among top researchers and scientists. Indeed, several institutions, both public universities and government-sponsored research centers, were repeatedly cited in our interviews as the best places for research in their fields or specialty areas in Japan.

Although targeted funding over several years has resulted in some significant successes, such as in nanotechnology, a significant number of respondents who observed this concentration recommended decentralizing R&D funding in Japan. The view was that spreading Japanese government R&D support to a larger number of institutions and researchers and scientists would make Japanese science stronger in the long term by increasing the depth and breadth of Japan's scientific capacity. Although the best researchers and scientists in Japan were regarded, in many cases, as among the best in the world, respondents did not see the promise of a sufficient number of young researchers and scientists to lead Japanese science in the future, a point mentioned above in our discussion of human capital in the Japanese scientific enterprise.

Respondents thought that the more targeted approach to allocating R&D funds made sense decades ago when Japan struggled economically. At that time, Japan simply could not afford to spend more, and it did not have as many researchers and scientists working in as many fields as today. Government R&D funding was also critical to generating technologies to improve Japanese industrial processes and products at a time when private firms had limited R&D resources of their own. However, the situation has changed dramatically. Some respondents said bluntly that targeted R&D funding has simply become a bad idea for present-day Japan. One respondent was particularly vocal in criticizing Japan for not investing more in R&D because it is a major economic power, with a gross domestic product (GDP) and population half the size of that of the United States.

There was another argument against targeting "winners" in Japan's approach to R&D funding: Sometimes the expected winner turns out to be a loser. One respondent noted that the Japanese government thought ceramics would be a winner and therefore invested a great deal of R&D resources and involved private companies to make Japan the world's leader this research area. However despite the initial excitement throughout the world (including the United States), investments in ceramics failed to generate the expected payoffs. Japan, like the United States, lost millions of dollars in R&D investment, but the

adverse impact was considered greater in Japan. When the Japanese government launches a national initiative, industry frequently follows the government lead and invests its R&D resources in ways that will support the public effort.

Government Priority-Setting

Japanese researchers and scientists were described as taking national initiatives much more seriously than do U.S. researchers and scientists. Respondents found that Japanese researchers and scientists reshape their research objectives to follow the government's lead and indicated that such shifts carry significant money, time, and opportunity costs. They contrasted this behavior with that of U.S. researchers and scientists, who were seen as driven primarily by their own research objectives. It was implied that U.S. researchers and scientists would rarely shift their work to support a national initiative. Also, national initiatives in the United States typically highlight the policy significance of a research problem and provide some resources to spur the interest of researchers and scientists, but they do not generally occur at the expense of ongoing R&D funding areas.

Respondents observed that Japanese R&D funders should abandon their emphasis on applied research and let researchers and scientists chart their own courses rather than dictating specific research targets. Some respondents reported seeing increased long-term commitment to fundamental research in some research areas. Respondents also thought that Japanese research needs a broader focus to develop capacity in fields of the future. Following the United States (or other countries) in deciding where to go with Japan's R&D investment was not considered a bad idea. Respondents said that leading scientific countries in Western Europe also follow the U.S. lead. When different countries concurrently take an interest in a research problem, the shared focus can generate positive competition and catalyze research.

Language Barriers

Language was a frequent subject in the responses we gathered. Our respondents generally agreed that improving the English language proficiency of Japanese researchers and scientists would benefit the Japanese research community. English is the *lingua franca* connecting researchers and scientists around the world, and the majority of the world's most respected scientific journals are published in English. Interviews implied that the practical effects of low English proficiency in Japan's research community are significant.

Several respondents complained that the written quality of articles submitted by Japanese researchers and scientists to major scientific journals reduced their chance of getting published, which lessened the visibility of their work in the international scientific community. One respondent, an editor of a major scientific journal, opined that, sometimes, a poorly written manuscript made it difficult to tell whether the research was poor or the writing was poor. Interview responses suggest that English proficiency is a challenge across fields and age groups. In a few instances, our respondents reported that a particular senior researcher they knew had good command of English or that English language proficiency was improving among young Japanese researchers and scientists but, on the whole, they expected a broad-based improvement in English language proficiency among researchers and

scientists in Japan. Such thinking explained one respondent's opposition to the translation of more physics textbooks from English to Japanese.

This issue applied to written as well as spoken English. Although a researcher may employ a translator to translate or edit a manuscript, as was observed by two respondents, spoken English was seen as critical to scientific dialogues and the informal face-to-face communication that occurs at conferences and is important to the development of scientific communities. One respondent complained that it was sometimes difficult to understand research presentations because of the limited command of spoken English among Japanese scientists.

Cultural Barriers

Communication involves more than language. Many respondents saw certain cultural and social norms in Japan as obstacles to more vibrant scientific dialogues within Japan and between Japan and the rest of the world. Several respondents regarded Japanese researchers and scientists as reluctant to raise questions and communicate novel ideas. They observed that the Japanese communication style is much less direct or straightforward than the communication style common in the United States. This preference for a more indirect style might even impede the publication of Japanese research in the best scientific journals. For example, one respondent, who was editor of a major publication, said that the significance of research is not always made clear in Japanese research publications. Within the Japanese cultural and social context, it would not be proper for those who are junior in position or age to challenge the ideas of their seniors. Even between peers, cultural and social norms that seek to avoid confrontation, differences, and challenge to consensus hinder communication among researchers and scientists. A few respondents said that the rigid social hierarchy in Japan was a primary reason for avoiding future collaborations with Japanese researchers and scientists.

"Internationalizing" Japanese Research

Many of our respondents commented on the issue of "internationalization" of Japanese science. Although their definitions of internationalization varied somewhat, these observers argued that Japanese science has to be more international to be competitive.

Respondents reported that Japan was a good host for professional meetings and that they had been welcomed as individual visitors to universities, industry, and national laboratories. Japan's top scientists, too, were regarded as active participants in conferences outside Japan, presenting their work and engaging in scientific dialogues with the international scientific community. However, in the view of our respondents, such participation was not enough to make Japanese science competitive and truly world-class.

Respondents felt that to encourage scientific dialogues and collaboration, Japan has to open itself more to longer-term research visits, such as sabbaticals by foreign scientists. One respondent reported that Japan's excellence in physics has made it an attractive place for U.S. scientists to go for their sabbaticals. Japan should also allow more opportunities for foreign students and foreign faculty at Japanese universities to build their careers in Japan. Several respondents expressed concern that not enough young Japanese scientists seemed avail-

able to lead Japanese science in the future. Creating these opportunities is particularly important if Japan hopes to avoid the potential shortage of scientific personnel that we described above in our discussion of human capital.

Respondents thought that it was good to see more foreign researchers, scientists, and graduate students in Japan today and noted greater diversity in country of origin and—although, as we noted above, the numbers are still low—a larger number of women in these groups. However, it did not appear to them that these students were contributing to Japanese science the way that foreign faculty and graduate students do in the United States. One respondent reported his impression that the use of fixed-term contracts to hire foreign faculty with no possibility for tenure discouraged these international researchers and scientists from staying on and building their careers in Japan. Placing foreign faculty on contract rather than giving them tenure status also meant that they did not have access to the Japanese government research funds that were available to their Japanese colleagues.

Also, Japan needs to encourage more of its researchers and scientists to go overseas for sabbatical and longer-term research visits in addition to traveling to attend meetings. Japanese graduate students, too, should spend more time overseas as part of their training rather than typically going overseas only for postdoctoral visits *after* they have completed their training in Japan. By this point, respondents thought, these young researchers and scientists were fairly set in their ways, making it much more difficult to teach them how to do science. Several respondents lamented that Japanese graduate students in U.S. science departments were virtually nonexistent—and this had been true for many years now—whereas large numbers of Chinese, South Asians, and other foreign students study at U.S. universities. The general absence of U.S.-based Japanese researchers and scientists (or Japanese-American researchers and scientists) represented the absence of a "bridge" for scientific communication and collaboration between Japan and the United States.

Several respondents attributed Japanese reluctance to go overseas for graduate training and longer-term research stays to existing incentive structures in Japanese institutions, which do not reward those who build their careers outside Japan. Respondents who had spent considerable amounts of time in Japan further connected this reluctance and current incentive structures to Japan's broader social structure, which organizes individuals into age cohorts and emphasizes group allegiance so that anyone who leaves the group would find it very difficult to reintegrate and advance professionally in Japan.

Also essential to efforts to internationalize Japanese science is raising the visibility of research carried out by Japanese researchers and scientists through publication in international journals. Although the majority of respondents indicated that Japanese scientists were active contributors to scientific journals, a few thought that Japanese researchers and scientists did not always submit their work to the most respected journals in their fields. The lack of proficiency in English that we discussed above was mentioned many times as a possible hindrance to publication in top international scientific journals. A few respondents wondered whether Japanese researchers and scientists—for fear of losing face—refrained from publishing innovative findings internationally. They observed that Japanese researchers and scientists frequently published their findings internationally only *after* someone else had put forward their research for international scrutiny. The Japanese work was typically presented as an affirmation of the new finding. This tendency had denied Japan the opportunity to show its creativity and innovativeness. (There was a flip side to this practice: Respondents said that the careful, low-risk approach to publishing internationally meant that Japanese re-

searchers and scientists rarely retracted their articles, which further enhanced their reputation for the immense care they put into their research.)

Improving proficiency in written and spoken English was considered highly important to connecting Japanese research to that in the rest of the world. As noted above, one respondent thought that a proposal to translate more physics textbooks into Japanese was a bad idea. He felt that it would be better for Japanese students to learn science in English. Another way to promote international awareness of Japanese research would be to translate more Japanese-language scientific articles into English.

A few respondents said that they have observed considerable delays—on average several years—between the time an innovation becomes known in Japan and the time it becomes known in the rest of the world. One respondent reported personal experience of hearing about a Japanese innovation at an international scientific conference and then learning from Japanese researchers and scientists through conversations that they had already known about it for many years within Japan. Therefore, he thought some very good work must be published in Japanese-language journals and lamented that the outside world could not easily access this knowledge in a more timely manner.

Access to Japanese research raised another issue that elicited strong opinions and divergent feedback from our respondents. Those who spoke on Japanese research in computer science thought that Japanese researchers and scientists were very willing to share data. Even corporate sponsors of university research did not impose unreasonable demands to restrain the timely publication of research findings in international journals. In fact, one respondent in computer science said that U.S. firms today are more restrictive than Japanese firms are in controlling findings from university-based research that they had sponsored. This respondent indicated that he would have expected the opposite pattern—that Japan would be less willing than the United States to disseminate findings from privately funded research. A respondent was frustrated by the unwillingness of the Japanese to share data internationally in the area of genome research, however.

Indeed, greater willingness of Japanese researchers, scientists, and institutions to share data in a timely manner with the international community might be interpreted as an expression of goodwill or an outreach to the world. It would affect Japan's ability to gain greater respect as a world scientific leader interested in advancing science rather than as a scientific powerhouse interested in using science to promote its own economic interests.

Finally, the language and cultural issues mentioned above were also seen to adversely affect efforts to internationalize Japanese research. Rigidities in Japanese social hierarchy and communication styles were seen to keep Japan from taking on more high-risk scientific research that could raise its visibility in world science and allow it to effectively engage in international research collaborations.

CHAPTER FIVE

Conclusions

It is true that responses from 52 respondents covering 25 fields provided only a small sample of observations about science and technology research and development in Japan today. It might further be argued that their observations are merely the impressionistic accounts of outsiders looking into Japan's scientific enterprise. However, these respondents are leading researchers and scientists in their own fields and experts in their particular areas of research in the United States and the world. In pursuing their research, they closely follow the latest research and know who is the best and doing important or interesting work, and what is the impact of that research. This was clearly seen in the responses we received in which respondents named the outstanding researchers, scientists, and institutions in Japan, and articulated the nature and impact of their work. Hence, although we counsel caution in generalizing from the responses we received, respondents' viewpoints offer valuable insights at a broad level.

Several major conclusions emerged from our review and analysis of comments from our respondents. It might be worthwhile to further investigate those that resonate with particular concerns and priorities of policymakers, scientists, and researchers in Japan.

- The Japanese government should target assistance at improving the communication skills of researchers and scientists and support more travel to international meetings. This could improve the international visibility and standing of Japanese researchers and scientists without investing directly in research.
- The Japanese government should encourage researchers and scientists to take sabbaticals overseas and graduate students to either go overseas for training or to spend part of their training overseas. A structural change in Japan's university system might be required and more funding made available.
- Japanese policymakers, researchers, and scientists should consider ways to tap into the increasing number of foreign graduate students studying science and technology in Japan, and should encourage more women to enter science and technology fields, to boost its number of scientists and researchers. This might require an examination of associated immigration and employment issues .
- Japanese universities have improved overall in their science and technology research and development capacity; the next step might be to spur greater innovation and growth in fundamental research capacity. Investment in infrastructure, facilities, and equipment might be necessary, as well as a review of government policy to promote more original, high-risk research.

- The Japanese government should consider spreading government R&D funding to a larger number of institutions and researchers and scientists across Japan instead of concentrating the bulk of its resources on the top researchers, scientists, and institutions in Tokyo and a few other major cities. This might reduce the disparity between the best and the rest within Japan and increase the depth of Japanese science and technology research and development capacity over time.

Category/Field: Life Sciences – Agricultural Sciences (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

In plant biology, the Japanese have played a major role in two areas: genomics and genome sequencing – in particular, rice sequencing. Beside genomics, there is a broad level of high-quality research. Japan puts out excellent papers across the board. Their research has advanced a lot in the last 10 years. Overall, interviewee thinks there is more good work produced out of the universities.

The interviewee readily named the main institutions involved in genomics and genome sequencing research in Japan. They include government sponsored research institutions, government laboratories, and universities.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Interviewee thinks the best Japanese science research is comparable to the work coming out of the best institutions in other countries. Japanese scientists are as good as the top scientists in other countries. However, he is less certain about the "depth" of this talent in Japan and how it compares to the situation in the U.S. In the U.S., there is a lot of "depth," meaning there are many good researchers even if they are not among the top in the U.S.

The interviewee has not had collaborations with researchers in Japan. However, he had received a number of Japanese government research grants and had many trips to Japan to visit institutions across the country.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japanese institutions have "certainly improved." In the 1950s and 1960s, there was high-quality research, but it was severely limited to very few research areas. Now, Japanese research covers a broad range of areas.

And there has been dramatic improvement culturally and socially. In the past, lower level researchers were much more reluctant to speak their minds. This behavior is very counterproductive to scientific research, especially if you cannot have an open dialogue. This contrasts with the situation in the U.S. where, younger scientists do not hesitate to voice their opinions. Interviewee feels that young Japanese scientists can now be more open and have a louder voice. So things have improved culturally in this respect.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The major recent contribution of Japanese research is in rice genomics. But in the area of epigenetics, the specialty of the interviewee, not much has been done in Japan. The interviewee was not able to name any major Japanese research contribution or prominent researchers and institutions in this area. He is not sure whether this observation means that Japanese researchers just have not produce anything significant yet—so that their work is not in the literature or read in conference papers—or whether Japanese researchers are just not working much in this area.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The interviewee comments that the "role of Japanese women in science is minimal." Once again, like the other cultural issue, this is improving, especially among the younger generations of researchers. However, there is still a dearth of women scientists in top positions. The interviewee was not able to name a leading female scientist in Japan.

Category/Field: Life Sciences – Agricultural Sciences (2)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The interviewee's research focuses on plant genomics and his comments focus, too, on this area of work in Japan.

There are many research institutions in Japan, and the amount of funding in biological sciences is quite substantial in Japan. Japanese research is always good, and the best work is at the top universities. Interviewee has a sense that either the government or young professors make sure that the funding keeps coming, but also that something comes out of it. People are likely held accountable.

However, Japanese research is not outstanding, as in Nobel Prize caliber. The density of Japanese research has a higher degree of applicability than 10 years ago. And interviewee notes particular small shifts. For example, 10 years ago, the orientation of Japanese research was toward the U.S. – that is, toward what was happening in the U.S. – but now Japan is at the leading edge of the field in a few areas, such as plant genomics. The interviewee readily named a top researcher in Japan in that area.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Interviewee is familiar with the major institutions in Japan. He says Japan is second to none in quality, especially at the big institutions. In volume of research, Japan is second only to the U.S. Further, 10 years ago, Japanese researchers primarily did applied research, but now Japanese researchers are pushing the envelope of what is known.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

There has certainly been improvement judging by the number of groundbreaking and novel publications coming out of Japan.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japanese researchers have more money and better instrumentation, and they promote their young researchers to study in the U.S. and return to work in Japan. His view is that there is a lot of collaboration with the sequencing of rice genome, especially with the U.S. and England, and the Japanese are leaders in this endeavor.

Interviewee has worked with Japanese researchers. He has received a number of very good post-doctoral fellows from Japan. But he thinks their academic system is muddled. You don't know who is calling the shots, and it is a big hierarchy. Let's say there is a big professor at an Imperial university, and his students go on to be professors at other universities. The big professor still has his name on all of his students' publications, usually as first author. That is hard for collaboration to occur. In this manner, the Japanese can be very inflexible. This goes on until the big professor retires. But even then, he usually becomes a consultant at one of his students' universities. It is almost like a mafia. And younger professors would not want to criticize the older professors.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Life Sciences – Biology & Biochemistry (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions that you have observed in your field of expertise (in the last 5-10 years)? (Details on what makes these accomplishments important or interesting.)**

His experience with Japan is limited to a specific subfield—glycobiology. Japan is very strong in this subfield. He has dealt frequently with the Society for Glycobiology in Japan. He stated that Japan is "recognized worldwide as being strong in this area."

He has collaborated on and off with Japanese researchers for 15 years. Generally, each collaborator funds his research within the collaboration.

One example of important accomplishments is the elucidation of glycan structures. This has had a "major impact on the field." Interviewee named several Japanese researchers as being influential in developing the subfield, including one who is the "grandfather of all." Forty years ago, this Japanese scientist discovered sugars that are central to this field of research. One can trace most of the strength of this research field to this specific Japanese researcher.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field? (Ask for details, e.g., example and criteria of evaluation.)**

This particular field (glycobiology) is emerging as a major research frontier. After the sequencing of the genome, people focused next on proteins. Right on the heels of that, people began to focus on sugars decorating proteins, so this field is becoming quite hot. Again, Japan was already strong in this field of research.

Within this field, some in Japan are cutting edge at addressing questions. However, they are often a step behind. He hypothesized that this may be due to the fact that there's still a language barrier. This affects the research in Japan in two ways. First, papers tend to be crudely written in English, which prevents them from being published in the top journals. Second, because they are not able to publish in the top journals, they set their sights lower and don't write the kind of paper that qualifies for a top journal. They "don't go that extra mile." They do publish many papers, but the very top labs, in comparison, publish fewer papers, but in much better journals.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same? (Describe.)**

The performance of Japanese institutions has improved while he's been watching them. He worked previously at a private company for 15 years, and, for five of those years, this company had collaborated with a major Japanese pharmaceutical firm. Scientists and managers there

frequently asked, "How do you teach scientists to do creative research?" The Japanese are now really looking to do creative research. Japanese post-docs are now coming to the best labs in the U.S. and returning to Japan with a better sense of how to do research.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

They are an important player as evidenced by numbers. Interviewee recently attended a meeting for the Consortium of Glycobiology and Glycotechnology. There is a similar consortium in the U.S. The U.S. consortium involves hundreds of researchers worldwide. While in Japan, he had meetings with 50-60 people. The Japanese consortium, with much less funding, organized a meeting with 400 people. The quality of the research was very high, although, again, there was a language issue—all the research was in Japanese. The sheer turnout and quality of science "rivals much of the top work."

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

He commented that his thoughts were very fresh as he was in Japan just very recently.

Category/Field: Life Sciences – Biology & Biochemistry (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

The Japanese are able to jump on things very quickly and are able to identify important research questions. However, they only do the initial observation work, and, in most cases, the work matures as a result of follow through research by scientists in other countries. For example, in the stroke field, Japanese researchers would examine a pathway/mechanism and then stop without trying to follow through to the end to understand the importance of the pathway. Research funds appear to concentrate in a few institutions that excel. This leaves by the wayside those who are not the top most performers. Interviewee cites a premier Japanese research scientist, affiliated with a major research institute, as being exceptional in that he follows through in his research to learn how an enzyme or pathway works in the disease process.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The bulk of Japanese research is superficial. They make a good start, such as identifying a number of proteins in a certain pathway, but then they stop there and do not dive deep into the mechanistic aspects, that is, identifying the therapeutic targets. Japanese research does not go into the details, for example, in examining the pathway using knockout or transgenic models. Japan develops many of the initial approaches and technologies, such as the knockout and transgenic models, but it is the U.S. universities—with their ties to pharmaceutical companies and access to private funding—that seem better able to exploit these technologies.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

There does not seem to have been much change. There seems to be less research money and more researchers competing for the limited funds. There also seems to be something of a "brain drain" from Japan. In general, it seems like the biological sciences in Japan lag a bit behind because of lack of funding. "It's difficult to do science when you don't have money." Interviewee has heard complaints about funding from many of the researchers in Japan. Lack of funding also makes it difficult for Japanese researchers to attend international conferences. They may be able to attend if the conference is in Asia or Europe, requiring less travel funds. But conferences in the U.S. are more difficult for Japanese researchers to come to.

The Japanese are very innovative, which makes them very good at identifying a novel idea. Yet, the novel idea gets dropped because of lack of research funds or is scooped by others who have money to do the research.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Interviewee credits a particular Japanese research scientist for showing the specific role of a certain enzyme in degrading ABA-peptide in Alzheimer's disease. This enzyme had been known for more than 20 years, but no one had determined its function. Other labs used this finding (including the interviewee's lab) to develop a fuller understanding of its function and the possibility that drugs could regulate this and other enzymes and possibly attenuate Alzheimer's disease. Japan has very good scientists, but these researchers seem interested only in testing a model, publishing, and moving on to another model—without exploring the model in depth. What results then is fairly superficial research.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Japanese universities seem to lose many researchers because of shortage of funds. In technology development, by comparison, Japan seems more able to tap private resources to fund research.

In a recent professional conference, he found Japanese scientists presenting some very nice work. However, their lack of proficiency in English makes it very difficult to understand them. The language problem is becoming less severe with the younger generation of Japanese scientists, who have better command of the language. But it still needs improvement. Written English also appears a problem for the Japanese. Interviewee underscores that even if the scientific work is great, a poorly written manuscript will not receive a good review.

To really excel in science, the Japanese government needs to devote more money and develop a fair and equitable process for review so the money is spread around and not concentrated with a few top researchers. Inviting international researchers to provide high-level advice to the Japanese government may also help Japan to better decide the directions they should pursue. And it seems money buy less in Japan. There are many research material distributors in the U.S., which helps to keep prices competitive. But this is not the case in Japan. Materials that cost $20 in the U.S. may cost $400 to $500 in Japan.

Category/Field: Life Sciences – Clinical Medicine (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee has paid particular attention to Japanese research on adverse drug effects. He has followed clinical trials in Japan and kept track on their progress. He observes that some of the drugs available in Japan are different from those in the U.S.; Japan has some drugs that the U.S. does not have at all. Interviewee follows Japanese research studies and says he likes working with Japanese researchers.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Interviewee indicates that Japanese researchers are very good. He believes that they pay better attention to details on drug safety than the U.S. and that both countries are comparable in terms of efficacy.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee could not comment on this.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Interviewee believes Japanese researchers to be important players in clinical medicine. He notes that Japanese researchers contribute to all the top tier medical journals. He cites that Japanese researchers produce good research on hepatitis. Japan does good work in this area given the high prevalence for Hepatitis-C there, and Japanese researchers are also active in research on Hepatitis B. Interviewee observes Japanese research producing a great deal of work on vaccination programs.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

In terms of research in the areas of cancer, hematology, urology, HIV, etc., Japanese researchers are significant contributors, as evidenced by the interviewee's observation that Japanese researchers contribute significantly to major articles on these subjects.

Category/Field: Life Sciences – Clinical Medicine (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee is an expert on virology and infectious diseases. He has familiarity with Japanese research in this field as a result of his involvement in bilateral scientific panels, participation in international conferences, and the presence of a Japanese post-doctoral fellow in his department at this time. His comments focused on Japanese research on virology in academia.

In his opinion, Japan has lagged behind in his area of expertise. More specifically, Japan is lagging behind in medical science research on rotavirus and the influenza virus, as well as in several other areas like the enteric viruses and flaviviruses. He notes that there were a number of Japanese researchers in virology in the past, but the country has lost ground over the past 20 years. He thinks that there is less innovation in their work today than in the past and that Japanese research today concentrates on developing assays.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

In a general sense, Japanese research is well done and it is reliable, but the work is not innovative. It is not at all exciting. In the interviewee's view, Japan has fallen behind other countries, including the U.S., Britain, France, Italy, and Mexico.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

In the area of virology, that is, studying viruses as a cause of public diseases, Japan appears to be devoting less and less attention to this area of research over time. There is less investment in developing vaccines and implementing vaccination programs.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

No comment.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions**?

None.

Category/Field: Life Sciences – Immunology (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

There are many important labs in Japan. Many came up in particular in the last twenty years; adding that quite a number of labs have made seminal contributions to molecular immunology. Interviewee named a particular Japanese researcher's lab as doing very important work. Most recently, this lab in Japan identified the AID protein, which plays a central role in somatic mutation. Other Japanese researchers were also cited as having done important work in suppressor cells research and research on the regulation of interferon and cytoclines.

The interviewee usually learns first about new Japanese discoveries at conferences and research publications. He underlined that conferences are a good source for information.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The Japanese have excelled in this research area. It is one of the strengths of Japanese science in particular. The best scientists in Japan are the same caliber as the best in the U.S. If one looks at overall immunology research, American immunology research is stronger. But the truly outstanding researchers in Japan are outstanding by any standard.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has certainly improved over the past 30 years through the present, judging by the number of Japanese discoveries and papers that have received international attention.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japan is definitely a major player in the field of immunology. Japanese researchers collaborate effectively with counterparts in the U.S., but physical distance imposes certain challenges. Most Japanese immunologists are trained in the U.S., so they develop friendships with researchers in the U.S. in addition to professional relationships. The interviewee said he had trained Japanese students. At present, he does not have ongoing collaborations with researchers in Japan.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

None.

Category/Field: Life Sciences – Immunology (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee mostly learns about Japanese research through publications. He thinks Japanese researchers are pioneering immunology with many discoveries and that Japanese research is outstanding.

He readily named several prominent Japanese researchers in immunology and showed detailed knowledge about their work. He easily described their specific research specialties, their institutional affiliation, a sense of the volume of their publications, and the significance of their research in the field of immunology.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan is currently the leading country, and the Japanese are much better at research than the Americans. The U.S. has spent over $180 million, and there is nothing to show for this investment.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Certain labs are growing as a result of their successes. One Japanese researcher, for example, has been publishing important papers in the last 10 years. Clearly, the Japanese have been improving. Interviewee is also aware that the research labs of this and other Japanese scientists mentioned have been growing. Japanese research today is extremely reliable and very controversial, addressing important scientific controversies. Japanese research no longer just confirms research produced by the U.S. as was the case in years past.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Same as above – the Japanese are a leader in immunology research.

Interviewee has collaborated with Japanese researchers, but the relationship has not been particularly close. Interviewee's British colleague just took a sabbatical in Japan at the lab of one of the most prominent scientist. This British research had good access to Japanese technology. This was also the case in the past when the Japanese gave U.S. researchers access to their mice-breeding colony when they could have just kept them for themselves. Although the

interviewee does not have more personal experience in collaboration with the Japanese, he observes that the Japanese are willing to share their information.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

A generation of very productive scientists has emerged in Japan. They are producing solid papers, and their papers are in good English. Interviewee thinks they must have assistance from a good translation company. As an editor, he has seen many papers from Japan, and there is obvious language improvement in their submissions.

Category/Field: Life Sciences – Microbiology (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Japanese research has been very productive in the area of antimicrobial agents. They have led a lot of the research in this area, and many of the pharmaceutical agents developed by Japanese institutions are bought by/licensed to U.S. companies. Interviewee was not able to name any particular prominent Japanese researcher in this area, but he noted that Japanese research has made considerable contribution to antimicrobials and antimicrobial resistance.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is as good as other leading researchers and institutions in this field.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee thinks Japanese researchers have always performed at a high level in this area, maybe even improved a bit recently.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Interviewee underscores that Japan is a leader in research on antimicrobials.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

None.

Category/Field: Life Sciences – Microbiology (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Japanese researchers have excellent basic understanding of the details of microbial processes that are important to environmental issues. They have been most notable for their work on anaerobes, which are important to waste treatment. These are very difficult organisms to work with, and the knowledge gained in that area is very important.

Interviewee is familiar with Japanese leading institutions and researchers in this area. One particular researcher is noted as exemplary in a variety of contributions. In general, the Japanese have been strong in microbiology for a long time. They originally focused on things more of commercial value, but, in the last decade, they have begun to focus more on environmentally important research. They also have broadened out; there are more people working in the field with a broader focus.

Interviewee had been involved in a U.S. federal effort to promote relations with science centers in Japan. The goal of this initiative was to build linkages with Japan that could be sustained over time. This initiative enabled 5 U.S. post-doctoral fellows to go to Japan and 5 Japanese post-doctoral fellows to come to his lab in the U.S. This initiative is notable, too, for the fact that it occurred at a time when there were concerns about Japan stealing U.S. technology and vice versa. The U.S. government was looking for areas for collaboration, and basic science and environmental studies were the areas chosen.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

At a general level, Japan, U.S., and Europe are equivalent. There's certainly no reason to say Japan is behind. In some subareas, for instance, in the molecular side of microbial applications to environmental problems, the Japanese are ahead. There has been significant improvement during the last 10 years. When he began collaborating with Japanese researchers in 1990-96, the Japanese university system didn't have much access to research funds and their equipment was not as good. Those situations have substantially improved. Two major Japanese government-sponsored researcher centers still have advantage in basic science versus Japanese universities, but the gap has narrowed.

Japanese basic science researchers are quite good at working together with engineers. Their publications and presentations at international meetings (especially in molecular areas of environmental research) are quite good. At a recent international meeting, Japan was the only country to receive more than one award to students for poster presentations.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japan's performance has improved. Japanese researchers have expanded their research in environmental science. Where there were two or three people in a certain area, there are now 10. At the international level, their English is much better. Many more young people can speak/write English quite well. They are continuing to produce young researchers. He has a sense that environment is quite important in Japan.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The Japanese often sponsor conferences where they get their work exposed, and they invite leasing international researchers. They also sponsor conferences in emerging areas. Interviewee was in Japan for one such conference early in the year and will be there soon again for another one. The Japanese sponsors tend to bring about one-third of the researchers from Europe, one-third from the U.S., and one-third from Japan. Investment in conferences helps draw international attention to Japanese research. Conferences also seem to facilitate the work of Japanese researchers – their interaction with international researchers helps to further stimulates research ideas for the Japanese.

Smaller universities have done quite well in environmental studies, building considerable strength. There are centers of excellence for green energy.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Japanese researchers have something of a financial advantage over U.S. researchers because the Japanese students fund their own master's degree studies. Thus, Japanese researchers receive good work from students at no salary cost. They can recruit people already experienced in research and who have risen to the top in abilities.

One of the goals for the joint projects he has worked on in the past was to have young Americans live in Japan. At some level, this should seem easy for the Americans, but there is a tremendous language barrier. The barrier was not in the lab and research work itself, but in the small conversations, with visiting speakers, or in social settings. This limits foreigners working in their system, though Japan seems to try to encourage international work.

Category/Field: Life Sciences – Molecular Biology & Genetics (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

A clone project in Japan produced a great deal of cDNA information about gene sequences. The Japanese also have been involved in some sequencing of the human genome. In addition, they have generated some very good models for his specialty. But more specifically, the Japanese are not big players in the interviewee's specialty of molecular biology or in molecular biology in general. In fact, Japanese are virtually absent from the two leading areas of his specialty, namely, genetic regulation of development and function of the ear and genetic components of deafness. For example, Japanese researchers have cloned only one or two genes out of hundreds for the genetic components of deafness.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Interviewee's relationship with Japanese researchers goes back about 30 years. There seems to be a lack of personnel trained in the right areas in his field. The Japanese did not seem to be interested in genetics earlier, so they are not positioned to make contributions. The work by Japanese researchers can be of good quality, but it is generally not groundbreaking. The Japanese today are about where Europe was 10-15 years ago. Part of this weakness may be attributed to the lack of research funding. For example, much of interviewee's research is funded by grants from private foundations, and private foundations do not fund much research in Japan.

He's been running a meeting on the molecular biology of hearing and deafness since 1992. Judging by the number of papers submitted by Japanese researchers, there has been improvement, but Japan is still catching up. In 1992, out of 125 papers there were 5 from Japanese researchers coming from 2 Japanese institutions and his lab. None of these papers was groundbreaking, strong, or original. In 1995, there were 10 papers by Japanese research groups from five schools. Again, the papers were fairly derivative. In 1998, 8 of the 108 papers given were by from Japanese researchers, and only five Japanese institutions were represented. One paper was original; the others were derivative. In 2001, there were 19 papers by Japanese researchers out of a total of 221 and 10 Japanese institutions represented. One paper was groundbreaking and the other 18 were solid. In 2005, 20 of the 216 papers will be from Japanese researchers and the participation of 11 Japanese institutions. Eight of these papers represent original, strong work.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has improved a lot but it but still far behind the best in the world. Interviewee has collaborated and trained Japanese researchers in his lab. He has noticed that Japanese post-doctoral fellows are very bright, and their background and training have improved quite a bit. In the past, he would get people who did not know how to do basic lab techniques. That's not the case today.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

For the field of molecular biology, a major government-funded research center has made important contributions and several labs are producing excellent models and targeted mutations. However, there is only a very small number of top notch researchers in his specialty area in Japan. The Japanese government has become interested in molecular biology only in the last 5 to 10 years, while this has been an important area of research in the U.S. in the past 20 years. So Japan is about 10 years behind even though it has grown substantially.

Japanese researchers that the interviewee has worked with have been very innovative. However, there seems a lack of direction in instruction or training in Japan. Those researchers that come to the U.S. in the past 10 years generally do very well when they return to Japan. Finally, English language proficiency among Japanese researchers seems to have improved a great deal.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Life Science – Molecular Biology & Genetics (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

The Japanese have had a very active role in the genome research center. They have been involved in sequencing parts of chromosomes and made significant contributions. They have also been involved in cloning full-length copies of genes, providing leadership in this area of work. Interviewee readily named prominent Japanese researchers in this area of work.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is top notch, producing good work and a lot of research results.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has cutting-edge labs and seems well funded. Japan continues to do extremely well, and continues as a leader in many technology areas. Japanese researchers have been involved in many genome sequencing projects. Overall, Japanese researchers have performed very well. They have made important contributions and will continue to do so. The one issue that affects academic research performance is the reluctance to release research results in a timely manner. This is an attitude more common to industry, and is true to U.S. industry, too. In contrast, research results are immediately released in the U.S. academia. This delay in data release diminishes Japan's influence in academic research.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japanese researchers have been leaders in producing full-length cDNA. They have expertise and huge resources. But their impact is somewhat limited because of the unavailability of their work to the rest of the worlds. The Japanese scientific community would get much more credit if these copies were available. Full-length cDNAs are difficult to get, so it's a bit of a waste of time to duplicate the research. It would be better if Japanese researchers would contribute to the international collection of full-length cDNA. Scientists seem to be frustrated by a government policy that gives priority access to data to Japanese industry. Although the Japanese institutions may get a small lead, the work will end up being duplicative and worthless from an intellectual property standpoint. Because of this government policy, the impact of Japanese research in international academic circles is limited. Their technology is very advanced – sequencing machines were developed with Japanese companies.

He knows of many projects that keep running into theme of accessibility. In Japan, the research seems fragmented – one person is associated with a certain project in Japan and no one else is able to work on it. Collaboration probably gets more done.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Funding came through for Japanese researchers to work in the human genome project, an international collaboration that has produced data freely available to all researchers. But in other projects, there appears to be more problems with data sharing. One example is the chimpanzee genome project. The bottom line is that U.S. researchers cannot work with Japanese researchers if the data cannot be shared.

Category/Field: Life Sciences – Neuroscience & Behavior (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions that you have observed in your field of expertise (in the last 5-10 years)? (Details on what makes these accomplishments important or interesting.)**

No comments because interviewee does not keep track of specific country advances.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field? (Ask for details, e.g., example and criteria of evaluation.)**

Interviewee feels research produced by Japanese institutions in neuroscience is the same as or better than that produced by other countries. He added that language issues sometimes make it harder to evaluate the quality of Japanese research; that is, is something poorly written because of a poor grasp of English or insufficiently rigorous thinking behind the work?

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same? (Describe.)**

Interviewee cannot provide an evaluation. He is only familiar with the work of one fairly new brain research institute.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Interviewee thinks Japan is definitely an important player in this field, but could not provide specific examples.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

When reading manuscripts submitted by Japanese researchers, it is often difficult to decide whether the research does not come across as very strong because of poor English writing. Japanese researchers need to "understand and grasp the universal language of science [i.e., English]" and be prepared to write their research results clearly in English. Many researchers return to Japan and still show little improvement in English language proficiency. Judging by their manuscripts, one would never know that they have spent many years in an English-speaking country.

Category/Field: Life Sciences – Neuroscience & Behavior (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

As far as enormous things go, he can't really say that they have discovered, for example, a specific sequence of human DNA, but Japanese scientists have contributed in a basic way to the total knowledge of things in this field. For instance, the very first cloning of one of the proteins in the family the interviewee works with was done by a Japanese researcher at a major state-owned company. (That protein was to be used in anticancer therapies.) There are clever Japanese researchers who have contributed well to the mass of knowledge that we have. An example is a group in Tokyo that developed a clever way to delete certain neurons in the brain as a method to determine what neurons do. Although he considers this work not to be a blockbuster category, it is still interesting basic research. He hasn't collaborated with Japanese researchers in 25 years. He has learned about this research either because it is research in competition with his work or the work complementary to it, and it behooves him to pay attention, such as the work done by the researchers at the major state-owned firm cited.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

He said that Japanese institutions are not quite up to what he would predict from such a large and well-educated country. He feels there's a focus on other areas that leaves them a step behind. There are very good people there that do clever things, but he would expect more in terms of quantity. They are behind Europe, but certainly better than South America. (His connection with Japan is that he sells products in Japan through Japanese distributors so his interest is in research they do and how many of his products they want to use.)

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

He remembers when he started working in this field, about 14 years ago, there were some key papers coming out of Japan that showed that they understood the issues very well and were tackling them in a serious manner. That has dropped off a little bit, not in huge amount, but slightly. There also seem to be a significant "brain drain." For example, he mentioned a researcher who graduated from a major state university in the U.S. and received a top international science award in immunology about 10 years ago, but he came to the U.S. It does not appear that this researcher has ever worked in Japan again.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

From his first two examples, the way of deleting specific parts of neurons is very clever, modern stuff. This research team that did this is a one-hit wonder. They've been steadily publishing in this area for several years.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

One of the interesting things about Japan is that in Europe there's Oxford University, Cambridge, etc., and other very famous universities. In the U.S., there's Harvard, Yale, etc. But if asked to name famous research places in Japan, he would have to say he's not really sure. He knows there's a major research funding structure run by the government, but he wouldn't be able to name it. That portrays a weakness of the Japanese system. If the international research community does not know those places, then the Japanese are not having the impact of some of the great universities in the U.S. and Europe.

Category/Field: Life Sciences – Neuroscience & Behavior (3)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

About 7 years ago, Japan built a major scientific research institute that includes a neuroscience wing. Interviewee served for five years on the board of advisors of this institute. This neuroscience wing is now housed in a 30-story skyscraper, with hundreds of neuroscience professors, technicians, etc., and it has the latest equipment, such as brain imaging equipment. They have also brought in international scientists from Europe and the U.S. It is very impressive to see this major commitment and to see action on it quickly. The research it has produced is superb. "Sought-after scientists are there in the dozens," and it's just "damn impressive."

Interviewee named several top Japanese researchers. One has done work in primate neurophysiology and the brain basis for perception. This work is excellent and very well regarded by the international research community. Another Japanese researcher is very well known for his work on the cerebellum

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is "first class." Japan has launched additional brain research institutes at other universities. Japan is right up there competing with other leaders in the field. One of the biggest things going on in Japan is the push to internationalize—sending Japanese researchers overseas and bringing in researchers from Europe and America. Another big attitude change in the last 10 years is that previously, when a Japanese scientist come up with something cutting edge or critical of research in the West, this work would usually be held until someone else publishes about it. Japan then publishes to provide confirmation. Nowadays, Japanese researchers are "out on the hunt and often publish first."

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japanese research in neuroscience improved with the creation of the national research center, which the interviewee served five years as a member of the advisory board. This institute is very good, and the interviewee is very impressed with the speed at which the Japanese would respond to his comments. Initially, he would "criticize the hell out of them," but seeing how quickly the Japanese respond made him more cautious with his remarks to make sure he was not being "too casual." Japan is past the imitation stage. It is now in the self-realization and initiative stage.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Answers to question one would apply here. Also, interviewee feels Japanese efforts to internationalize are making them more important. Japan is picking up new technologies and using them instantly.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The self-realization in Japanese science today is increasing the strength of Japanese research and spurring creativity. Corporate leaders, too, are beginning to understand this. In the interviewee's view, Japan is becoming more creative, at least in neuroscience research.

Category/Field: Life Sciences – Pharmacology and Toxicology (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

The interviewee frequently visits pharmaceutical companies in Japan. He thinks Japan is a major player in toxicology, but he addresses his answers specifically to the area of drug toxicity as it relates to pharmacology.

Basic research related to cancer has gained considerable prominence in Japan, particularly with ideas such as carcinogens in burned foods (which really came about in the 1970s). Interviewee credits a particular researcher and national institute as having spearheaded this and many other research studies. Much of the information about drug toxicity also benefited from Japanese research in the area of molecular biology in events concerning GstP (glutathione S-transferase Pi), which the interviewee associates with a particular Japanese researcher. Finally, interviewee cited a third Japanese researcher as having done the critical work on arylhydrocarbon receptor (AhR).

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The interviewee believes that top-flight academic work is done at a level that makes Japan competitive with Europe and the United States in basic research areas. In applied research, however, the caliber of work is not comparable. Interviewee thinks institutions in Japan do not favor innovation. One reason—specific to drug testing for toxicity and safety assessment—is that the pharmaceutical industry in Japan "makes up" its own regulations. Also the interviewee remarks that, to some extent, these companies work to keep out foreign companies. According to the interviewee, this circumstance does not help Japanese pharmaceutical companies when they try to sell to the rest of the world where international harmonization is important. In this manner, Japan is not doing well to be competitive at the applied level.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee thinks the consensus is that fewer people in Japan are interested in careers in science and technology than in the past. He is not aware of which fields young people are entering, but fewer people are interested in graduate study and training in science and technology.

The interviewee notes that in the academic labs in Japan today, there are many Chinese students and students from other countries—especially Asian countries. He indicates that this is a telltale sign that things are not well in Japan. The interviewee notes that when these people are trained, they do not typically stay in Japan for the long term, owing to laws in Japan. Such conditions do not capitalize on the capability of foreign students educated in Japan because Japan is a closed

society, and foreigners cannot become part of the system. The Japanese environment is not really suited to bringing in foreigners and using their expertise.

The interviewee indicates that another problem is that the system in Japan is hierarchical, antiquated, and shows limited signs of change. For example, a professor in Japan heads a large group and controls all junior faculty under him. In the U.S., this is considered a waste of young talent. The interviewee is aware of voices in Japan calling for changes, but he thinks it is not happening. The outcomes are not changing. In his view, there are few Japanese pharmaceutical companies capable of competing in the global market. The interviewee can bring one, perhaps two, pharmaceutical companies to mind as being international players and notes that these entities are large enough to have sufficient exposure and experience at the international level to know how to be competitive.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The interviewee thinks that Japan is certainly an important research player in the field of pharmacology Japanese companies comprise a major segment of the whole pharmaceutical industry. Japan's importance is reflected by articles in the major scientific journals, which show a lot of good research is coming from laboratories in Japan.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Japanese education relies on rote training, as opposed to emphasizing original thinking. The interviewee would like to examine how academic research is supported and reconsider the structure of academic departments in Japanese universities. In addition, pharmaceutical companies in Japan have to modernize and globalize.

Category/Field: Life Sciences – Pharmacology & Toxicology (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee identified himself as an expert in immunotoxicology and spoke on his views on pharmacology and toxicology from this perspective.

In his view, the Japanese have been at the forefront, leading the way in diesel immunotoxicology. With twenty years of significant work in this area, Japanese researchers were the first to demonstrate how diesel use may be exacerbating asthma—that diesel is linked to the induction, or increased incidence, of asthma. This finding has been presented in the scientific literature. Interviewee has collaborated with Japanese researchers on this issue and has been invited to visit Japanese government offices with a focus on environmental/pollution issues. He was not certain about funding for this research in Japan, although he thought some support comes from the government as well as the auto manufacturers.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Interviewee thought Japanese research is of high quality based on his collaboration experience and his own expertise. Another indicator is the quality of Japanese publications based on his review of articles in high-quality toxicology journals, and the interviewee notes how Japanese researchers have been successful in publishing in the European and U.S. journals.

The interviewee commented on the quality of research facilities in Japan, noting that the laboratories he saw were quite old. The interviewee's comments are limited only to the government facilities he visited; however he stated that, on the whole, Japanese researchers are capable and do sophisticated research and would benefit from laboratory upgrades.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

On the performance of Japanese research institutions over time, interviewee thinks they are not improving. Based on his observations, the quality of Japanese publications, and their advances in sciences, Japan made some early and important discoveries in immunotoxicology. Nevertheless, Japanese research is not as dynamic today as it has been, although Japanese research is keeping pace and the quality of the work remains very good, as evidenced by presentations at conferences attended by the interviewee. Japanese researchers are more active at presenting their research at overseas conferences, although the interviewee notes that it is usually only senior researchers that are doing this.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japanese researchers have made important contributions, but interviewee was not quite sure how things are at this time in the academic research community in Japan.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions**?

None.

Category/Field: Life Sciences – Plant & Animal Science (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

The researcher's area of expertise is in plant molecular biology. He focuses primarily on basic plant biology and looking at agronomic trades.

Interviewee states that the Japanese scientific community is a "powerhouse" in this field, because there is a government-funded institute that is very strong in basic science. This institute has a couple of teams that are very visible in this research area. One team has been at the forefront of using technology to make research results widely available to international researchers. He has taken information from the plant genome project to build a database that is available to researchers around the world (including full research genome clones, which wouldn't be available otherwise). It is a hallmark of the Japanese research enterprise that this type of research is made available. It is great that the Japanese are interactive and make this research available internationally. This research team has also done beautiful work in plant hormone signaling. Another team from the same institute has also done excellent work in functional genomics, which is another strong area for Japanese researchers.

Another two researchers at another government research institute were also said to be doing very good work. One team works in the molecular genetics of rice, taking lessons from basic genetics and applying it to rice production. Another team does great work in cell biology, which is rare in this research field.

Most of the high-flying research done in Japan seems to be done by independently funded research institutes – not universities – as is true in most other countries (including the U.S.). One major university in central Japan is the main exception and is very strong. One researcher there does excellent work in plant developmental biology—his whole team does excellent stuff. And a very good and young independent researcher has produced great models in this area.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is very solid. They do very high quality work, with neatly done research papers. These papers are generally very citable for other work that you are doing yourself. Japanese researchers produced very few things that are highly controversial, which can be good and bad. It is very infrequent that papers are retracted, because they are solid. On the other hand, Japan is usually not the country that comes up with the real revolutions like sequencing whole genomes. These initiatives usually come from U.S. (sometimes with help from the United Kingdom). This holds true throughout the field. Japan seems to do better work in normal science, taking revolutionary work done in other counties and applying it to real world problems.

Work done by Japanese researchers comes out in highly visible journals like *Nature*. About 2 articles (10%) of the articles in the main journal in this area, *Plant Cell*, are from Japan, which is pretty good.

A lot of high quality research done in Japan is published within that country, which is unusual since so many of the journals today are published in the U.S., U.K., and the Netherlands. It is unusual, and also a good thing, that Japan is still publishing its own journals and making them available in English for international consumption. The interviewee wonders why universities don't play a larger role in this arena.

It doesn't appear that young researchers have the same level of freedom that they have here in the U.S. It also appears that there are very few independent women investigators that fare well in Japan. They actually tend to come to the U.S. to do a lot of their work. People in this field (and others) are looking for women to be integrated into the larger scientific community, which would increase the productivity of the national science community.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

No strong opinion, basically because he has only paid attention to Japan for about five to ten years. Within this period of time, Japan's performance seems more or less the same.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan is a major player. It is on par with Britain and Germany. Japan is behind the U.S., but much stronger then most other nations. Japan is much better than countries like Canada, the Netherlands, South Korea, and Switzerland, for example.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Life Sciences – Plant & Animal Science (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's expertise is in plant biology, genetics, and plant physiology.

Japan has consistently been a strong player in basic plant physiology. This has mainly been in the area of light signaling and responses in plants, a particular area of strength for the Japanese. The Japanese have numerous major accomplishments that involve research into light receptor molecules, such as phytochrome and kryptochrome.

The interviewee is aware of the top researcher in this area. This researcher is known as the principal person that has led most of the research in this arena within Japan. He has many disciples and students that are involved in his work. This researcher has worked at a government-funded research laboratory and may have moved to an industry research center. Both places are known to do important work in this arena. Another research center was also mentioned as an important actor. Its construction of a large spectrograph has been critical to a lot of these studies.

Interviewee gets insights into Japanese developments from conferences and publications, but the main avenue is through collaborative work conducted in Japan. He is about to embark on his fifth trip to Japan (in the past 15 years). Generally, he stays between 3 weeks to 3 months on each visit to Japan.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Within the field of plant physiology, particularly light receptors, Japanese research is top notch. It is on par with both U.S. and European research. Japan was an early leader in the field of light receptors. This early Japanese work helped U.S. and European researchers to move forward in their own research. Japan has tailed off in this specific area in recent year judging by the number of their publications.

Research laboratories in Japan are excellent facilities. The same could be said about those visited at government research laboratories and industry. Universities he has visited have good facilities, if somewhat older buildings in some cases. Interviewee does not know about research funding in Japan. Japanese researchers he has worked with seem to be pretty successful at getting funding, but overall not sure what the situation is throughout Japan.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Research productivity has at least held steady, but not sure how to quantify this answer. He has certainly not seen deterioration over time.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Within the light receptor area, Japan has made major accomplishments. Japan is a major actor within this field. His interaction with smaller universities in Japan tells him they are quite active in sending researchers to the U.S. and Europe for collaborative work. They are not insular; they interact internationally by going abroad and bringing people to Japan for joint work. They have been highly collaborative and are pretty much equal players in the field of plant physiology.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Environment – Energy Engineering (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's area of expertise is energy engineering, particularly electric machines and hybrid vehicles. Interviewee gets information about Japanese developments mainly from conferences and publications. Electrical, electronic and energy society conferences and other professional forums are important places for the exchange of information.

Japan has been very active in advancing fuel-efficient vehicles, specifically hybrid cars. Their work in developing crucial control algorithms for these vehicles is cutting edge. Interviewee is familiar with the top private and public research institutions in Japan in this field.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The Japanese are doing pretty good work in this field. They are on par with Europe and comparable with the U.S. in some areas. However, one does not see the same variety of research activities in Japan as you would see in the United States. Japanese researchers produce a good number of research papers, which are well regarded throughout the field. They also seem to have good research labs that produce good results, particularly in the applications area.

In some respect, the Japanese seem to be following the U.S., and they are very good at following major innovations that emerge from U.S. and European research labs. When the U.S. came up with major new ideas in the area of fuel-efficient vehicles, the Japanese jumped on these new results and figured out how to make them perfect for the marketplace. They make things better, cheaper, and more efficient. However, they are not producing as many new ideas, and indeed very few new ideas when compared to the U.S. Still, when the Japanese choose to do something, they do it very well. The Japanese are great engineers, but they are not the primary innovators in this field. They focus more on applications than on doing original research that will lead to innovative breakthroughs.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

The Japanese have improved over time. This has been helped by increased communication with U.S. and European researchers. Japanese researchers have become increasingly active at international conferences and more inclined to join international research partnerships. They are dong more collaborative work than before and this helps them to improve their performance.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan is a major player in the area of hybrid vehicle engineering. Japan is a strong competitor against the U.S. in this area.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Although they have improved over time, Japanese researchers still do not work internationally as much as U.S. researchers. Interviewee wonders if Japanese researchers hesitate working with the international community because they do not want their expertise to leave the country.

Category/Field: Environment – Energy Engineering (2)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The interviewee's area of specialty is electrical engineering, specifically power electronics, electric motor drives and controls, and advanced vehicles systems

The most cogent accomplishment by Japan has been the introduction of hybrid vehicles by a major automobile manufacturer. This was an extraordinarily bold and visionary move taken by this company, done in the face of tremendous opposing interests and ignorance – particularly within the U.S. automotive industry. As a consequence, the Japanese have been so successful, and particularly in the area of hybrid vehicles. Interviewee thinks this technology is going to change the entire picture of the automotive industry for the foreseeable future and guarantee Japan's dominant position in the economic arena.

At this point, interviewee thinks major U.S. automobile manufacturers are basically playing catch up and pretending to be in the same league as the Japanese company cited. The American companies used to say this research was impossible to perfect, that it would not be useful even if perfected, and too costly regardless. As a result, they will probably never catch up with this Japanese lead, and U.S. companies are not doing a very good job playing catch up.

Another Japanese automobile manufacturer was also cited as becoming an important player by signing a technology licensing agreement with the Japanese automobile company that developed this hybrid technology. The second Japanese company will use the drive train developed by the first one in their own brand of hybrid vehicles. This allows the second company to put their own hybrid cars in the market. This second company understood early on that it did not have the technical depth to keep up with the first company. So a decision was made to buy that technology and insert it into their vehicles. Of course, this means the second company will always be one step behind the first one technologically, but it will still produce good products and the consumer will not perceive that these products are not as good. This partnership will allow these two Japanese companies to maintain their lead.

U.S. companies, apparently for political and economic reasons, have not signed licensing agreements with the Japanese automobile manufacturer that developed this hybrid technology. Instead, U.S. firms are trying to copy the Japanese, and they are not doing it very well. Interviewee reported that the last time he was in a U.S. industry lab, engineers there tried to reverse engineer a Japanese hybrid vehicle and simultaneously build their own rudimentary vehicle. He said these were elite U.S. researchers in this field and they weren't doing a great job at producing a viable vehicle. He added that hybrid vehicles is one area in which U.S. automakers are doing a great injustice to the U.S. by falling so far behind and using taxpayer dollars to avoid playing in this game.

Interviewee says that conferences are an important venue for learning about developments in Japan. But for him, the main source of information is his consulting work for automobile manufacturers in Japan and the U.S. His visits to Japan research institutions and visits by Japanese researchers to his lab in the U.S. also provide him with much information.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Japan is as good and in many cases better in this academic research area. There are several reasons for their high-level performance. First, they have long-lasting and reliable relationships with industry. This results in real and productive information and personnel exchanges, which leverages the intellectual power of academic research labs so industry can focus on innovations that will make a difference in the commercial marketplace.

In promoting power electronics research, interviewees think a "horrendous strategic mistake" was made by a major federal funding institution in the U.S. to focus its resources on a few institutions. This approach lends prestige to very few institutions and has led to a shrinking of the overall field in the U.S. Since only those institutions receiving major federal support are the top institutions, they also absorb the lion's share of industry funding. This means that there are only a few centers of excellence in this important arena. Japan has many more centers of excellence and the government there lends support to many different players in this field. Japanese research labs of major companies also have superior instrumentation and are more professionally run.

Interviewee attributes the approach taken in the U.S. to the inability of many U.S. agencies to understand how technologies are developed within academia and how they can eventually be transferred to the market. He thinks this process is better understood in Japan. In his view, concentrating U.S. research dollars in a few centers of excellence has dealt a deathblow.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

The Japanese have progressively improved in quality and quantity academically. On the industry side, Japanese companies (even the largest companies) still do very innovative things – whereas large companies in the U.S. tend to avoid risk. In the U.S. it seems we need startup companies to bring about paradigm shifts, but in Japan the big companies are the ones producing these major innovations – this has been a key to their success.

Perhaps one reason the Japanese have been so successful is that top managers are paid a similar wage to regular engineers, and they often have technical backgrounds. This is not true in the U.S., where managers get paid much larger salaries and rarely have technical backgrounds – this produced an entirely different universe of thinking among top managers. U.S. managers seem overly concerned with the bottom line and don't seem to understand the role of investing in

innovation to produce future profits. On the other hand, the Japanese really stay within the technology, which is how they believe the company will make money over many years.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The Japanese are the inventors of many key electrical devices used in advanced motor drives. Even today, Japan is the biggest producer of the key components for these engines. Japan is the biggest producer of electric motors. The Japanese have the most patents in this area and are the most ambitious technology developer. The interviewee says that Japan and the automaker that developed the hybrid engine, in particular, come to mind as the leader in this research area, not U.S. companies.

The limitation the Japanese face is the availability of human resources, investment capital, and world influence. The rise of China is somewhat disturbing for Japan, particularly given the U.S. ability to enter relationships with both countries (an ability that Japan doesn't enjoy because of regional politics).

The Japanese have consistently beaten the U.S. for 20 years in the area of advanced electric motor drives. In the interviewee's view, the U.S. government, and certain agencies in particular, has done more harm then good.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Environment – Environment & Ecology (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee has not conducted research in Japan or collaborated with research scientists in Japan. He learns about Japanese research by reviewing publications by Japanese researchers, as well as through interaction with Japanese researchers at professional meetings in Japan and by serving on committees with Japanese colleagues. Interviewee is most familiar with work by Japanese scientists conducting research on plant ecology and wetland ecosystems.

Japanese scientists are doing interesting work on the effects of disturbances, such as windstorms, in temperate forests. Interviewee has used literature produced by Japanese researchers for information that could be applied to understand hurricane effects on forest systems in southeastern U.S. Generally, the work in this area is quite good, especially that done by some of the younger Japanese ecologists. Much of the plant ecology work in Japan has been associated with description and characterization of plant communities. Interviewee has also seen some recent efforts to study wetland restoration, especially in riparian areas, and some good work is beginning to emerge in that area. Interviewee also has had electronic interaction with graduate students in Japan, reviewing their papers and broadly discussing research.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

In some cases, the Japanese may have lagged behind a bit. A lot of Japan's vegetation description work is influenced by earlier European studies, possibly a reflection of the fact that some Japanese vegetation scientists were trained in Germany. They use approaches that are not much in fashion in North America, because these methods are less quantitative and more subjective in the way sampling is done. These methods do not lend themselves to the quantitative approaches used in the U.S. and other parts of Europe. The interviewee has seen some good papers by younger scientists in Japan that use more quantitative approaches.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan's performance has improved over time based on comparisons between the work of younger and older Japanese scientists.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japan is an important research player, especially in the areas mentioned above. Interviewee has turned to Japanese studies of the effects of disturbances in temperate systems, the responses and recovery of forests. Japanese scientists are producing good work that serve as models for the effects of hurricanes and tornadoes in southeastern forests in the U.S. Except for their work on disturbance efforts, Japanese research is good but not among the absolute best in the world.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Environment – Environment and Ecology (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

There is a very good Japanese researcher studying the origin of life and its molecular basis (interviewee could not recall the researcher's name). However, in her research on the ecology of deep sea thermal vents, there have not been many major accomplishments. However, things are changing in her field. Key players are starting to publish heavily. There are a few strong researchers who are presenting at conferences, publishing numerous papers, and being very ambitious about getting noticed.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is of good quality. Interviewee has worked with Japanese scientists in the past, but she is less willing to collaborate with them in the future. She cited bureaucratic hurdles and difficulty in communication as reasons for this hesitation. When she thought there were some very interesting research questions that could be pursued, Japanese scientists could not pursue these ideas without approval from upper echelon researchers. Generally, she has found Japanese scientists unable to do anything without approval. There are some exceptions, but it is much more cumbersome to collaborate with Japanese researchers than with researchers in other countries, such as France, Russia, China, Chile, and others.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

The quality of Japanese research has been improving. There also seems to have been some improvement in the cumbersome bureaucracy, but it's still not very productive for her to pursue collaborative work. She reviews a lot of Japanese publications for journals. Interviewee has noticed a significant improvement in the quality of English used in manuscripts submitted by Japanese researchers. She thinks this may be due to the use of commercial translation and editing services.

She has a Japanese student currently in her lab. He's not very innovative, but his work is solid and he works hard. He has problems speaking in English but writes very well.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

She suspects that biotechnology companies are providing more research and development funding. There is some highly creative, leading edge science. However, given all their

resources, she feels that Japanese researchers should be leading the field to a greater degree than they are now.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

She feels Japanese researchers should be more innovative. They have increased their rate of publication, but they're all very straightforward, basic research. This certainly adds to the "database of knowledge" but it doesn't really move the field in new directions.

Category/Field: Environment – Geosciences (1)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The interviewee's expertise lies in weather monitoring and climate change. Two major accomplishments stand out as the top Japanese contributions within this arena. First, Japan has the Earth Simulator, which is the largest and fastest computer in the world. It provides truly cutting-edge simulation of weather and climate change. It is a simply amazing technological feat to have all these processors working together, achieving computational speeds that are ten times faster then anything else in the world. This speed can be used to produce very high-resolution simulations of climate change for the whole Earth system. Second, the Japanese have made important strides in making meteorological and climate change related measurements using GPS receivers at the surface. They have a network of high-density receivers within the Japanese home islands producing excellent data on the total amount of water vapor in the atmosphere. This technology is used to create vertical profiles of water vapor in different columns of the atmosphere. The technology also measures delays in signals from GPS platforms in orbit, to measure water vapor in the atmosphere. This provides an important data source for weather prediction and climate change. The Japanese are really at the forefront in this subfield. Japan has also made important early contributions in the field of tropical cyclone research.

Interviewee readily named the top institutions in Japan in these research areas, including universities, government meteorological agencies, and government-funded research centers.

Interviewee learns about Japanese research in a variety of ways, including the *Journal of the Meteorological Society of Japan*, and he has collaborated with Japanese researchers on the use of GPS technology for climate change simulation. He has also been able to use the Earth Simulator to run U.S. climate change models using the amazing computing capability available in Japan. Interviewee notes that there have been important exchanges of personnel and interactions at international conferences.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Interviewee considers Japanese researchers as being the top of the field, equivalent with U.S. although perhaps just slightly behind. The Japanese don't seem to do quite as much original research as the U.S. – this is a qualitative assessment.

Important peer reviewed journals have a good amount of papers from Japanese researchers. Given the size of the country in comparison with the U.S. or Europe, it seems they put more of emphasis on generating a large output. . Japan has an impressive number of articles for a small country.

The Earth Simulator is truly one of a kind It is without a doubt the best facility of its kind in the world – an order of magnitude better then anything in the U.S. or Europe. It is a truly remarkable achievement

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

More or less the same. Twenty years ago they were tops in tropical cyclone research, but they have been less active in this area then they once were as it has reached a higher level of maturity. This type of work has been replaced by research in areas like GPS ground detection, so the overall balance of work has changed but production of results has remained steady.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

The Earth Simulator is number one in the world; other counties are trying to catch up. In ground-based GPS, Japan is among the top five (along with U.S. Europe, Australia, and China). The TSUAGA research institute held a very important international workshop organized by a Japanese research institute and held in Japan in January 2003 has resulted in the publication of its proceedings in a hardcover book that has become an important reference around the world. The fact that Japan can attract top researchers from other top research countries is evidence of Japan's importance within the field.

Interviewee indicates that Japanese scientists are among the leaders in atmospheric science and coequals with researchers in the U.S.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

None.

Category/Field: Environment – Geosciences (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's area of expertise is meteorology, specifically looking at convective storm dynamics and numerical weather prediction (that is, trying to find ways to understand evolution of storms through numerical models and data simulation). Interviewee learns about Japanese research mainly through interaction with other researchers, particularly Japanese researchers, at conferences and seminars. Another major source of information for the interviewee are other research groups that collaborate with Japanese researchers. International journals are not a good source of information because Japanese researchers do not seem to publish much in these journals. Also, U.S. researchers rarely consult Japanese journals so they are not a good source of information for him.

The first big area of Japanese accomplishment was the development of GPS-based research, which crosses over into the geophysics area. Their ability to use these resources for very fine motion detection, particularly in relation to plate tectonics, has been vitally important. In addition, Japan's pioneering work in using GPS signals delays to develop moisture profiles within the atmosphere has been cutting edge. The Japanese were pioneers in this area.

The second area of Japanese accomplishment was the development of models to produce accurate small-scale weather forecasts. They were ahead of the U.S. in regional spectral modeling, although the U.S. has caught up.

Finally, Japanese researchers have been very strong in the data simulation area, particularly with variational data simulation. Interviewee cited an imperial university as a key player in this area.

Within the area of small-scale weather prediction, a government meteorological research agency and the imperial university mentioned above are the really important players. Another major university in central Japan is also a player. These institutions have become important in this area because Japanese weather effects are so localized and complicated. Japan does very good work in small-scale weather prediction out of necessity. For example, the largest private weather organization in the world is based in Japan. This organization has a big presence in the U.S. as well. This is an important global company, and it is important to note that this is a Japanese company. This company has a new chief executive officer who is doing incredible stuff, which has helped Japan and this company to maintain a position as an important player in the weather prediction arena.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

At this point in time, as a very broad assessment, Japan probably ranks third in the world in this research area after the U.S. and Europe – particularly if based on the number of articles in the major refereed journals. Australia actually may be on par with Japan in this area. One does not see a lot of articles from Japanese researchers in international journals. For this reason, you do not hear about major breakthroughs coming out of Japan. Even when looking at English versions of Japanese scientific journals, one still does not see major breakthroughs. Regardless, they produce excellent technologies that are used in this field.

In the area of computer simulation and computational infrastructure, the Japanese are ahead. They excel at high-end computing. The Earth Simulator is an example. This program was impressive mostly because Japan was able to marshal the resources to build it. The interviewee was not terribly impressed with the machine itself, but acknowledges that it is doing important work in weather prediction and climatology. This project and its computing power had a great shock value.

Several Japanese conglomerates have been leaders in the computer simulation area, which has led some European countries to buy equipment from these Japan-based companies instead of U.S. firms. Access to this type of simulation technology gives them an edge. Still, having great facilities and equipment does not guarantee great results. Although Japanese researchers have cutting edge facilities, they do not have as many good people. Thus, the overall quality of Japanese work in this field is not as good as in the U.S. or Europe. As an aside, not many Japanese graduate students seem to be studying in the U.S. China and Taiwan send many more to the U.S. for graduate training than Japan does.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japanese industrial labs have gotten better, particularly in manufacturing computers and remote sensing technologies. It is hard to evaluate on the academic side. They seem to be a fairly steady actor and certainly have not deteriorated. In the 1950s and 1960s, there was an infusion of scientists from Japan coming to the U.S. This generation of scientists does not seem to have been replaced.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The Japanese are definitely a major international player in global climate change. Organizations like the government meteorological agency mentioned above have been very important. They are respected around the world, although Japan is not considered to be at the very top.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Information & Communication Technology – Computer Science (1)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

Interviewee came to learn about Japan through two sabbatical visits to Japan in the 1990s, one at a university, the other in industry. Interviewee has since typically traveled to Japan 2 to 3 times a year. Interviewee specializes in distributed systems and highly dependable systems, e.g., how to keep them functioning despite specific failures.

Japan's work in this area is not groundbreaking, but it is competitive with the best in the world. There are research communities in Japan that work in his area of research and publish internationally. In this narrow area, Japanese research is well known, and the greater strength is in hardware side.

Globally, Japanese research is underappreciated, not well known. Japanese researchers do not publish enough internationally. English may be a language barrier. There is a vibrant domestic research community in Japan, sharing information and collaborating in research. Just engaging with the domestic community absorbs a great deal of Japanese researchers' time. Maybe this helps explain why Japanese researchers are not as involved in the international research community and communicating their research through publication in international research publications.

Also, the incentives are not sufficient for Japanese researchers to go international. The Japanese computer science community is small, at least in academia. Industry researchers in computer science make up a larger group than their university-based counterparts. (The opposite is true in the U.S., but U.S. has a very large computer science research community.) Japanese researchers find professional rewards by engaging the domestic community. There is no need to go international to advance their careers. In fact, Japanese researchers succeed by building their career with a focus on the domestic environment, rather than the international one.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Japanese research is competitive compared to the leading scientific countries like the U.S. But what makes Japan different is that while in the U.S. there is a top tier of truly outstanding computer science research institutes/centers that stand far above the second and third tier ones, there is not such a great disparity in Japan. Interviewee observes it as a "flatter" playing field there. But he is aware that Japan is trying to be more like the U.S.

Interviewee had visited many universities in Japan. He thinks they do good work, but the international community just doesn't know about Japanese research. Japanese researchers have

their own informal and formal networks domestically, e.g., the IEICE, to share information and build professional networks. There are lots of professional society meetings and lots of high quality science journals published in Japan.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japanese universities have definitely improved. For example, one institution was established in the last 10 to 15 years specifically to be more active in international research. It takes a more international focus in its work. Some universities hire foreign faculty and that helps, but foreign faculty typically do not get tenure, getting 3 to 5 year contracts instead. This does not encourage people to stay and make a contribution. Some institutions try to find creative solutions to get around these institutional hurdles. Overall things are getting better. Computer science is a very dynamic, and Japan has a large role to play in the world.

Industry research is very dynamics. Firms suffered from the financial crisis and other problems in recent years, but they do well and are productive overall.

Government labs really represent a broader collection of institutions, some are clearly government sponsored, others quasi-government. It is less clear to the interviewee how they fit into the picture. But they have had successes, like the GRID computer project. Interviewee thinks Japan does better in integrating academic, industry, and government research labs in large-scale research projects and getting private firms, in particular, to work with each other.

In terms of facilities and equipment, Japan was not as competitive as the U.S. in the early 1990s, but now the price of computing has gone down. Personal computers are much more accessible to individual researchers. Japan has built specialized infrastructure and clusters of computing networks. Some of this is as good as the U.S. or even better than the U.S.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

GRID computing makes a good example. Japan has taken a lead in this area, providing a framework for doing experiments worldwide even when the core may be in the U.S. Some Japanese research teams are very well known. Japan also has strong application teams in bioinformatics. Japan is strong in the hardware side of distributed computing, producing low-level devices that can be used in fault tolerant architectures. Japan also has strong networking expertise. Japan is very well known and exercises impact through the Internet Engineering Task Force, a bottom-up group that began in the 1970s to define standards for the industry. And Japan has strong experimental networking infrastructure.

There are many ways to have impact in computer science, not just through publications. Impact may be through supporting other scientific disciplines, products, supporting network infrastructure, etc. Japanese influence in computer science is probably greater than people realize, going beyond their publications in international journals.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee wants to encourage U.S. and other researchers to collaborate with Japanese scientists and research teams and access the resources there, e.g., publications. Most U.S. scientists currently would not choose to go to Japan for their sabbaticals or to find collaborators. Logistics may be a problem; cultural distance may be another. More U.S. researchers still look generally to European research and work with collaborators there. Working with Japanese researchers requires a long-term commitment. First, one has to build relationships before getting down to do research. His experience tells him that this is a worthwhile investment, as relationships with Japanese researchers last through time. The trust and relationship built can be tapped at anytime and anywhere to support research. But most U.S. scientists do not see this and do not want to make the investment.

The Japan side too, lacks a strong drive to work with the international community or communicate their research to the world. The reward structure in Japan does not encourage Japanese researchers to go international. Those who choose to publish internationally are the exceptions.

Not that Japanese researchers or the system do not recognize some value in interacting with the international community. Sabbaticals are not part of the Japanese system, but most within industry or academia typically get a chance to spend time overseas once in their career.

One observation is that there are not as many Japanese scientists in the U.S—as many other ethnic groups like the Chinese and Koreans have—to serve as a "bridge" to engage researchers in Japan.

Interviewee cites a personal experience: On both sabbaticals in Japan, he was asked by the U.S. Embassy in Japan to speak with Japanese recipients of U.S. exchange fellowships before they make their trips to the U.S. Many felt they were sacrificing their careers with their decision to take the award. How they will be judged as professionals and advancement in their careers depend much more on their networking and achievements in the domestic environment. This kind of thinking and the larger environment that enforce this thinking need to be altered for Japanese researchers to become more interested in working internationally. Further, interviewee does not recall seeing any Japanese graduate student at one of his previous appointments at a U.S. university. Those seeking graduate education stay in Japan rather than go overseas. This contrasts sharply against the large number of Chinese, Korean, and South Asian graduate students he observed at that university.

"Internationalizing should be the focus" of Japanese science for the future. This means not only doing collaboration with foreign researchers but also efforts must be made to have Japanese research become more visible, better known in the international community.

Category/Field: Information & Communication Technology – Computer Science (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's research straddles basic and applied research with a focus on enabling formal verification. He spent 10 months on a sabbatical in Japan in the 1990s and has continued to interact with Japanese researchers in academia and industry.

Interviewee cannot think of any truly important or interesting accomplishment by Japanese researchers in his area of research. Japan has made useful contributions, but nothing groundbreaking. In his view, the main strength of Japanese researchers is their ability to take ideas and apply them.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Interviewee thinks the total volume of publications by Japanese researchers is not quite high. As interviewee moves more toward theoretical research, he has seen a smaller Japanese footprint in computer science research overall today than it was 10 years ago. Japanese industry historically focuses on hardware. In fact, Japan has never been strong on the software side. Japan never quite mastered software; perhaps it is too intangible for them to see how to set up processes and execute them. And Japan is seeing increasing competition from Taiwan, South Korea, and China in the hardware market.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Overall Japanese researchers have done a good job with staying with the state of the art. They are doing more sophisticated work than they were before but not any real gain yet at the world level. Privatization of universities in Japan may change things over time, but changes are not yet evident. The Japanese research environment is not competitive. Japanese researchers are constrained from doing research with industry because working with one company—but not another—would not be deemed appropriate (as in playing favorites). Also, there are ceilings on how much funding they can receive from corporate sponsors. Recently, interviewee has seen a few researchers being able to move from industry to academia, and vice versa. And some private universities have been proactive in bringing back Japanese researchers who have established careers overseas. These are talented people they're bringing back, but the pay off is not clear yet. Interviewee expects to see the impact of these changes in 10 to 15 years.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japan could benefit greatly from sending doctoral students overseas for training, but only a very small number come to the U.S. They need to learn how to do research. The interviewee's perception is that the safe route is typically chosen in Japan. The whole environment does not encourage risk taking, which does not encourage science at the cutting edge.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee has the general feeling that university-based researchers in Japan are not the ones pushing forward the research agenda because of the bureaucratic nature of university research. Industry research labs in Japan are more advanced. Declining birth rate and other factors have made it harder for research labs at universities and industry to hire enough qualified researchers. Even offering higher pay does not seem sufficient to attract enough people to work in industry research. Japan should look to the success of the U.S. in bringing in talent from around the world. Interviewee has seen more Chinese graduate students studying in Japan recently. He suggests that Japan should try to build up this talent. Also, with stricter immigration control in the U.S., young researchers from many countries will seek alternative destinations in Europe; maybe Japan should consider how to attract this talent and bring them to Japan.

Category/Field: Information & Communication Technology – Computer Science (3)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's research straddles basic and applied research with a focus on speech processing. In his specialized area, he finds Japanese researchers in universities and industry working hard to build structure for data collection. Their work takes a long-term view, compared to the short-term outputs that U.S. research targets. There is a great deal of interaction between Japanese university researchers and industry researchers the interviewee has worked with, and there is more funding flowing from industry to universities. Yet, for the most part, industry does not ask for fully functioning algorithms or outputs, seeking instead research from academia to support industry research and application needs. Also, while companies want to see results, they do not stop researchers from sharing their findings with the larger research community. Maybe certain details of algorithm development go only to the companies, but, by and large, researchers are able to publish and contribute to the field quite freely. And these companies make long-term commitments to researchers. For example, research grants would last for three- to five-year periods. In contrast, U.S. companies fund work that will yield practical results in six months, e.g., for in-vehicle voice systems.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan is tops in the area of speech processing. Japan and the U.S. are the top two players in the world. The difference is that U.S. research is more visible and the U.S. has more researchers. Japanese researchers produce a large volume of work. Japanese strength in this area is not recent. Japanese researchers have been visiting the leading speech processing labs in the U.S. for decades. Their research results are now used everywhere.

Japanese tend not to publish as aggressively as U.S. researchers. Interviewee thinks Japanese researchers actively publish in domestic journals so that they focus their energy there, leaving less time for submissions to U.S. or international journals. And maybe Japanese researchers see some U.S. journals as strictly U.S. journals, rather than international journals—though U.S. researchers may regard them as "international." Also, interviewee surmises that the reward system in Japan may not value publication in international or external journals. Interviewee estimates Japanese researchers are responsible for one-third or one-fourth of all Asian papers presented in some international conferences. The Japanese are clearly preeminent.

Recently, the interviewee had sent one of his doctoral degree students—a female, Chinese citizen—to work with his collaborators in Japan for three months. The collaboration has been highly productive, resulting in several papers. Interviewee reports that he likes working with Japanese researchers. He says that Japanese researchers are very focused on solving problems.

They don't spend their time fighting for first or second author name placement in articles. They do not let ego get in the way of doing good work, which is refreshing. Even a top researcher he knows who has received the highest recognition from the government of Japan shows no arrogance. When the interviewee's lab ran out of money to support the Chinese student, the Japanese just jumped in and gave her funding to continue the work that is part of his collaboration with them.

And in speech processing, a Japanese professor actually stepped forward in the early 1990s to take the lead in organizing an annual international meeting for this subject. This has since become the premier conference for the field. This researcher has a great deal of interaction with labs in the U.S. What the interviewee admires most is the balance between science and technology that is emphasized at these meetings. Japan has really spearheaded the field, not the U.S. The Japanese are able to do interdisciplinary research, accepting it, promoting it, organizing themselves in ways that will support it. In contrast, speech processing in the U.S. is typically situated in computer science departments or linguistics departments. Getting researchers to work with colleagues in other departments and departments to work with each other in the U.S. is very difficult. It's about protecting turf, which the interviewee finds is not the case at all in Japan.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

In speech processing research, senior researchers in industry and universities in Japan are all very experienced. They have tremendous knowledge. However, graduate students in Japan typically refrain from asking questions. Interviewee observes they have to work independently to find answers. He thinks this may have something to do with Japanese culture. In the U.S., researchers are more hands on and direct with their students. Maybe the requirements of funding and deliverables demand that they work directly with students to produce what is expected. In Japan, advisors just give students a task, and any student who asks too many questions would appear as insulting his professor. Interviewee has seen this kind of behavior at conferences as well.

The quality of their publications varies considerably. Some are top notch; some are not. Most of the lower quality work comes from smaller universities. Think they just haven't put enough time and thinking into their work.

In terms of research facilities, the Japanese researchers he works with have the best in the world bar none. This is true for both the universities and industry. The Japanese make investments for the long term. U.S. industry labs have good facilities but they don't publish—treating research as proprietary goods. The Japanese, on the other hand, publish, whether they are university researchers receiving corporate support or industry researchers. By publishing, they share and build knowledge.

And graduate departments are changing in Japan. In the early 1990s, departments were made up of Japanese students only. In the last three years, interviewee has an increasingly international student body—Irish, Turkish, Chinese, Malaysia, etc. This surprises him in a good way. And

Japan is very interested in sending students and researchers overseas. For example, his lab/university had hosted an industry researcher for 9 months. It is more common now to have international exchange involving young researchers (the senior ones are very international, well-networked). This is a big change over the past 15 years.

And the Japanese are very professional and focused. Their goal is to get first-rate work done; that's the goal. They pay attention to details to get things right. They're helpful not only to established U.S. researchers but even junior ones, like the interviewee's Chinese student who has just spent time in Japan. The Japanese make sure the details are taken care of. This helps to make collaborations more productive. From that student's time in Japan, 3 journal articles were produced. Interviewee is certain that this would not happen had his student been sent to collaborate with another university in the U.S.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan's formulation of speech features and speech modeling, developing "line spectral pairs" is an enormous contribution. Today, every single cell phone in the world uses this standard. This is a breakthrough that came out decades ago. And interviewee praises the Japanese for their effort to bridge science and technology, more so than he observes in the U.S. The Japanese are able to leverage advances in fundamental science across different fields.

The U.S. in the past 10 years has emphasized short-term research and payoffs, more like what Japan was 10 years ago, whereas Japan today is becoming more like what the U.S. was 20 years ago, that is, emphasizing fundamental research and taking a long view. For example, a particular U.S. industry research lab was pre-eminent in the world 30 years ago. But business decisions by the corporate entity have resulted in the break up of this research lab, even closing parts of it. This research lab, which used to fund projects that lasted 3 to 5 years, now makes grants that expect results in 6 to 9 months. The reverse is true in Japan, where multiyear funding is more common. And there are very few funding sources for longer-term research in the U.S., really just two major federal sources, which are very competitive.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The time is ripe for developing joint funding mechanisms to support research between Japan and the U.S. For example, to promote in-vehicle speech recognition, 25 teams of U.S. and Japanese researchers have met five times since April 2003, and the hurdle now is to find joint funding opportunities.

Category/Field: Information & Communication Technology – Computer Science (4)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's research focus is on the applied side, specifically computer networking. He travels to Japan at least once a year and also learns about the latest in Japanese research through email communications with colleagues in Japan and a regular digital newsletter on technology news in Asia. He also reads articles put out by Japanese researchers in his professional society newsletters. In computer networking research, it seems Japanese researchers are fairly good about submitting their papers for publication in international journals, but one should not underestimate the importance of information sharing via electronic mail. Publications are to meet tenure requirements; promoting research relies more on online sharing of information and other types of interaction among researchers.

Japan has contributed much to the field of computer science and more specifically to computer networking. The work of one particular Japanese researcher at a private university in Japan was cited for its significance in developing Internet Protocol (IP) Version 6. This particular Japanese researcher is characterized as an "Internet samurai." IP V.6 is important to broadening mobility with applications. It is a very creative initiative on the part of the Japanese.

Another example of outstanding Japanese work is in consumer electronics, in particular research that makes things increasing Internet enabled. For example, Docomo's I-mode phone allows access to the Internet. The Japanese designed something better than the Europeans did. Japan uses the standard IP so that as long as the web server uses compressed HTML, mobile phones can correctly interpret the data. The Europeans, on the other hand, developed Wireless Application Protocol (WAP), which is totally useless because gateway coding is insufficient.

And one more thing to add is the Japanese fascination with toys that are computer-based, e.g., Tamaguchi. They are slightly crazy ideas, but the Japanese are creative and exploring new frontiers through these efforts.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The performance of institutions varies, but few, apart from the private university where the "Internet samurai" professor led development of IP V.6, come to mind as outstanding players. Japan excels in optical communications, but that research is in industry labs, not the universities. Interviewee has the impression that computer networking research at universities in Japan is generally weak. Also, Japan has not done well in manufacturing Internet hardware, such as routers. Interviewee cannot think of a major Japanese player in this area, when even the Chinese

have become a competitor in the global market. He is also not impressed with data networking capacity in Japan. Japan had done work on automatic teller machines, but that is old stuff.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japan has improved somewhat over time. Japanese government support for university research is historically weak. Government funds go instead to industry, which is a "serious flaw." In the U.S., a substantial amount of government research funds goes to universities. This may explain why even research produced by the imperial universities does not have the quality to command a higher level of respect. The simple truth is that they do not have money to do research.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan led development of IP V.6. Other examples are Japan's research enabling mobile phone access to the Internet as well as general use of mobile devices. Yet, Japan has not built any large-scale routers even though it has produce what may still be the largest, most powerful computer in the world.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The old "salary men" model of Japan is rapidly deteriorating into a more mobile environment, which is more common to the rest of the world. Every model has its pros and cons, but this transition will enable Japanese who are bright and hardworking—like many that the interviewee has worked with—to excel. Of course, some will not survive. But overall there will be greater accountability.

Category/Field: Information and Communication Technology – Electrical, Electronic Engineering (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's field of specialty within this larger research area is nanoelectronics. In this area, Japan is doing excellent work in developing future semiconductor devices that are at the limit of sizing. They also excel in producing top quality single electron devices, particularly silicon-based ones. They are also doing good work in the emerging field of spintronics. Finally, they are on the cutting edge in the field of mesoscopic physics.

Interviewee named several top players in industry, academic, and government research centers. He gained much of his knowledge about Japanese research through his experience as a guest professor at a major Japanese university in 1996. He has stayed current by helping to organize joint conferences, many of which are held in Hawaii to bridge the geographic divide between the U.S. and Japan.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan has risen to the top; it is among the very best. It has achieved parity with the U.S. and Europe. This is something that has emerged during the past 25 years. Today, Japan compares very well with the U.S.

Japanese universities seem to suffer from poor physical infrastructure, which hurts their work somewhat. There are some new facilities and their equipment is generally state-of-the-art, but the physical infrastructure is not as good. Corporate labs in Japan are great overall. They have everything that U.S. and the European labs have. The difference between U.S. and Japan is that the latter is more focused at the long term. Even corporate research is longer term in Japan. In the U.S., most comparable corporate labs have all gone away or shrunken dramatically. Japanese companies invest more in basic research than their U.S. counterparts do.

There is a reasonable number of publications coming out of Japan – about equal with the U.S. and Europe. Korea is also emerging as a major player and reaching parity with the Japanese. The Koreans have invested heavily in this nanoelectronics research.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has improved quite a bit during the last 25 years, reaching parity with the U.S. The stereotype in the 1970s was that the Japanese were copying U.S. research. Now that has changed to the point where it is almost the other way around. The Japanese are now leading in many areas of research, particularly in applied research. Basic research was always strong in Japan. Now they have also added a strong infrastructure for applied research. The U.S., Europe, and Japan are now equals, which was not true 25 years ago.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

As indicated in response to Question 2, there is a rough parity in nanoelectronics research among the U.S., Europe, and Japan, and Japan is ahead in some subfields, such as silicon-based nanoelectronics.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

There seems to be a sense in Japan and elsewhere that there is growing competition from other Asian counties. For example, the Japanese semiconductor industry has lost a large part of its market share, and China is emerging as a powerful player (with a lot of investment from both government and foreign investors). There is a sense is that Japan is looking over its shoulder at China and others.

Category/Field: Information and Communication Technology – Electrical and Electronics Engineering (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's expertise is in weather and disaster prediction using space-based assets. The biggest accomplishment by the Japanese is this area of research is their development of the first space-based weather radar. This satellite, the result of a U.S.-Japan collaboration, has allowed Earth-based researchers to study and monitor large-scale weather systems such as hurricanes. Weather events, such as Hurricane Ivan, show the importance of these space-based assets for disaster prediction. These assets provide high-quality and detailed pictures of entire hurricane systems. Interviewee readily identified what he regards as the top Japanese research institutes in this arena and observes the presence of great scientists and excellent technologies.

Conferences are not always the best source of information about Japanese research in this area, perhaps because this research area is not regarded as highly important in Japan.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is comparable to that in U.S. and Europe, not much higher or much lower. In terms of quantity, Japan may produce less than the U.S. or Europe. U.S. is the dominant force in publication, followed by Europe, and then Japan. But in quality, what the Japanese have taken on has made them comparable with the top players in this field.

Japan has few research laboratories studying weather and disaster prediction using space-based assets. Japan has a narrower coverage in its research, focusing instead on a few things and doing very well in them. Japan makes good investments, particularly in infrastructure. Equipment in Japanese labs is relatively state-of-the-art, and certainly good enough to keep them among the top tier nations in this research area.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has improved over time, particularly within the last ten years. The Japanese have placed a definite emphasis on science, particularly on creativity (as much as they do to manufacturing).

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

The Japanese have tried to play a leadership role in global observations (interviewee is not sure what is driving this policy). They were the first to invest in weather radar, which has improved our ability to observe large-scale systems like hurricanes. And Japan is planning to follow up its early work with more advanced space-based systems. They have taken a leading role in the creation of a computer program called the Earth Simulator, an important effort within the environmental monitoring field. The Japanese have expanded their collaboration with Pacific Rim countries and India, demonstrating a desire to be a leader within that part of the world. This move seems to be driven by Japan's political leaders.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Information & Communication Technology – Mathematics (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's research is in nonlinear Partial Differential Equations (PDE). Japan's strength in math varies across fields. Specifically, the Japanese have historical dominance in probability theory in algebra and number theory, but they are not especially strong in differential equations. Recently, Japan has started to develop in this area. The Japanese are not stellar or world class at this time, but they are still good and young. It is hard to develop expertise in a new field; it is a slow process. Essentially, great breakthroughs happen outside of Japan and Japanese researchers come to the U.S. to learn about them and return to teach them in Japan.

Interviewee is familiar with the work of several Japanese researchers and their teams, noting that some of the work has had international impact.

Interviewee learns about scientific breakthroughs and important Japanese research contributions in areas outside his own through participation in committees, hearing other members speak highly of Japanese research. In his field, a major breakthrough involved contribution from a Japanese researcher who came to the U.S. and worked on this research with the interviewee and other researchers.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The best schools are American and French. There are Japanese individuals that are strong in narrow subareas, such as Pattern Diffusion Reaction at a particular imperial university, but Japan does not have great pockets of strength.

Speaking of his research collaborations, he and a Japanese researcher among others had contributed to a major breakthrough in his field. Interviewee has also collaborated with another Japanese researcher to study nonlinear conservation laws. Some Japanese researchers have broad collaborative ties in the U.S., and they appear to receive sufficient research funds.

Science is changing all the time. What the Japanese need to do, and this is in general, what everyone needs to do, is that when there is a breakthrough, and it happens internationally, you need to spend the money to send some young people over there to learn it and bring it back.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee says he has seen things more at an individual level rather than at the institutional level. He does not see Japanese research as having been institutionally driven. He attends conferences in Japan, but doesn't see Japanese research as timely or producing some major breakthrough.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Interviewee thinks Japan has made important contributions sporadically and within some fields. Japan has made definite contributions to the Pattern Reaction Diffusion Centers, but this contribution is considerably less in comparison to other countries. Japan's contributions have relied on the expertise of several individuals.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The interviewee shared some personal stories and perspectives. For example, his son just returned from a year in Japan. His son is currently studying mathematics and took math courses in Japanese. He son reported that the older professors lecture at the chalkboard and are hard to approach, whereas the younger professors have a more Western style and are more open to dialogue.

Interviewee thinks the culture in Japan is changing and that there is less prestige attached to older, stuffy professors. It is becoming more egalitarian—more like the U.S. Japanese culture places a lot of value on respect. There seems to be a feeling of danger when great breakthroughs occur with the older, prestigious professors. You aren't allowed to criticize professors. When he was in Japan, his Japanese collaborator told him a story to illustrate how there is no constructive criticism in Japan. His impression is that Japanese culture does not seem open to science needs. Sometimes this is an impediment to progress when you lack openness to accept new findings.

Category/Field: Information & Communication Technology – Mathematics (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's research focuses on Partial Differential Equations. He thinks Japanese researchers lead in a few areas. They have made contributions to the Boltzman equation, waterwaves, and general theorems for hyperbolic waves.

Interviewee learns about Japanese research through his participation in conferences and reading Japanese research papers. He has not collaborated with Japanese researchers. He is familiar with the work of several Japanese researchers, noting that they have produced technical results to hard technical problems. Specifically, these Japanese researchers have handle nomiliarities and singularities well. The Japanese are better at this than any other group.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

In Applied Mathematics, Japan is doing well, but significantly lower quality than the U.S. and Europe. There was a great effort in the 1980s and early 1990s, but it has tapered off.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Essentially, there was a big improvement in Japanese work in the 1970s and 1980s, but it has tapered off. Not as many Japanese researchers are coming to the U.S. to meetings and conferences. Interviewee thinks the key people are getting older and no one is replacing them. He knows one exception, a younger and energetic Japanese researcher who is doing good work.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

The Japanese were very important a decade ago. They are still important, but not a major player anymore.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

None.

Category/Field: Information & Communication Technology – Mathematics (3)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee learns about advances in Japanese research through professional meetings, published papers, and interaction with visiting scholars from Japan. He also had a Japanese post-doctoral fellow in his lab a long time ago.

Interviewee is familiar with important research and the scientists behind it in Japan. For example, a Japanese research team took the lead in developing quantum groups theory which has matured in the past 5 to 10 years. Japanese scientists also contributed to advancements in calculus, mathematical physics, and factorization methods. Japanese work on stochastic differential equations and processes is considered very important and has been going on for two decades in Japan.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan ranks high, but it not at the very top. U.S. research is better overall, along with the West European countries. In research fields the interviewee is familiar with, he thinks there appears less interaction between the Japanese and their U.S. and European counterparts. It seems that there is less activity than 15 years ago, but interviewee is not certain about this perception.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

This is hard to say as things are changing. Japan seems to have covered a larger number of areas 20 years ago. Today a broad-based research field no longer exists in Japan. Research funding has become more targeted to areas that appear more important to the Japanese. Japan is focused on bioinformatics, biology and geology tied to mathematics, network analysis, and communication theory.

Interviewee's involvement in organizing an annual program with a different thematic focus on math each time has enabled him to meet researchers from all over the world. One area that developed in Japan was the application of fuzzy logic to control theory, like subway cars. Japanese researchers pioneered work in that area, which was a hot topic 10 years ago. The interviewee's affiliated institutions had considerable interaction with Japanese companies 10 years ago when the Japanese economy was riding high. Today, this interaction has lessened, and Japan has become less visible and Japanese official research funding more concentrated in focal areas.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

In quantum groups theory, the interviewee's field, Japanese researchers have made fundamental breakthroughs recently. Japanese contributions to stochastic differential equations and calculus mentioned above were significant at an earlier time.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee readily named a number of Japanese institutions covering his area of research and their areas of expertise, but he was unable to say whether one institution is better than another.

Category/Field: Information & Communication Technology – Mechanical Engineering (1)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The interviewee's research focus is support infrastructure. The Japanese introduced automation in fabrication and building processes. Japanese research has made huge contributions in new welding processes and new steel material development.

The automation in fabrication and building processes is a significant contribution to the international research community. Essentially, all bridge structures and components are built using an automated process. Japan uses robots extensively. In the U.S., use of robots is limited, primarily, to the automotive industry.

Japanese steel companies are the leaders in steel development and implementation. "Their thermal and mechanical processing of steel is just now being introduced in the U.S., whereas they [the Japanese] have been practicing them for decades." Japan has experience working with these processes and has been enhancing the quality of steel, specifically in infrastructure use.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

There are some pros and cons to Japanese research. On the positive aspects, because companies rather than academics or the government do most research, they are most likely to implement the new technologies and invest in risky technologies. Also, companies in Japan implement technology quicker than their competitors in the U.S.

However, as a result, there is much less reliance on basic research at universities and their research programs. Companies do most of the research in this field. So you have major Japanese contractors making huge research facilities. Only in the last year have Japanese faculty been allowed to consult and be in the research process; faculty are "not in the research stream."

Interviewees think Japanese companies have a stranglehold on research in Japan, due in part to tax treatment of research. This allows greater investment in research and development by companies if they get a tax break of some sort.

It is important to note that China and Brazil are coming up with low fabrication costs, which are not developed in the U.S. or in Japan. This new competition beefs up the pressure to reduce costs.

Interviewee learns about Japanese research mainly through personal interaction with Japanese researchers. He has known researchers at Japanese universities since the mid-1970s. He knows

them well. The Japanese researchers have spent sabbaticals with him, and he has spent some time in Japan through a fellows program.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

In certain areas, the Japanese have made major advances. They are definite leaders in construction research. For example, in bridge building, the U.S. doesn't have the construction capability, though the U.S. has the engineering capability. In Japan, they have both. The Japanese are also a major player in infrastructure research as well.

One improvement is the opening up of the universities as consultants to these companies that run research institutions. This will be a positive development in the future.

There are a lot of joint programs between Japan and the U.S. Universities in Japan have "appallingly poor research facilities." Interviewee thinks research fund allocation is political [how they get money distributed], though he is not sure how. Responsibility for ministry facilities is given to political parties and interests, which control a great deal of money. There are a few quite large government ministries that fund research. One spent a huge sum, $400 million, to build a facility that tests full-scale earthquake capabilities of buildings. But at the colleges, even the imperial universities, which are supposed to be the best, they don't have the facilities to conduct this type of cutting-edge research. They need to collaborate with the ministry to use their facilities or with companies.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

In the specific area of bridge building, Japanese researchers have done a lot of experimental research. For example, the Japanese have come up with orthotropic deck systems, which involve using higher strength cables to build suspension bridges. However, a lot of these inventions are more costly. In the U.S., the least cost approach is used.

Other inventions are the dehumidified cables, so that weather won't cause problems. Deterioration with time is common, especially for older bridges. The problem is that, once again, the cost is quite high, even to upgrade materials. The Japanese are investing a lot in developing new materials. Now the Chinese will become a new competitor due to their lower development cost, but interviewee does not think that the Chinese research is as well thought out as Japanese research.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Japan is much more susceptible to earthquakes, much like California. Therefore, a lot of Japanese research is related to these natural disasters and they have made the appropriate investments.

Category/Field: Information & Communication Technology – Mechanical Engineering (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee learns about Japanese research mostly through participation in conferences and by reading journals. Interviewee thinks a particular Japanese researcher was instrumental in developing international building standards, which makes Japan a leader in the 1990s.

Interviewee works mainly on composite materials, and he commented on Japanese research in this area. The first area where the Japanese have contributed interesting accomplishments is the application of composite materials to civil engineering structures. This was a hot research area in the 1990s, perhaps due to earthquakes, but it has since tapered off. In new construction applications, Japan is ahead of everybody. The Europeans, Canadians, and Americans have caught up, but the Japanese were certainly there first. A second (and earlier area of) accomplishment for the Japanese, dates back to the 1970s is carbon fibers. Japan is still the best in the world in this area, having done a lot of research on carbon fibers and reinforced polymeric substances. A third area of excellence for Japan is in high temperature applications of composite materials, such as in rocket and jet engines. Japan has published a lot in this area. There is now more Japanese research than many other applications. The fourth area is in smart composite materials. Japan publishes a great deal and leads this area of work. Its research looks at voltage and heat applications and how material deforms.

Interviewee is surprised he does not see more Japanese research on nanocomposites. He thinks Japanese research may be involved in other areas of nano research, but there is not much evidence of it in mechanical and structural areas. He cited China as being more active in nanocomposite research than Japan.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is certainly comparable in quality to the best anywhere else. It seems like they have more organization from the top level or government there. There is direction from the top.

As for funding, interviewee is not entirely sure how it works in Japan, though he is aware that a lot of work is industry funded. He thinks Japanese organization in science is more established, but this may not be a positive thing.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee has been in the field for only 20 years, so he hesitates to comment on the big picture. He thinks it seems the same over time, with some shifts in different areas. This opinion is based on the prominence of Japanese research, which he feels should be judged by more than the number of papers produced.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The Japanese are definitely major players. Interviewee thinks Japan still dominates in carbon fiber development, but the focus has moved from basic research to commercialization.

Interviewee observes collaboration between Japan and other countries dramatically decreases as research and development move to the commercialization stage. Companies want to make a profit, and market competition is intense. But it is not easy for others to catch up with Japan, as it is so far ahead. The Japanese are entrenched as leaders in nanoelectronics. Back in the 1980s, Japanese researchers were very forthcoming with their composite research. Japan was 5 to 10 years ahead of other people, and they helped build design standards internationally.

Interaction with Japanese researchers has happened in a number of ways for the interviewee. He is the chief editor of a major journal and there are a number of Japanese researchers on the board. Japanese are a major international player and actively contribute internationally. On the research level, interviewee has done research for a Japanese firm that is a major producer of carbon fiber.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The language barrier is a problem. A great deal is published in Japanese language journals, and U.S. researchers cannot access this work. This has the implication of limiting international awareness of Japanese research.

Category/Field: Nanotechnology and Materials Science – Ceramics (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Within the field of electrical ceramics, Japan's accomplishments in the last 15 to 30 years are mainly in "reduction to practice" (reduction to practice refers to building something into a well understood process such that it may become part of manufacturing or industry).

Interviewee also commented that Japan universities and industries laboratories produce much better materials in the areas of ceramic sensors, actuators, transducers, etc. The country clearly has a national policy in the area of materials and has set goals to be the leader in materials. The country has demonstrated several cases where it has national programs with long-term (7-10 year) goals directed at particular applications. These initiatives have a high degree of coordination, follow up, and can be characterized as being largely successful.

There seems to be a change in philosophy, for example, Japan has organized an S&T agency through METI and has been building national programs that address specific applications.

In terms of specific accomplishments, the interviewee pointed out that in terms of industry, Japan probably controls about 90 percent of the world electro-ceramic market, which was not the case 25 years ago. 30 yrs ago Japan was not even able to make a multi-layer capacitor. On the ability to build products, companies that can make multilayer structures incorporating nanomaterials have moved away from precious metals and rare materials to base metals (Ni) for many applications. They have demonstrated an excellent capability to "reduce to practice" technological innovations and doing S&T for ceramics-based applications.

Many Japanese companies have some of the best laboratories and are well equipped. For example, steel corporations have the best transmission electron microscopes. More recently, Japan universities are starting to catch up. Historically, Japanese universities and their facilities were considered sub-par in many ways.

In addition, the S&T programs at industries include many young people working on projects in collaborative approaches.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan, in the interviewee's field, has always been ahead. According to the interviewee, when discoveries and progress in Japan becomes well publicized on a global scale (e.g., presented at an international conference), it has already been well known throughout Japan for several (5-6) years.

The interviewee's comments do not cover basic or fundamental research. With regards to market and products integration and development, the Japanese are outstanding in the areas related to electro-ceramics, and is definitely leading the world. Examples where Japan is leading include multilayer capacitors and much of the substrate industry. Intel and the semiconductors industry rely on Japan for most of their substrate materials.

Interviewee has always wondered how the Japanese were so successful at taking scientific innovations and research and "reducing it to practice." He described that during his visits and sabbatical in Japan, how he would attend "the-big-group-meeting," and it would be attended by students presenting work; industry students, managers, individuals from throughout the research and manufacturing process. Some would travel long distances to attend. An extraordinary amount of information is exchanged between these individuals. Such relationships, he believes, helped S&T and enabled "reduce to practice" for many discoveries because information flow began very early in the process.

In terms of discoveries and other developments in the field, it seemed there was not as much of a concern about intellectual property rights in these groups. If a discovery was made, before it would be presented at an international conference in Japan or overseas, it would first be published in Japan and become common knowledge in Japan. And only 3 to 4 years later would it eventually be presented, for example, at an American Ceramics Society meeting. And only after that would it be published in an American or international scientific journal. Hence, the technology/innovation/scientific discovery is always known in Japan before it is shared internationally.

He also commented that many Japanese professors have industrial support groups or industry sponsors that donate money to research labs, including those in private universities. There is a tremendous effort to organize and network people and facilitate information throughout the entire development, integration and fabrications process for industry. In many cases, these efforts are supported by the Ministry for Economy, Trade and Industry (METI).

Apparently some companies choose not to participate in this exchange of information, which (the interviewee was not sure of the reasons or details behind this) seems to be a more recent phenomenon. The interviewee characterized the appearance of companies that choose not to participate in the information sharing are becoming more like American companies. These companies have fewer government restrictions placed on them and fewer requirements to share information than those that choose to participate in the information sharing infrastructures.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Improved, especially universities. The interviewee commended that the Japanese universities used to have very poor conditions (not clean) or bad equipment. Today they have beautiful equipment. The interviewee would say that over the last 25 years, their growth has been enormous. Over the last 15 years the growth has been explosive, exponential (non-linear) growth.

The major industries have always been well equipped, and while there has been progress and growth with Japanese industries, it has been more constant (linear) growth than what has taken place at the universities.

One of the metrics by which he can evaluate this improved performance is the amount of capital invested in universities and by industry. Evidence is visible in the new facilities, more buildings, and construction. And investment is a means by which improvement has been demonstrated, and it appears those targeted investments are paying off.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

The U.S. and Europe are leading in the basic atomic and molecular sciences. Some Japanese labs have followed suit. Japan is following the lead of the U.S. (e.g., the National Nanotechnology Initiative).

However in the interviewee's research area (electro-ceramics), Japan is the important player in the *application* of materials science. He is constantly asked when in Japan: "what are the applications of memory, sensors, actuators, etc.?" Japan is very good at thinking through how the S&T can lead to applications and made those discoveries "reduced to practice" for use by industry. Japan is a very important applied research player, and is principally application driven, and Japanese companies do it very well.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee cited a particular Japanese firm, which he estimated controls 80 percent of the magnetic medium market. When the interviewee visited this firm, he expected it to be very secretive – like U.S. companies are. But the interviewee found it not very secretive at all. In fact, it was very open. By comparison, when he visited similar American companies, he never got past the board room – if even there at all. Japan companies seem to be very open and willing to discuss and share ideas.

Japanese companies have also invested in equipment, highly skilled, university-trained people, responsible for equipment at every stage of manufacturing process. Scientist/engineers who manages equipments at each stage would have a team of trained engineers that they oversee and do quality control. A given production line may have 8-9 university trained (Ph.D.) material scientists, and twice as many support staff, with very few production workers (mostly automated processes). Japanese researchers are very skilled people with incredible attention to detail.

The interviewee contrasted this to his experience in similar U.S. companies, where there are far fewer university-trained specialists. Most are high school trained, and all of their knowledge comes from working on the line and in the process. The Japanese model has considerable costs involved, but appears to be reaping the rewards for those investments.

Also, historically Japanese were not known for their innovation. Interviewee said this perception was recognized within Japan. At some point, Japan seems to have overcome this, for example, universities appear to have gotten better at teaching innovation.

There was also an active movement within Japan to get away from the 7-day work week, and adopt leisure lifestyles. There was a national policy to get away from the 7-day work week. The interviewee had participated in a small (15 persons) conference in Japan that included many individuals from very diverse backgrounds (neurosurgeons, deep sea experts, etc.) and from around the world. It was hosted by Japan and focused on how to improve the quality of life in Japan. Interestingly the discussion connected improvements in quality of life to "Entertainment Technology," which has helped driven some of the application sectors and technology areas. This is part of the greater initiative to move away from the 7-day work week and provide "Entertainment Technologies."

Category/Field: Nanotechnology and Materials Science – Ceramics (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Identified one of their interesting accomplishments as being able to "reduce to practice" many aspects of science to engineering.

However, the interviewee is not particularly impressed with the Japanese ability to develop new concepts. Many of the concepts that the Japanese utilize are common knowledge and in the public space. However, the interviewee was extremely impressed with their ability to take these concepts and refine them and "reduce them to practice" and make new and improve products from them.

As an example, the interviewee referred to a Japanese visitor in his laboratory working on issues related to grain size in ceramics and causes of failure. The Japanese, in their lab, were able to get a 3-fold improvement in toughness (500 MPA to 1500 MPA) just by doing the fabrication process more carefully. They pay painstaking attention to detail. The interviewee described the Japanese as very good engineers, but commented that they often did not understand why things worked as they did. Interviewee wondered whether the Japanese ability to "reduce to practice" and their attention to detail are reflections of Japanese culture.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Many of the interviewee's comments were based on personal interactions and experiences.

Quality of education is in general low in Japan. Students do not learn new concepts. The only things that really impressed the interviewee are the practiced, practical and rigid orientation of the students and structure. However, the interviewee did not feel they were the same caliber as U.S. or European graduate students and researchers in this area.

In industry, unless they have a strong research lab, they tend to have no theorists, and are largely focused on manufacturing devices. Interviewee thinks Japanese researchers are very clever. But they do not understand how devices operate (the fundamental physics that allow it to work) even when they know how to get it to operate. The interviewee compares the U.S. and Japan, taking the development of molecular memory as an example. The interviewee commented that if you ask a U.S. industry researcher to describe molecular memory, you would get a very detailed scientific answer with many, many details about the science involved, and a very thorough explanation of the underlying physics. By contrast, in Japan, you could get a very detailed explanation of how such a device was fabricated, but little understanding of how it operates. In

the U.S., first there is understanding, then device fabrication; in Japan, devices are built, and after the fact they try to understand how it works.

The interviewee commented that the Japanese innovate through observation and have very clever ways of putting things together, then afterwards gain understanding.
The interviewee used another example. When a Japanese research once explained carbon nanotubes by comparing them to Japanese baskets. If you ask a U.S. scientist the same question, you will hear about sp2 bonds, etc.

The interviewee commented that the Japanese society is very hierarchical, and staff will not question the advice of the supervisors. Therefore, if the supervisors provide good guidance, there is no question that the people working for him can achieve what they set out to do, and that they will accomplish their goals.

The interviewee commented that by comparison there is much less respect in the Chinese culture. Interviewee's observations are drawn from people who have come to his lab. The Japanese are more hierarchical, their society is more structured, based on rules. The Japanese are a detail-oriented society. The attention to detail is a part of Japanese everyday life: the correct way to fold an envelope, small but meticulous hotel rooms, etc. The interviewee suggests that this attention to detail show in their manufacturing and technology. The Japanese do not often miss things when putting devices together.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

The interviewee travels to Japan about once a year. He first visit to Japan was in 1984. In the 10 years since, he has seen tremendous growth (e.g., in construction of facilities, laboratories, etc). However, since the 90's, he has observed less growth overall. He compared this U.S. and Japanese automobile development. In the 80's, Japanese cars improved dramatically compared to American cars. In the 90's, American cars improved, but Japanese cars have not improved dramatically since.

Japan tends to follow the U.S. lead. Japan believes the ceramic hype coming out of the U.S., for example, and jumped into the area. It tried do better than the U.S., but it got hurt in the end. Many companies have dropped many projects.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

None. In his 20 years of research experience, the interviewee has not learned many new or innovative ideas from the Japanese. The interviewee is always impressed with how the Japanese are able to make things better, but in general they do not produce new ideas.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

In general, the interviewee is puzzled why the Japanese are not further ahead than they are, and believes they should be far ahead of where they are now. He thinks something is missing. Perhaps the very hierarchical nature of the society, in general, is hurting Japan. Also, women are starkly absent from high-level R&D positions. Interviewee asserts that Japan is perhaps using only using half of the intellectual assets available in the country.

Category/Field: Nanotechnology and Materials Science – Chemistry (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee is familiar with Japan since early in his career and has seen much changed. He learns about Japanese research through his collaborators, both in academia and industry, and on trips to Japan to give lectures and attend conferences. He had worked with a prominent Japanese scientist who has been credited with much of the early work in carbon nanotubes. This Japanese researcher's early work in this area completely changed the interviewee's expected career path and certainly has contributed to his current area of research.

He has seen a huge trend in nanotechnology in Japan over the past 10 years and a huge investment in the area. During the time he lived in Japan and his subsequent trips there, he has met many of his collaborators (both Japanese and non-Japanese). Japanese investments in nanotechnology are also now producing an increasing number of payoffs.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The research in Japan is first class, particularly in areas related to nanotechnology. In nanotechnology, the interviewee considers the commercial side in Japan to be probably on par with the U.S. The country is also considered world class in terms of its research in advanced materials, in general, and the interviewee considers its research in advanced materials to be on par with the U.S. as well.

The Japanese publish a huge number of articles in peer-reviewed scientific journals, especially in the areas related to nanotechnology. Interviewee considered the number of articles in peer-reviewed journals to be a good metric. The country had made huge investments in nanotechnology and those investments are actually paying off.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan's performance has definitely increased over the past 10 years. Interviewee observes an apparent bifurcated pattern in the distribution of R&D resources in the country. There are those institutions that are doing very well and are very visible; they tend to gets the largest support from the country for its research. In essence, the country is probably supporting what it knows it is very good at and the institutions (academic and industry) that are very good performers. Investments tend to go where there is the greatest amount of visible success. Similarly, those institutions that are not performing as well are getting considerably less support. The interviewee seemed to think this approach is more dominant in Japan than in the U.S. The performance of

Japanese nanotechnology-related research is on par with U.S. and European research and has certainly improved dramatically over the past 10 years.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan is an important player in nanotechnology in general and especially in the areas related to carbon nanotubes and advanced materials. It is also an important player in fields like nanobiotechnology, as well as semiconductor technology

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The emphasis and support for specific research areas over the past 10 years has increased substantially. The situation today is much better than it was 10 years ago.

Category/Field: Nanotechnology and Materials Science – Chemistry (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

The interviewee's expertise is in physical chemistry, and he spoke on Japanese science in this area. He learns about Japanese research through Japanese visitors to his laboratory, review of the literature, and participation in conferences. There have been some Japanese accomplishments of significance. For example, several Japanese researchers are applying lasers to the study of ultrafast spectroscopy. Their work is quite good and well reported in publications. Japanese researchers have also done well with the basic development of methods for understanding complex molecular dynamics. Their work in this area is respected and used by researchers worldwide.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Just a few people in Japan do Japan's very best research is this area. Japan does not compare well with other countries considering the number of universities in the country, the size of its population, the size of the country, and the size of Japanese industry. Japan does not provide adequate research support for academia. Japan spends a fraction of what the U.S. spends in this area when Japan has half the population of the U.S. and half the GDP of the U.S. Overall, Japanese research is quite limited when compared to Europe and the U.S. Interviewee added that even the Netherlands, a much smaller country in terms of the size of population and economy, is doing much more in his research area than Japan. The Netherlands has stronger research capacity than Japan.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan's performance has stayed more or less the same over time. Japan has good researchers who can do good things, but, as a whole, Japan is not a real player in physical chemistry at a level on par with the best countries. Interviewee was aware of some initiatives to improve research capacity, but states that basic research at the university level is poorly supported and laboratories are poorly equipped. In his view, it would require a major infusion of money to change things. Interviewee underscored again that Japan's population size and GDP are half that of the United States, yet Japan does not have a comparable level of investment in physical chemistry and it does not have any impact in the field. Interviewee compared Japanese science to Japanese automobile manufacturing. In the 1960s, Japanese cars were laughed at for their poor quality, but they have become leaders in world automotive engineering over time. In science, the Japanese have not had the same success.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan is a minor player in international research on physical chemistry even thought the best Japanese researchers in this area are comparable to the best anywhere else. The problem is that there just is not a critical mass of Japanese researchers in this area, and again the interviewee stressed how the number of Japanese researchers in physical chemistry is so small considering the size of its population.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee had a sense of which universities are the leaders in physical chemistry research in Japan. The best is probably one of the imperial universities. Yet, in his view, there is a shortage of institutions active in physical chemistry research in Japan overall. Based on his interactions with Japanese and other researchers, he had the impression that universities do not receive sufficient resources to do basic research in general. Interviewee thought that this problem could be fixed within a decade by an intense infusion of resources into basic research. Such a move would have to address improving salaries of university-based research scientists and raising the stature of basic research to help persuade bright, young scientists to stay in academia rather than going to industry.

Finally, interviewee noted that, each year, U.S. universities receive thousands of applications from Korea and China, but only a small number from Japan. He had read about a stigma in Japan regarding Japanese students who choose to study abroad. The interviewee comments that, in such places as Germany and the Netherlands, top scientists regard spending time studying or doing research in the United States as an enhancement to their careers. In the case of Japan, it seems very few or virtually none of Japan's top scientists want to study in the United States.

Category/ Field: Nanotechnology and Materials Science – Chemistry (3)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

In the late 1980s through the mid-1990s, U.S. researchers in basic chemistry felt beaten by Japan. They were not so much distressed by advancements in Japanese basic research in chemistry as they were anxious to see how Japanese researchers were able to successfully leverage discoveries made elsewhere in the world to advance their work. Scientists in the U.S. recognize that Japan has good universities, good chemistry departments, and good capabilities—the sources of their strength.

The recent downturn in the Japanese economy eased this sense of threat from Japan. Ten years ago, many Japanese came to study in the United States. There are now far fewer Japanese coming to U.S. universities. The decline in the number of Japanese post-doctoral fellows is particularly remarkable. Today, the largest number of foreign students coming to chemistry departments in the United States is from China, followed maybe by India.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japan is on par with the leading scientific countries. One indicator of Japan's excellence in basic chemistry is the fact that Japan has become a top destination for senior U.S. researchers for short research visits and sabbaticals.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Over the course of the past 15 years, the performance of Japanese institutions in basic chemistry has improved. But within a shorter time frame, it is less clear how best to characterize the extent of its advancement. Other people may have different responses to this question, but based on observations the interviewee had heard from his colleagues, the general consensus would be that Japan's performance has improved. However, he noted that the language barrier remains a significant issue.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

In the nuclear area, Japan has a very active program, something that is missing in other countries. Nuclear research in the U.S. has been scaled back. Politics restrains many U.S. researchers from doing something more in this area, but this is not the case in Japan. At least Japan has not cut back its funding on nuclear research. The interviewee thought that if the U.S. will be driven by

politics to reconsider non-carbon dioxide emitting energy sources, Japan would be ahead of the U.S. In fact, in his view, Japan is already ahead of the U.S. psychologically because ongoing nuclear research in Japan gives Japanese researchers the capacity to excel in this area.

Other Japanese research accomplishments include work that has won Japan a Nobel Prize in chemistry, Japanese excellence in catalyzed hydrogenation, and effective work in drug synthesis.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Nanotechnology and Materials Science – Chemistry (4)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee has no personal collaborations with researchers in Japan at this time. She learns about Japanese research through publications in journals and meeting fellow researchers at conferences. She thinks Japanese researchers have good representation at conferences; their work continues to be seen.

Interviewee thinks that very good science in chemistry is done largely at an imperial university and several top universities in Japan. These efforts had helped Japan to win the most high profile international scientific award a few years ago. She characterizes Japanese research as mostly iterative, that is, lacking in innovation and re-doing what is already known but making small improvements, as opposed to undertaking riskier research programs that pushes out the frontiers of the field.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese research is very high quality. It is methodically done, very reliable, and trusted. Japanese research is well reported in the literature, and Japanese scientists are open to presenting their work. However, interviewee thinks the work is frequently iterative rather than riskier research.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee thinks some universities and institutions have certainly improved. She mentions, as examples, an imperial university, a major institution of technology in Tokyo, and major leading universities in central Japan. She observes a greater focus on fundamentals at key institutions, which she thinks is a positive thing.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Interviewee thinks Japan is definitely an important player. The work of one scientist, who had won one of the most coveted top international prizes in chemistry, was cited. She also thinks the work of another scientist in increasing understanding on the chemistry of the environment will be very important in the future. In her view, Japanese research today has growing technological significance and Japanese scientists are producing significant breakthroughs.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Nanotechnology and Materials Science – Metals (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

In the area of materials science, and more specifically, Thermal Electro oxides, Japan is one of the world leaders. Other areas in which the interviewee considered Japan to be among the world leaders were molecular beam epitaxy (MBE) and High Temperature Superconductor superlattices. The interviewee mentioned work done by a specific researcher on Van der Walls epitaxy (depositing very thin films) and work in titanium oxide as very, very innovative. In many of these areas, Japan is very strong and probably among the world leaders.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Japanese labs are comparable to those in the U.S. and Europe. The best labs in Japan are equivalent to the best labs anywhere else. The interviewee also had the impression that in general Japan government invested more money in material science-related research than in the U.S. government does.

Integration between academia and industry is much stronger in Japan than in the U.S. In Japan, he felt a greater ease interacting with industry. There was more synergy between industry and academia in Japan than in the U.S. Interviewee learned about Japanese research at conferences he attends and through publications. Also, a Japanese company funded some of the interviewee's research, which has allowed the interviewee insights into science in Japan.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

The interviewee has less familiarity with industry and government labs than academia. His observations suggest that Japan has improved across the board, particularly in the area of materials research. There are recently many more publications from Japanese researchers in international top journal than was the case 10 to 15 years ago. Further, Japanese are doing more "stuff at the top of the pyramid than on the sides," referring to the discoveries being made as contributing to the top of the scientific pyramid and advancing new science than just filling in the sides.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Japanese leadership is not in any one particular area. It seems to spread across the entire field of materials science. Through his interactions with a U.S. company, interviewee learned that Japan

is purchasing more Focused Ion Beam Sources (FIBS), which will be an enabling technology for the country.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Nanotechnology and Materials Science – Metals (2)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

Interviewee's research focuses on superconductors and magnetics among others.

Japanese do very well in materials synthesis. They realized the importance of this research and have focused on this area. They realized that world-class materials are needed for world-class research. Interviewee said many Japanese laboratories have tens of equipment stations and tens of graduate students and staff focused on the problem of synthesizing materials. By comparison, in the U.S. there may only be one. The interviewee describes a 10:1 ratio of the level of effort applied to synthesizing new materials in Japan compared to the situation in the U.S. The Japanese fabricate absolutely world class samples.

The interviewee cited as an example of Japanese accomplishment: an YBCuO (Yittria-Barrium-Copper-Oxide superconductor) sample that was fabricated in Japan and tested it using neutron scattering. Results showed remarkable properties. This gold-standard sample, created in Japan, has enabled several remarkable discoveries.

Interviewee also commented that Japanese researchers seem to be better at focusing on long-term strategies than the West. The Japanese would focus on a problem and strategy and work on it for 5 or more years. One explanation/comparison that the interviewee made is that, in the U.S., individual researchers and research groups tend to set more local, personal long-term goals or strategic plans. There is synergy where they overlap with government initiatives (e.g., the National Nanotechnology Initiative and others). But the researcher's personal long-term strategy is the ultimate driving force in his day-to-day research. In Japan, the interviewee observes that researchers—down to the individual researcher—seem to support and work toward that national strategic goal. Interviewee says Japan is really very well organized at the national level for scientific goals and, by and large, has excellent buy-in from the individual researchers.

In general, interviewee would describe Japan's theorists as getting better. The Japanese have not always been particularly strong, but they are learning to do it better. Japan has also become open to inviting non-Japanese for long-term positions, and lots of East European researchers are heading there to take advantage of the opportunities as a stepping stone or to stay there for the long term. Japan is also making the environment more hospitable for non-Japanese researchers. All this is having a positive impact and improving collaborations, but more could still be done.

University researchers in Japan are at the same level and as forthcoming and collaborative as researchers in the U.S. However, Japanese industry people were characterized as being very tight-lipped. They seem afraid of saying something and accidentally giving away proprietary information. In terms of the quality of facilities, the national laboratories are a notch below the universities. Japan has excellent buildings and resources, but not the best researchers. There is lots of room for improvement.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Interviewee learns about Japanese research by reading Japanese research publications and through participation in conferences.

Japanese researchers publish a lot. However, they seem to lack the ability to explain how their research moves the bleeding edge of science forward and contribute to some better understanding. Interviewee said that after reading Japanese papers or publications, he ends up asking, "What is the point?" The contents and the data are generally excellent, but Japanese publications don't provide a conclusion that clearly explains the relevance of the scientific discovery. Japanese researchers would do well to improve the quality of their publications by explaining the critical or strategic value of the discovery.

Interviewee has this impression of Japanese research in general: Japanese tend to have lots of worker bees doing the work, but there are few strategists who know why they doing the work or the value of what they are doing.

Regarding universities, the best in Japan are on par with the best in the U.S., but the average capacity of professors in Japan is lower than in the U.S. The Japanese are less critical of their own work, which may be a reflection of their culture. On average, U.S. academics do better work.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

There is certainly improvement over time. A particular imperial university has always been a top institution, and others are coming up. Their performance is as good as or better than two years ago. In general, the competition for funding has increased, which is a good thing. There used to be a very strong "old boys' network." Its disintegration will allow more improvement at institutions outside that network and help contribute to the overall improvement of universities in Japan.

Interviewee observes continuing improvement at one of the major research universities. A government lab nearby also does fairly good work, but it is not driven to excel and has not become a great performer. Culture may be a factor for this kind of environment and outcome—no expectation to excel, no excellence. The Japanese need to set higher standards and expectations of the government labs, and they need to improve their self-image.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japan has done very well in creating new materials.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee gives the Japanese kudos for sample preparation and fabrication. Japanese exchange with the West and other non-Japanese could go further in scope and scale. Competitive funding should intensify and be expanded.

Category/Field: Nanotechnology and Materials Science – Physics (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee's area of specialization is high-energy physics, with an emphasis on neutrino physics (basic research that can ultimately be applied in the materials arena).

In this area of research, Japan has no equal. They are the best and remain a growing force in this area. The Super-Kamiokande, which uses phototube sensors and a huge vat of water to capture neutrinos, is a world-class facility. It was originally designed to detect neutrinos from the sun, but the Japanese were also able to detect neutrinos from supernova elsewhere else in the galaxy. This facility is truly world class, and results produced in 1998 set the field on its head.

The KamLAND experiment is also a world-class project, which has started to determine the fundamental properties of neutrinos. Combined with a Canadian project called Snow, the interviewee believes they will be sharing a Nobel Prize within a short period. That is how important the joint KamLAND-Snow work has been for fundamental physics.

The Japanese have also used existing facilities operated by government ministries to locate earth-based neutrinos. The Japanese are barreling along. They decided to make a difference in one field. This is the one field they have chosen, and they have hit pay dirt.

The interviewee met many of the experimentalists at a recent Nobel forum. He is well aware of who the top researchers are in Japan and their institutions. The interviewee thinks the Japanese are way ahead in this field. He further comments that it is shameful what the U.S. has done in this area—building one of the original neutrino detection facilities but not following up with newer facilities to continue that work.

The Japanese are extremely focused and regimented. Once decisions are made, they go for it. While the U.S. talks, Japan really does it. For example, when a Japanese ministry funded new facility in this area, instead of celebrating that victory (which U.S. researchers would have done), they decided their work ethic needed to be even stronger to fully use the facility.

A good example of dedication in this area was a serious disaster with the Super-Kamiokande. Specifically, most of the phototubes broke. The Japanese worked very hard to repair the facility and get it back online. In the field of experimental neutrino physics, the Japanese are the best.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The emergence of Japan as a leader in this area of research has been spectacular.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Fifteen years ago the Japanese were minor players in this area. Now they are the major player. Their participation in colliders and experiments is quite good. For example, the BELLE Collider has provided great work on CP violation.

Japanese research is generally not involved in higher energy machines, focusing mostly on lower energy machines—although the interviewee knows Japanese researchers would like to work on the Linear Collider.

Now Japan is the powerhouse in this area. They are the best at it. Japanese research institutes now actually bring U.S. researchers to Japan to work on their biggest projects. Japan built the Tristan Collider, which was ambitious but ultimately failed, but Japanese researchers learned a lot and took the lessons learned to the other programs like the Super-Kamiokande.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Japanese researchers are the biggest player. They seem to husband their resources very well. They have multi-year appropriations, which help a great deal for long-term research. This approach to funding provides Japan and Europe with a great advantage over the U.S. They also have the best facilities.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Nanotechnology and Materials Science – Physics (2)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

Interviewee's research focuses on carbon science, and, in this area, she thinks Japan has done some extraordinary work. Japanese researchers have been very active and have been successful in this field for 25 years. The interviewee states that the Japanese excel in applied research overall, and, recently, they have made advances in basic research areas as well. For example, the interviewee cites advances in Japanese carbon science extending beyond the area of nanotubes. She believes that Japanese carbon companies are far ahead of everyone else worldwide given Japan's work with carbon nanostructures for the past 20 years. The interviewee notes the advances in carbon technology used in Japan to increase both the lifetime and performance of lithium ion batteries. Additionally, the interviewee is aware that Japanese researchers have done important work on boron doping and have made great advances in small nanostructure components.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

What the Japanese have managed to do is very impressive. The universities, giant labs, and industry do mostly applied research. In carbon science, interviewee cited a particular researcher at one of the imperial universities as having influenced the building of basic science in industry research labs. In most efforts, it is the applied science area that is keeping the research strong, even during tough economic times.

The interviewee has heard that the university structure in Japan is supposed to change. She notes that, in the U.S., the coupling that exists between industry and the university has been strong. In the carbon business, businesses have focused mostly on the synthesis—that is, on making nanotubes, adding nanostructures into batteries. In Japan, by comparison, this coupling is weak. There is little, if any, synergy between business and universities. These relationships were even barred by law. The interviewee said that we would have to wait and see what changes in this area will bring about in the future.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Interviewee commented that while industry was booming in the 80s and the 90s, performance was strong. Then the boom stopped. While the Japanese economy does not look good today, they have good products. When the Japanese solve their problems, she believes that they will be once again be formidable because they have well-trained people who work hard.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Where carbon science theory is concerned, Japan excels in that field. Interviewee is familiar with the research labs in this field in Japan, but she is less familiar with Japanese research excellence in other fields. She states that the source of this strength in carbon science may be the presence of outstanding experimental groups at Japanese universities.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Interviewee notices significant changes in Japan. First, in outreach – that is, interacting with researchers in other countries – she believes the Japanese have improved their communication and language skills. More researchers are going abroad, and they do very well, for example, at international conferences. Japan is also inviting more foreign visitors to their labs in Japan. Such interactions are very important. Second, a new university structure will come about. Interviewee is not clear about the details of this change and cannot predict its outcomes, but she thinks this is new and changes are expected to occur.

Category/Field: Nanotechnology and Materials Science – Physics (3)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The interviewee's specialty is in high-pressure physics, which has applicability to studying the deep interior of the earth. Interviewee noted that academic institutions in Japan have been responsible for almost all the work done in the area of high-pressure physics. For this reason, the interviewee's response here does not cover Japanese industry research in this area. Nevertheless, the interviewee is aware that Japanese industry is interested in high-pressure technology because it has potential applications to commercial production (but the interviewee is not familiar with the development of these applications).

Interviewee considers Japanese research in high-pressure physics as truly world class. In certain areas, such as the application of high-pressure physics to earth science, Japan has been one of the top countries for the last 20-30 years. This leadership is based on research that began in the late-1960s and early-1970s. Interviewee says Japan is still a leader in this area, continuing to build on its successes.

The interviewee is familiar with prominent Japanese researchers in high-pressure physics. He named one as having produced particularly important early work that he characterizes as "revolutionary." This work earned the Japanese researcher high honors from the top professional organizations in Japan. Interviewee named two other prominent Japanese researchers in this area and their institutional affiliations.

Interviewee said there are quite a few Japanese labs that are top notch in the area of high-pressure physics. Several institutions, along with their principal investigators and research teams, were named. Interviewee considers these academic research teams as world class in the area of high-pressure physics, indicating that their research is often cited in this area of research. Further, within the narrowly defined area of the application of high-pressure physics to earth science, the work of these Japanese researchers is said to be among the very best in the world.

Within the related area of seismological topography, with application to earth sciences, there are also some important players in Japan. However, the interviewee does not think they are as highly regarded as those in high-pressure physics. He named three university-based researchers and their research teams as particularly good. One of these named is of Chinese heritage [not sure if this researcher holds Japanese citizenship]. These three groups conduct important seismological studies with application to earth sciences, and their results are well received by the international scientific community.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

The quality of research coming out of Japanese institutions varies a lot. The top university groups the interviewee cited are producing top-level work that is on par with work coming out in the U.S. and Europe. However, compared to the U.S., there are few top groups in Japan. Compared to the U.S. researchers, these top university groups in Japan are at least equal – if not better – but university groups in other Japanese universities do not receive big grants from the Japanese government and the quality of their research is not as good. Japan invests only in a few select groups – a strategy Japan believes will guarantee that at least some world-class research will be conducted. This strategy has worked for the main groups that get government support, but other universities suffer from a lack of funding.

A large number of important articles are coming out of Japan. In high-pressure physics, Japanese research is comparable or even better than work produced in the U.S. and Europe. In seismological topography, their work is comparable, but the work is less consistently good.

The top Japanese labs have the best equipment in the world because they have an incredible amount of money and are able to purchase superb equipment. The major shortcoming is the miserable quality of technical support. As a result, top scientists in Japan spend a good amount of time maintaining and setting up equipment, work that is done by qualified technicians in the U.S. and Europe. This distraction takes time away from pure scientific pursuits.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japanese research in high-pressure physics has been getting better. Research results have been getting better at the same rate as in the U.S. Japanese researchers are fully competitive with U.S. and European researchers over the past ten years. The performance of Japanese research varies by specific fields and subfields; on average, Japanese researchers have been holding steady or getting better.

The Japanese government's policy to make large investments in a relatively small number of research groups has worked in certain areas. Within these areas, progress has been particularly rapid because researchers have a lot of money to support their work.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

In the two areas discussed in this interview, Japanese scientists have played a major role, particularly in high-pressure physics and seismological topography. The overall contribution of Japanese research has been great.

However, the interview noted that the production of qualified technicians to assist important scientific work has been done very poorly in Japan. Also, the Japanese government's policy of providing big investments to selected groups has had a positive impact. But university-based research groups that do not receive substantial Japanese government funding are being eliminated because without sufficient funds they cannot support their work. In the U.S.,

decisions regarding government funding are very competitive, but always very fair. In Japan, the interview thinks there is still a lot of bias in the selection process.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

None.

Category/Field: Nanotechnology and Materials Science – Physics (4)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

The biggest accomplishments of the Japanese would be in the areas of advanced materials (fabricating novel and unique materials for others to study) and nanoscience.

Japan has had tremendous success in the development and research in areas related to high temperature (HTc) superconductors and would be considered among the leaders in this field. Japan is also among the leading countries in carbon nanotube fabrication and research.

Japan theorists are extremely creative and innovative researchers. Japanese theorists jumped in early and formed much of the basis for the understanding of carbon nanotubes. Interestingly, historically they had a few national treasures (that is, great scientists) and were often criticized for not being creative and being good only at improving on other people's discoveries. Today Japanese researchers in condensed matter physics are among the best in the world.

Interviewee commented on an interesting trend he has observed over the past decade. Historically, most scientists were locked in to the caste system, where only a few scientists could be at the very top, and all of the research was very centralized in a few specific locations. However, over the past several years, new opportunities are emerging at more universities across Japan, and scientists enjoy an increasing number of career paths. This helps to decentralize Japan's scientific intellectual capital from Tokyo to the rest of the country. Interviewee thought this would be a good thing because it increases the overall level of capability across the country and gives more opportunities to Japanese scientists. (Interviewee noted that France, another country that centralizes research in its capital, is starting to reduce the level of concentration in Paris.)

Another observation by the interviewee was the level of interdisciplinary activities in Japan compared to the U.S. In the U.S., universities are built on old classical disciplines (physics, biology, chemistry, etc.) and that encouraging interdisciplinary research is sometimes hard because it is difficult to get people from those different disciplines to work together. It was the sense of the interviewee that this was less of a problem for Japan. In Japan, it seems inherently easier for researchers to work across disciplines because the walls between disciplines that seem to exist in U.S. academic institutions do not appear to be as high or as impermeable. Another good example is how the U.S. views "interdisciplinary" work at academic institutions as more "revolutionary," while in Japan it is considered "evolutionary." In some sense, interdisciplinary work appears easier to conceive in Japan.

Finally, there appears to be an increasing number of foreign students at Japanese universities.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work

with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Japan is leading in the areas of advanced materials. It is certainly on par with the U.S. and Europe, perhaps even leading in the fabrication of novel materials (from a theorist's perspective who studies these materials.)

The best researchers in Japan could also easily fit in with the best researchers at leading U.S. universities. The best industry leaders in Japan could also easily fit in with the best industry leaders in the U.S.

There are new fundamental discoveries (particularly in the area of high temperature superconductors) being made that demonstrate Japanese leadership in the world. An example is the Japanese discovery of "liquid superconductors" (NaXCoO2 - add water and under the correct conditions it superconducts). In ranking the best scientific research in high temperature superconductors, Japan would be in the top two places with the U.S. Japan may even be number one.

Suggests there could be better cross breeding among researchers in U.S. and Japan. The U.S. typically receives only Japanese post-doctoral research fellows. The system in Japan is set up such that students are penalized for leaving the program during their graduate education. If more graduate-level researchers could move from the Japan to intern programs or exchanges with U.S. researchers and graduate students, there would be increasing cross-fertilization of ideas.

There have been significant improvements in Japanese command of English since the 1960s and 1970s. "Broken English" is the unofficial language of physics, and it enables more cross-fertilization of ideas. In fact, interviewee thought translating more physics textbooks to Japanese language was wrong and that the material should be taught from English textbooks to encourage further international collaboration.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Japanese institutions have definitely improved over time. Historically, Japan (like every country) had their intellectual treasures, that is, a few great scientists. However, the increasing decentralization of intellectual capital and availability of more career opportunities for Japanese scientist at institutions outside the top centers promote the quality and capability of all institutions across the country.

Japan is also pushing, as a country, to be more international. Doing this raises the bar internationally. They are encouraging more of their scientists to take sabbaticals overseas to acquire more international exposure.

In the area of nanoscience, the U.S., Japan and Europe are all comparable, and the level of innovation of Japan in these areas has certainly increased.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Interviewee collaborates with Japanese scientists mostly in nanoscience research. He said that the original discovery of carbon nanotubes in Japan has done quite a bit to raise the national psyche of Japanese researchers. It demonstrated to Japanese scientists that world-leading, innovative, original research could be done in Japan.

Japanese experiments have provided a wealth of information for physical theorists and competition for U.S. scientists. Japan is the leader in some areas of investigation.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Neutrino research is also very big in Japan, and Japan is recognized for having excellent instrumentation in this area. Semiconductor research is also very large and recognized as world leaders in this area. They are also recognized for doing excellent research and having excellent instrumentation for synchroton radiation.

In general, Japan does very well in research fields in which it chooses to focus resources. As it is, compared to the U.S., a smaller country with more limited resources, Japan must strategically choose areas to conduct research and cannot provide a high level support for as many disciplines as can the U.S."

Interviewee also commented on a societal aspect of Japan. In general, the Japanese are excellent hosts and are intent cross-fertilization and collaboration between Japan and the U.S. It has been the interviewee's experience that whenever U.S. scientists go to Japan, they always have a very positive experience and are treated amazingly well. Japanese host very well and are very patient with Americans in general. Japanese conferences are desirable, and this has served to increase Japan's international appeal. Japan is sending more scientists to international conferences and, when hosting conferences, make sure that it is a very positive experience for attendees. Japan seems very concerned and cares about how it fits in internationally. Therefore, in a sense, Japan is opening itself up internationally in the scientific communities to encourage more interest and collaboration in Japan, which the interviewee thinks has been, by and large, successful.

Finally, interviewee noted that Japan traditionally has close scientific ties with the U.S. and European countries, but questioned what will happen to these traditional relationships as Japan continues to grow economically and become more significant in world science.

Category/Field: Nanotechnology and Materials Science – Polymers (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

In terms of the interviewee's field of expertise, one particular Japanese scientist at an imperial university is recognized as a leading world expert in this field.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

Given the size of Japan compared to the U.S., Japan obviously has far fewer publications in this scientific area. However, the interviewee would say that the quality of Japanese publications is on par with what is published in the U.S. The interviewee would also comment that the amount of publications coming from Japan is on par with the numbers put out by Britain.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee said university research has improved over time, and Japanese research has improved at a faster rate over the last 15 years (0-15 yrs ago), compared to the 15 years before that (15-30 yrs ago). But the interviewee would still characterize the improvement as slow, steady improvement. The interviewee has had little interaction with Japanese industry and government labs, so he did not comment on them.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Interviewee again cited the work of the leading Japanese scientist mentioned in response to question 1.

5. **Any additional comments on research at Japanese institutions not covered by the four previous questions?**

The infrastructure in Japan universities is much worse than the laboratory facilities in similar American universities. There has been some improvement over time, but interviewee said he can't ever visit a Japanese university lab without being impressed by the quality of the work being done given the limited facilities that they have.

Category/Field: Nanotechnology and Materials Science – Polymers (2)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Interviewee indicates his specialty is theoretical condensed matter physics, with a focus on "soft" matter and the interdisciplinary field of polymers, membranes, physics, chemistry, and biology.

In his opinion, the most spectacular discovery from Japan over the past 5-10 years (which is outside of his area of expertise) was the discovery of the blue laser. The person who made that discovery has since left Japan and is now a researcher at an American university.

In his "unique interdisciplinary" field of expertise, he could not identify any specific Japanese discovery worthy of note. However, Japan has done excellent work in protein folding. In fact, he characterized this as world-leading work. Yet, much of the truly spectacular work done in Japan that is related to his field was done in the 1950s and 1960s. Much of that work is being rediscovered, and Japan is now gaining recognition for the work it did in this area. He is aware that some of the best work going on in Japan related to his research area is happening at a major Japanese conglomerate's research laboratories.

Based on his conversations with Japanese colleagues, he thinks one of the reasons Japan is not spectacular in this area is that academic bureaucracy in Japan is much worse than in the U.S. This bureaucracy gets in the way of good interdisciplinary research and prevents Japan from becoming a leader in this area.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The interviewee only commented on work taking place at academic institutions because he does not have enough experience to comment on conditions at industry or government labs. The best work in his unique interdisciplinary field of research at this time is occurs in the U.S., France, and Germany. Japan's standing is probably slightly behind these three for the reason mentioned above. In his view, interdisciplinary work is difficult in Japan. Within a single discipline (e.g., within chemistry or chemical physics), Japan is probably among the best in the world, but he has the impression that they are not very good at doing interdisciplinary work.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Interviewee couldn't really comment on this. He has made frequent switches in his fields of expertise, so it is difficult to really follow long-term trends in any of the related fields in Japan.

However, the interviewee said it does not appear there have been any dramatic shifts in the fields he is aware of. They remain more or less the same.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

In certain "point-like" areas, Japan is important. In such fields as polymer physics, solution chemistry, conjugated polymers, and self-assembly of polymers, Japan is strong, but Japanese researchers lack the broad expertise necessary for successful interdisciplinary research.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The Japanese government was clearly supportive of the sciences, which the interviewee felt was rare. He thought Japan has done well in using their scientific discoveries over the years. In his view, if scientific research in Japan could be reorganized to support more interdisciplinary work, Japan could also be very successful in those areas. He has observed that people who pursue interdisciplinary research in Japan frequently have trouble finding a job.

Category/Field: Nanotechnology and Materials Science – Semiconductors (1)

1. **What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?**

Bulk metallic glass was originally developed in Japan. It is an area the interviewee is most familiar with, although it is admittedly a niche application. Other areas where Japan had made very significant contributions include electro-ceramics, Piezoelectric materials (PZT), high temperature superconductors, rapid solidification of materials, hard magnet design, and powder metallurgy.

Interviewees identified several institutions and researchers as excellent in the field across academia and industry in Japan. In general, when the Japanese steel industry in Japan is doing well, much effort is focused on innovation for steel, but if it is not doing so well, industry tends to start doing innovative work in other fields.

2. **What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?**

The most important metrics for assessing Japanese standing are results presented at meetings. Other metrics are the quality of the output and publications produced. It is usually at meetings that one learns of the truly leading-edge research that is taking place and the newest results.

In the area of bulk metallic glass, Japan is on equal footing with U.S. and Europe. Japan has invested enormous resources in this area. Japan is, in some ways, way ahead of the game. Japan is also traditionally strong in the areas of Piezoelectric materials (PZT), ceramics, electronic materials. In some of these areas, the U.S. is behind Japan. Although a specific U.S. university was cited as doing some very innovative work in this area, it is not necessarily as strong as Japan.

3. **What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?**

Japan has definitely improved over the past 10 years. The research infrastructure is much improved compared to 20 years ago. Japanese researchers are well prepared, very solid, and Japanese students and post-docs are well prepared and perform very well. Considering the investments that Japan has made in these areas, the results are definitely showing.

4. **Comment on and provide examples of whether Japan is an important research player in your field of expertise.**

Definitely. [See responses to previous questions.]

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

Comments that Japan is also a leader in such areas as carbon nanotubes and electronic materials. Research on Gallium Nitride (GaN) Semiconductors was led by work completed in Japan.

Category/Field: Nanotechnology and Materials Science – Semiconductors (2)

1. What are the important or interesting accomplishments of Japanese scientific institutions (academic, industry, government) that you have observed in your field of expertise (in the last 5-10 years)?

Interviewee became aware of much of the innovative work coming out of Japan through personal contact with Japanese researchers and from going to conferences.

In nanotechnology, the obvious example was the Japanese discovery of carbon nanotubes. This discovery started the entire field of research on carbon nanotubes, and that kind of development does not happen everyday. It is a testament to the good R&D infrastructure that is present in Japan to nurture this kind of discovery.

In terms of technology, compared to the United States, large Japanese companies tend to move with more gusto than big U.S. companies. In the U.S., there are very innovative small companies that are using and producing products with nanotechnology, but in Japan this seems to be dominated by the efforts of large Japanese corporations. Example would be fuel cells based on carbon nanotubes. Large corporations have moved very aggressively to get nanotechnology into products in a way that hasn't been seen in large U.S. corporations.

The Japanese government investment in research has certainly contributed to world knowledge in many areas. Japan has hosted some very well respected conferences and has demonstrated support for R&D efforts. Japan's strategy (he also commented on Europe's strategy) is to basically follow the direction of the U.S. investment. If the U.S. puts a considerable amount of funding in a particular area, Europe and Japan tend to follow, matching the general amount of investment. The positive side of such behavior is that the U.S. typically responds with more funds, which drives further Japanese and European investments. This kind of scientific arms race is a good thing overall.

Research in semiconductors is near the break point. Interviewee underscored that scientifically we have almost used up all the innovation that have driven advancements in semiconductors in the past 20 to 30 years. There is not much left and we need new innovations. There is a need to invest in research with no clear expectations to encourage new discoveries to fuel growth in the next 20-30 years. Not all investments are practical; if we only invest in practical research, there would be no new discoveries.

Japan was the leaders in the 1980s with semiconductors, and there was a real fear in U.S. that the U.S. would fall far behind. Now the U.S.'s head is above water, but the entire semiconductor area is coming to the breaking point. Japan is putting investments in exploratory research, funding very aggressive and imaginative research—the type of stuff that the U.S. would not put money into. He felt Japan is investing in more imaginative research than the U.S.

He also commented that the style of research in Japanese universities is very different from that in U.S. universities. The seniority structure at Japanese universities is very rigid, and funding sources are not competitive in the same way that they are in the U.S. He thought that Japanese universities are not responsive to industry needs as U.S. universities are. One area for improvement for Japanese universities is for them to become more sensitive to and aware of market drivers for industry.

2. What is your evaluation of the research produced by Japanese institutions in your field of expertise, in particular, how would you compare these institutions and their work with those in other countries (U.S., Europe – the leading scientific countries) that are considered the best in your field?

Japan is on par with much of the R&D in Europe and the U.S., but as far as visibility goes, U.S. research is clearly more visible than similar Japanese research. In terms of metrics, Japan's research performance is illustrated by the quality of their research publications and the impact they have across the field. For industry, the testament to their development capability is the innovation that appears in their products.

Looking at Japanese industry development work, Japanese industries are definitely first rate. They are very good at moving discoveries and development to products.

3. What is your evaluation of the performance of Japanese institutions over time? Would you say they have improved, deteriorated, or remained more or less the same?

Interviewee considers the performance of Japanese institutions over time to be spotty. They can be very aggressive and innovative, and some have been incredibly successful, while others have produced very few useful outcomes. An example of a less than successful effort was the "5th Generation Computer" in the 1980s. It was not clear that any useful outcomes, either in terms of new knowledge or products, came out of that effort. An example of a useful/very successful effort was MIRAI (Japanese for "the future"). MIRAI is the government-led consortium of industry that actively pursued 5 or 6 major themes in the semiconductor industry. (Interviewee thinks the Japanese government would go to great extent to compel industry to participate in such consortia.) Several Japanese university research teams participated in it, although they were generally led by former industry leaders who had moved to academia. U.S. researchers were allowed to participate. This effort established several labs, both real and virtual labs linking the collaborators.

4. Comment on and provide examples of whether Japan is an important research player in your field of expertise.

Interview said if he would miss a lot of information if he reads all the journals on semiconductors and didn't read any of the articles from Japanese institutions. Japanese research is important to many areas—nanotubes, nanowires, surface chemistry, organic interface, etc.

5. Any additional comments on research at Japanese institutions not covered by the four previous questions?

The Japanese are very important players in science and technology internationally. If Japan decided to stop funding S&T, as it had done in the past, science and scientific discoveries around the world would suffer and be less interesting because of it.