At Home in America: Applied Scientific Research
(アメリカの応用科学：歴史的展開)

F. Scott Howell*

SUMMARY IN JAPANESE: アメリカでは伝統的に実用的な科学研究が良しとされてきた。アメリカの文化は常に研究のための研究というよりは，実生活の役にたつような応用科学を支持してきたのである。偉人の科学者として知られているベンジャミン・フランクリンにしても，トマス・エジソンにしても，彼らのイメージは真理の探求者というよりも「発明家」である。文化体系もまた発明や工夫につきものの肉体的労働や身体の危険をいとわないといった側面を有しており，自分の手を生産的に用いることを貴いとする。

実用科学技術をめぐる問題の一つに，機密保持の問題がある。科学技術はその性質上すべての人に情報が公開されて始めて発展し得るが，同時に軍事的あるいは商業的理由によって非公開とすることが望ましいという矛盾を含んでいる。
この矛盾を解決するためアメリカは二つの方策を考えだしたが，それは（1）個々の科学者の身許調査と（2）特許制度であった。

アメリカの教育制度も応用科学者を育成するようにしくまれており，社会はこのような科学者を尊敬し優遇する。教育機関は多様であり，その数は極めて多い。また研究のための資金源も多様であり，助成をおこなう政府機関も多い。

日本とアメリカの共同研究体制には問題が多く，例えば技術の軍事利用や商業利用に関しても見解の食いちがいが見られる。アメリカは世界中から政府関係の研究施設にも学者を招き入れるが，日本では困難な状況にある。

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*Lecturer, Department of Chemistry, Sophia University, Tokyo

This essay will point out some aspects of the wide support that applied scientific research has enjoyed throughout American history. American culture has always been very sympathetic to such research: why ? Here I will limit the meaning of the word scientific to the physical, chemical, and biological sciences, with apologies to the readers of this journal who are mostly social scientists. Applied physical and/or chemical science leads through engineering to inventions and new methods of construction. Applied biological science leads through research on pollution and diseases to new drugs and life-support machines. The process in both cases is often referred to as "R&D," or research and development.

Every month new discoveries and inventions are reported in the daily press, weekly news magazines, and monthly specialist journals. I have found the editorials and summaries of controversies to be particularly revealing. The weekly journal *Science* contains articles about the interaction of American politicians and science leaders, especially about funding problems. The monthly journals *American Scientist* and *Scientific American* contain both news items of new research and survey articles about new applications and old controversies.

The first section of this essay will give an overview of some American value systems, as summarized in a book on argumentation written by two professors at the University of Utah. I will use Benjamin Franklin and Thomas Edison as models of American researchers and show which value systems their lives illustrate. Then I will pick up with some attitudes that citizens of the United States, from the time of Franklin to the present, have exhibited. They have tolerated the dirt and danger and likelihood of financial failure, and they have continued to respect the manual skills needed to pursue research and development. Current American customs such as doing home repairs, trying to fix machines that break, and giving construction model kits as gifts for children illustrate the respect for people who can use their hands productively.

The second section will introduce the conflicts between scientific openness and secrecy, for military or commercial reasons. These conflicts are becoming more serious as countries with different views of military security and different sensitivities to export controls get access to the same devices. The Americans have perfected two procedures for avoiding some of the consequences of too-much scientific openness. They have established a system of security clearances for individual scientists and engineers who are engaged in military-related research. And they have improved upon the British system of patents and licensing for devices invented by a person who wants to make sure that he gets some profit from their commercial exploitation.

The third section will describe briefly the educational and social systems that support young people who choose to make a career in applied scientific research. Educated Americans as a group show great respect for researchers in the physical, chemical, and biological sciences. Researchers get credit for improvements in health care and communications, while politicians are blamed for cost overruns on weapons systems or for new forms of pollution or dangerous wastes. Students with the appropriate talents are rewarded with prestige and prizes from junior high school through university. After graduation from engineering or science courses, so many well-paying jobs are available that there is a disincentive to pursue graduate studies. Thus half of the graduate students in science and technology programs in America do not hold U.S. passports. The best-funded and most widely respected programs will be listed, but one strength of the American higher education system is that it is diverse beyond description, and many unknown institutions have excellent small programs in science and technology.

The fourth section will describe in general terms the sources of funding for applied scientific research. A diverse and redundant set of government agencies have money for grants to research groups for basic research or development of new devices. Actual commercial development is done in companies which want to make a profit, and the current attempts to link such companies with academic and government research programs will be discussed.

Finally, some recent developments in research cooperation between Japan and the United States will be summarized. The two countries have different value preferences with regard to the problems of secrecy in the military and commercial fields. The large role of American university-related research institutes will be contrasted with the role of private companies in funding research and development in Japan. The American tendency to welcome researchers from all over the world into government-funded laboratories will find nothing comparable in Japanese research centers, due partly to the language problems.

American Value Systems

Richard Rieke and Malcolm Sellars of the University of Utah give an overview of persuasive argumentation in American forensic terms in their 1975 book *Argumentation and the Decision-Making Process* (John Wiley and Sons, New York). They discuss three kinds of support for arguments, which interact continually in an actual situation: evidence, values, and credibility of the human sources. They distinguish values, beliefs, and attitudes in descending order, following Milton Rokeach:

> A belief, then is the smallest unit. Any simple statement like, "I believe ice cream is good,". . . will qualify as a belief. An attitude must be directed at a specific object, person or idea. It is "relatively enduring" like the attitude blacks may have toward religion. . . Attitudes are, therefore, beliefs which are organized and lasting and directed toward a specific object. Values, then, are the general conceptions that a person or group has, which he or they use as criteria to make decisions. They [values] are both more basic than an attitude and more general. An adult. . . probably has tens or hundreds of thousands of beliefs, thousands of attitudes but only dozens of values. (p.118)

The authors give useful distinctions between motivation and values, and between instrumental and terminal values. From page 124 to page 131 they explain in detail six basic value systems which they consider to be standard American.

> Two values that are common in these systems and sometimes operate alone that we would like to mention briefly are *nature*

> and *patriotism*. From the beginning of our nation [the United States] there has been the idea that the natural is good and there for our use and preservation. There has also been since John Winthrop first proclaimed that the New England Puritans would build "a city on the hill" for all the world to see and emulate, the idea that America is fundamentally a great nation, perhaps God-chosen, to lead the world to the true life. This idea may be somewhat tarnished in some quarters today but there is no doubt that it will revive as it has in the past, and linked to other value systems we have discussed, will once more be a theme that will draw the adherence of arguments. (p.131)

Rieke and Sellars give names to each value system, with examples of Americans who fit the system. They also give lists of words that are associated with the value system in a positive or a negative way. The first described has the compound name Puritan-Pioneer-Peasant value system. The authors add peasant to take account of the "strain of value brought to this country by Southern and Eastern European Catholics, Greek Orthodox and Jews who could hardly be held responsible for John Calvin's theology or even the term 'Protestant Ethic'." This system is rooted in the idea that persons have an obligation to work hard at whatever they do, even if they fail often. They have obligations to others and must be selfless. Positive words that underlie a tendency toward applied science include: activity, work, thrift, dedication, dependability, savings, and dignity. Negative words include waste, vandalism, and disgrace.

The Collectivist value system which the authors treat sixth and last in their list can fit well with some aspects of the above Puritan-Pioneer- Peasant system. "There has always been a value placed on cooperative action. The same person today who would condemn welfare payments to unwed mothers would undoubtedly praise his ancestors for barn raising and taking care of the widow in a frontier community. Much rhetoric about our 'pioneer ancestors' has to do with their cooperative action." The positive words include joint action, social good, the team, and together. Negative words include disorganization and selfishness.

The predominant value system at the foundation of the United States was certainly the Enlightenment value system, which influenced the early documents and the men who wrote them. This position "stems from the belief that we live in an ordered world where all activity is governed by laws similar to the laws of physics. . . the Enlightenment man believes that man can discover these laws for himself. . . He can do this because he has the power of reason. The laws of nature are harmonious and one can use reason to discover them all. He can also use them to provide for a better life." The positive words include science and nature, knowledge and reason; the negative words include dictatorship and error.

According to Rieke and Sellars, this Enlightenment value system has two companions, one of which is quite sympathetic to science and the other at least indifferent and often enough hostile. The sympathetic system is the Progressive value system, the hostile one the Transcendental value system. "Progress was a natural handmaiden of the Enlightenment. If these laws were available and if man had the tool, reason, to discover them and use them to his advantage, then progress would result. Things would continually get better." The Americans were able to take in the science of Newton and the philosophy of Locke without the aberrations of the French revolutionaries. Almost all the positive words in this value system are linked to research and development: practicality, efficiency, change, improvement, science, future, progress, modern, and evolution. Backward and impossible are the negative words.

The Transcendental value system rejected the emphasis on reason and substituted intuition. So it rejects activity in favor of contemplation. Here the negative words include science and reason and mechanical, though truth and respect are the positive words. This is an antiestablishment expression of the young, seen most recently in the hippies, or flower children. American Zen and commune living are expressions of this system. It respects nature but distrusts chemicals and machines.

The least social American value system is the one based on the terminal value of personal success. "It can be related as a part of the Enlightenment value system but it is more than that because it involves a highly pragmatic concern for the material happiness of the individual. . . 'The Lord helps him who helps himself' has always been an acceptable adage of the most devout in our nation [the United States]." The values are career, identity, family and economic security. Rieke and Sellars consider this "a personal and pragmatic combination of the progressive and transcendental." Positive words include enjoyment, health, and fair play, while negative words include dullness and disease.

American Value Systems Fit American Inventors

American children are encouraged to read short biographies about men and women who are commonly considered heroes. Besides the expected political or military leaders from the time of the American Revolution [George Washington, Patrick Henry] or later, a number of these heroes were inventors of products considered valuable and typically American. Benjamin Franklin is an example of a Revolutionary political figure who also made great contributions to American life by inventing bifocal glasses and a stove for home use, and by contributing to the understanding of electricity. Thomas Edison is famous to American young people because of his research on electric lighting systems. A list of inventions and inventors given in a recent almanac edited in America gives 75 entries of inventions credited to Americans, far more than those credited to scientists of any other nationality. Germans and British would be in the next ranks.

Most American inventors and developers have led lives that serve as model cases for four or five of the standard American value systems. The exception would be the Transcendental system, though many inventors used intuition to perfect the machines they were tinkering with. Franklin's non-scientific life was led mostly in Revolutionary France, where he became a folk hero. His almanac and many other practical writings show a mixture of personal success and progress values. His devotion to public service and his willingness to cooperate in political projects even after his own model plans had been rejected show a collectivist value and a part of the Puritan–Pioneer–Peasant value system. Franklin was not a Puritan in his religious beliefs or lack of them; he might best be considered a reluctant Deist. But he certainly worked very hard himself and expected commercial or political associates to do the same. And the aphorisms of *Poor Richard's Almanac* encouraged more ordinary Americans to a thriftiness that Franklin himself was only occasionally successful in fulfilling. Franklin also reflects the supervalues of nature and patriotism: he had a great devotion to an alliance of semiautonomous English colonies, what has now become the commonwealth, and worked hard to prevent the War of Revolution. But when British stubborness gave him no other alternative, he moved with skill and devotion into negotiations with the French on behalf of the rebels. He wrote in 1780 to Joseph Priestly, the discoverer of oxygen:

> The rapid progress true science now makes occasions my regretting sometimes that I was born too soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter. We may perhaps learn to deprive large masses of their gravity, and give them absolute levity, for the sake of easy transport. Agriculture may diminish its labour and double its produce; all diseases may by sure means be prevented or cured. . . O that moral science were in as fair a way of improvement, that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity ! (Hornberger, p. 802)

Thomas Alva Edison is a much less attractive folk hero than Benjamin Franklin. He has no French Enlightenment fan club of scholars and essayists, and no experience in the printing trade. His life reflects more the personal success value system and the hard work priority in the Puritan–Pioneer–Peasant value system. He started his experiments as a lonely individual researcher working part-time, but finished as the leader of the world's first industrial research laboratory, where Collectivist values worked in harmony with the freedom needed for inventors and designers to play around with new machines. His dominant trait was curiosity and he was very skilled at curing balky instruments, especially those connected with communication of electrical signals. He had no intellectual training in the philosophy of the Enlightenment, but his reading of Michael Faraday's research notes became the inspiration for his own excellent laboratory practices. He made progress rather than believed in it, and he was able to predict his next experimental success and get prior funding for it, most notably in the case of the incandescent electric light. His view of nature was very electrical and chemical, but he saw the advantages of doing research in the rural quiet of Menlo Park rather than in the bustle of Newark. Josephson calls him a democrat rather than a patriot, but the distinction is not too meaningful. During World War I, Edison, by then in his sixties,"headed the Naval Consulting Board and directed research in torpedo mechanisms and antisubmarine devices. It was largely owing to his agitation that Congress, in 1920, established the Naval Research Laboratory, the first institution for military research."

Edison made inventing new machines into a business, but he often lost the profits from one success on a later failure, without regret. According to Josephson (p.309), he said of himself that "he was no scientist but a 'commercial inventor' who worked for the 'silver dollar'. What he meant was that he consciously directed his studies to devices that could satisfy real needs and come to practical use. Indeed, it may be said that in applying himself to technology, he was fulfilling the ideals of democracy, for he centred his attention upon projects that would increase the convenience and pleasure of the multitude."

American Attitudes Are Tolerant

To include inventors among a country's heroes may be specifically American. Several supportive attitudes are apparent. Inventors must work with their hands and must be willing to get wet and dirty. Edison's first laboratory was in a corner of a baggage car on the train where he worked selling candy. The 17-year-old Franklin remembers wandering the wharves of Philadelphia looking for work as a printer.

Indeed all of Franklin's printing was done with handset type, which he often picked with his own hands. European noblemen are not allowed to get dirty or handle pieces of type ; citizens of a democracy may and do get as dirty as the job requires.

Another supportive attitude is the tolerance of danger. Accidents often occur in developing new machinery. Sometimes the experiments themselves are dangerous : the best examples include Franklin's flying a kite during a thunderstorm to attract lightning to a key on the kite-string. If the lightning bolt had followed the string down to Mr. Franklin, we would have had a martyr to the investigation of the nature of electricity, rather than a successful scientist and inventor. The early flights of the Wright Brothers are also good examples; if the plane glides in for a landing, the experiments are successful; if it nose-dives into the sand, it's off to the hospital for whichever brother is in the pilot's seat. This same willingness to face danger to health, even to life, is evident in the experiments and research connected with space exploration. In so far as the jet pilots who become astronauts are scientists rather than just passengers, their developmental work is a kind of inventing of techniques for space travel.

Another American attitude that is evident in the lives of most inventors is that failure is not final, and should not be a source of lasting embarassment to the inventor. Franklin went bankrupt more than once in the printing business while he tried to develop some of his inventions. His debtors had to settle for rather less than they had lent him, but a couple of years later Franklin was back in a different business with new financing and new risks: he had found what we would call now venture capital.

As an expert night telegraph operator for Western Union, Thomas Edison had a good idea for his first patented invention. So he borrowed some money from a friend, gave up his job in the autumn of 1898, "and became a free-lance inventor, taking out his first patent for an electrical vote recorder. Although the invention worked well when exhibited before a committee of Congress, no one bought it--a lesson Edison never forgot." But the next summer he is able to solve a similar mechanical problem and makes a sudden fortune:

> At a moment of crisis on the Gold Exchange caused by the breakdown of the office's new telegraphic gold-price indicator, Edison was called in to try to repair the instrument; this he did so expertly that he was given a job as its supervisor. Soon he had remodelled the erratic machine to such effect that its owners, the Western Union Telegraph Company, commissioned him to improve the crude stock ticker just coming into use. He performed this task by creating the Edison Universal Stock Printer, which. . . brought him a sudden fortune of $40. 000. With this capital he set himself up as a manufacturer in Newark, N.J.. . . (Josephson, p.309)

Edison made $4 million with his electric-light system inventions. He lost the same fortune in trying to develop a magnetic ore-separating process for low-grade iron deposits. His quoted reaction was: "Well, it's all gone, but we had a hell of a good time spending it!"

Americans Respect Manual Skills

Besides these tolerances for failure, for dirt and dampness and even danger, Americans from the time of Franklin to the present have had a respect for people who can use their hands skillfully. The distinction between technicians, who work with machines, and scientists, who work with theories and numbers, has always been very fine in American laboratories, from Edison's Menlo Park invention factory to the industrial laboratories of giants like General Electric and Westinghouse today.

Children learn this respect for manual skills from their parents and relatives. Franklin's father walked around Boston with his 12-year-old son looking for a congenial trade. They settled on printing because Benjamin liked books. Edison had a chemical laboratory in the cellar of his home at the age of 10. Underlying these model cases were ordinary American living arrangements: each family had its own home; these homes were full of devices which the children had to learn to operate; the family chores were performed by the children, not by servants; old devices and machines were available for tinkering, and they could be taken apart if they were broken and a reward obtained if someone could fix them or make them work better than before.

Franklin and Edison, like many modern engineers, devoted a great deal of their free time to experimenting and tinkering with gadgets. What started as a hobby often resulted in an invention or a new career: Franklin worked out the plans for his famous stove under such conditions.

Tinkering and taking things apart are still considered desirable pastimes for young Americans. How does something work? It is always a valid question when it comes from a young American, and parents are often embarrassed when they are unable to answer it. Thus magazines such as *Popular Mechanics* continue to enjoy popularity over the years.

There are many crafts which are still actively practiced in the homes or garages of contemporary Americans. Pottery kilns or home-made beverages, canning or preserving fruits or vegetables, making quilts: these are all hobbies as well as professions. The children who grow up watching their parents devote time and energy to such a craft will have acquired a wide variety of skills that will be useful to them if they decide to pursue a career in science. Even if they just get a good idea for a new machine, the availability of tools and farm implements will make it easier to try these ideas out. In America's research laboratories, quite a few scientists have the skills of technicians: soldering, shaping on a lathe, mechanical drawing and the like are not the exclusive preserve of technicians.

This attitude of respect for manual skills is very much alive in most of the United States. There is a great deal of attention paid to what are called "home repairs." Quite a few young men and women are trained by their parents in the fundamentals of painting walls and replacing roof shingles or broken panes of glass. Some even learn how to install electrical wiring or plumbing fixtures. These abilities to repair parts of a house are, I think, a function of the large number of wooden houses in the United States. Brick and stone houses are much more difficult to repair, but such houses are generally made of wood on the inside [inner walls, stairs, and the like], so even Americans who live in such non-wooden houses have some opportunity to learn how to repair or rebuild parts of their home. The typical suburban home owner would take pride in a beautiful lawn or garden and would expect to spend some time on Saturdays or holidays in garden work, raking leaves or transplanting flowers as the season dictates. Home repairs save money, of course, but they are also a source of pride for a homeowner.

Modern middle-class families often pass on their attitude of respect for manual skills by teaching their children to make things out of wood or clay, to sew or cook, and to clean and reassemble machines used around the home. Until rather recently many teenage boys were given the use of an old automobile, and many of them learned how to take the motor apart and rebuild it for more speed or better mileage. American gifts include many model kits. The child is expected to build something from parts provided by the toy manufacturer, following a plan of assembly provided with the kit. Sometimes the resulting model can fly or respond to radio commands. Simple electrical devices such as radios can also be purchased and assembled. Skills such as reading directions and soldering electrical connections which are picked up during the enjoyable construction of these kits are just the same skills which are needed if an amateur scientist wants to try something out in his basement, as Edison did. These skills can also result in part-time jobs at companies where older full-time workers will take an interest in the young person and teach him or her manual skills that are the product of experience. Many leading scientists and engineers have been tutored by technicians who are much less educated, but are very clever in using their hands and getting machines to run better.

Secrecy in Applied Science

Before the Renaissance in Europe, there were few experimental scientists and little communication among them. But at least from the time of Francis Bacon, experimenters formed associations and shared results and theories either at meetings where papers were read or by letters which were often published later. For example, Franklin's first reports on electrical phenomena came in letters to Peter Collinson which were read before the Royal Society of London; later, in April 1751, a book appeared titled *Experiments and Observations on Electricity*. Franklin received no money for his research efforts, but received a great deal of fame and praise, including honorary degrees from Harvard and Yale. He was a corresponding member of scientific societies in at least six nations. This is the ideal for science, that the best minds around the world are in constant contact.

The ideal falls short when either of two problems arise with devices invented or perfected during research: the first is when the device is a weapon or is likely to make current weapons more effective; the second is when the device can be developed for commercial use and its sale or licensing can create substantial profits. In the former case, either the inventor, or at least his government, is anxious that the device not be available to current or potential enemies. The American supervalue of patriotism is often a function of research and development of weapons and techniques for use against the enemies of the United States, who are in the most cases, the enemies of the value systems of freedom and individuality. In the latter case, the inventor or developer can become rich from his intellectual efforts if he can keep them secret or if the government will protect his claim to having invented the new device. The guilds in the Middle Ages kept their techniques secret. Lewis Mumford records the change that capitalism exerted:

> . . . In the beginning, it was knowledge, skill, experience, that had been the subjects of guild monopoly. With the growth of capitalism came the bestowing of special monopolies, first to the chartered companies, and then to the owners of special patents granted for specific original inventions. This was proposed by Bacon in 1601 and happened first in England in 1624. From this time on it was not the past heritage that was effectively monopolized but the new departure from it.
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> *Technics and Civilization*, 1934 (1963, p.132)

The Enlightenment and Progressive value systems have no basis for secrecy legislation. The values they want to foster are individual rights, to read and to write freely and to communicate freely by publication and meetings. But the exception is treason: no citizen has the right to betray his country or its military plans to an enemy power in time of armed conflict. Thus the United States has developed a system of loyalty checks and security clearances for scientists and engineers who have access to military technology. The workers who have access to sensitive information must in principle be American citizens, but foreign scientists who start to work in such laboratories can easily become naturalized as part of the procedures for employment. The Federal Bureau of Investigation has the legislated duty to conduct security checks on the scientists involved with development of military devices. Three classifications result: a worker is said to be cleared to have access to "confidential," "secret," or "top-secret" information. The worker must swear not to disclose this material to others, especially to those working for other governments. Fingerprints are taken as a matter of course during these security clearance checks. I suspect all of this description makes my Japanese academic readers very uncomfortable.

Most Japanese academics, both scientists and humanities scholars, have an allergy to military issues, especially to serious discussions about the preparations for military defense of Japan. That the Soviet Union might attack Japan, and that Japanese soldiers and sailors might have to use weapons against such invaders : these scenarios are not discussed in academic circles. "Japan is a peace-loving country" is taken to mean that military hardware research and development are somehow impolite and unsuitable for professors or academic researchers. The common sense of most Americans dictates the opposite response: that unless American government agencies devote quite a lot of money to funding research connected with weapons development, the Soviets will take over the world by force or threat of force. The Japanese distaste for public discussion of military development and the American addiction to public spending for such development make discussion clumsy. In this article I will sometimes refer to American science and technology which is to some extent funded or inspired by militaristic, counter-Soviet, goals. Let me apologize only once for this too-simplistic political view of Cold War Americans, who are victims of their own brief history and of their cowboy movies, where the black-hatted villains have forfeited any right to be treated as dignified human beings. I will also point out that new scientific discoveries, whether theories or patented devices, often outgrow their funding agencies' inventions. Navigation devices such as radar and sonar can be used by cargo ships and passenger planes as well as by attack submarines and strategic bombers, to give just one example of many.

Some American companies that deal with licensed exports of items such as precision-measuring instruments are complaining that export licenses are slow in coming because these items are "dual-use" products, having both military and civilian applications. This problem overlaps the two forms of secrecy and introduces the possibility that what America deems secret technology may be on sale by European or Japanese suppliers (*Scientific American*, 256, March, 1987, p. 44 and 258, June, 1988, p. 18).

The perceived demands of national military security are given precedence to the freedom of publication upon which scientific progress is based. The second dilemma of how to prevent new discoveries from being kept secret for commercial advantage has been more or less solved by the patent laws and licensing procedures.

> A patent is a governmental grant conferred upon the inventor or discoverer of a new and useful art, machine, manufacture, or composition of matter, securing to the patentee the right to exclude all others from making, using, or selling the invention for or discovery for a designated period of time, in consideration of the patentee's disclosure in his patent application of the details of the patented matter, in accordance with the requirements of law, for the benefit of the public and the promotion of science and the useful arts.
> Generally this right to exclude all others from exploiting the patented product operates to invest the patentee with a monopolistic franchise to make, use, or sell the patented invention.
>
> H. Silver, *Collier's Encyclopedia* 1960 15 (p. 105)

This system of patents was incorporated into the constitution of the United States (Article 1, Section 8) and the original patent act was passed in 1790. The influences of Franklin and Thomas Jefferson, who had many inventions at Montecello, are obvious. Every incentive is given for fast and complete reporting of the new device or discovery. Access to every one of the 2,500,000 patents filed in the United States is available for a modest fee from the Patent Office. The hope is that inventors will stimulate one another and will make deals with investors to promote the development and implementation of the invented devices for the benefit of the ordinary people. There is even a register of patents available for licensing, so that industries can more easily begin negotiations with inventors. So, in theory, the inventor has no choice but to file for a patent, and in so doing reveal the details of his invention to the federal government, which will protect his right to profit from the use of his invention. If the inventor does not file for a patent, he may be scooped by some other inventor and get no return for his efforts. Military technologies are never patented in the final form, but some detailed functions may be patented if the description can avoid hinting at the direct military use.

How Young Americans Begin Applied Research

What sort of influences would cause a young American to choose a career in science or engineering? The model of a relative or respected neighbor would be influential. How many scientists and technicians are there in the United States? An interesting model calculation was presented by the Office of Technology Assessment in 1985. As summarized by the president of the American Association for the Advancement of Science (AAAS),

> The report described an initial cohort of 2,000 male and 2,000 female students at the ninth grade level. Of that original cohort, only 1,000 of each group will have sufficient mathematics at the ninth grade level to remain in the pipeline. When the two groups are followed to the end of high school, 280 men and 220 women will have completed sufficient

> mathematics to pursue a technical career. A major drop in women students occurs with career choice upon entering college with 140 men and 44 women choosing scientific careers. . . at the B.S. level, 46 men and 20 women receive degrees. . . Of the original 2,000 students in each group, five men and one woman will receive the Ph . D . degree in some field of the natural sciences or engineering.
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> Sheila Windall, *Science* 241 (30 Sept., 1988, p.1740-1)

So about one in 50 Americans who enter senior high school will eventually deserve to be called a scientist or technician.

About one in 20 Americans is considered to be "literate" in science, though the definition or testing procedure is thought to be flawed by some critics (William Hively, *American Scientist* 76, Sept.-Oct. 1988, pp. 439-444). ". . . the scientifically literate should understand the scientific method and vocabulary well enough to follow public debates about science and technology." About 18 percent of the American adult population was considered in 1979 to be an attentive public for scientific issues: they would turn to a newspaper story on science and technology early on in their reading (p.444).

These figures would indicate that the prospective young American science student would be rather lonely; yet he or she would also enjoy quite a bit of respect from peers and adults. According to Hively, "Polls have generally confirmed that the majority of Americans are well-disposed toward scientific research. They may not understand it, but they realize that science and technology have contributed mightily to their high standard of living, and they expect that the people in white coats will continue to produce good results." (p.444)

It is commonly believed that young American scientists tend to come from families that have relatives in the professional military service. For example, most officers in the U.S. military services who are graduates of the professional academies [West Point, Annapolis, Colorado Springs] receive degrees in science or engineering. Certainly before the Vietnam War, both military officers and professional scientific researchers enjoyed more respect in American society than lawyers, probably more than medical professionals. The failure in Vietnam and some of the odd uses to which scientific tools were put during the conduct of the war have lowered the respect for military and scientific professionals, but I am unable to find social surveys to confirm or quantify this conclusion.

As a side issue, I might remark that the position of American military officers in American society is much more central than the position of Self-Defense Forces officers in Japanese society. I have asked groups of Japanese students in good universities how many of them were acquainted with even one SDF officer; perhaps one student in 50 will reply in the affirmative. The American officer is considered by non-officers to be a patriot, a person with pioneer values, who is willing to sacrifice comfort to defend Enlightenment values. This favorable image of officers extends to those who used controversial weapons during World War II [i.e. the two atomic bombs] and to those who perform research and development of new and much more horrible weapons.

There might be more men and women choosing scientific careers at the end of high school if the science education they received there were better. Recent evidence developed by the Educational Testing Service shows that "only about 7% of 17-year-olds are adequately prepared for college-level science courses. Even worse, the report says that more than half the nation's 17-year-olds have so little scientific understanding that they cannot hold down jobs that require technical skills, benefit from specialized on-the-job training, or make informed decisions as citizens." (Gregory Byrne, *Science* 241, Sept. 30,1988, p. 1751)

If the general level is indeed so dreadful, then a student who has good teachers in mathematics and science and enjoys his or her classes has all the more reason to be attracted to a career in these fields. Summer programs and part-time affiliations with research laboratories and projects are readily available to the fortunate 5-7 percent of the students. These are intended to help introduce the next generation of engineers and scientists to their future work environments. Associations of college-prep-level junior and senior high schools will sponsor science fairs to allow talented students to display the results of their guided research projects. The student winners of such competitions can expect university scholarships and support from research laboratories.

High school graduates in America are accepted into universities by admissions committees who examine a variety of documents submitted by the candidates. The high school grade report is important, as are written recommendations from teachers or other esteemed adults. American students can be roughly ranked by their scores on the Scholastic Aptitude Tests or the American Council of Education Tests. The former exams produce two scores, one for reading skills and general knowledge and one for mathematics, each score between 200 and 800. In most cases the sum of the two scores is used as a cut-off for admission. Thus a well-read student with good mathematical skills has a great advantage over his or her classmate who may be very good at English grammar but is weak in arithmetic. Very competitive schools generally want a total score of 1200-1300.

Recently, the weekly news magazine *U.S. News and World Report* (Oct. 26 and Nov. 2, 1987), published a set of special reports on America's best colleges. The magazine was severely criticized by the presidents of the two testing agencies for using average admissions test scores to rank colleges, but I have seen no better criterion (Jean Evangelauf, *The Chronicle of Higher Education*, Nov. 23, 1988, pp. Al and A26).

Students who enter science or engineering departments at an American university declare their major field of study at the time of application. It is possible to change university or to change the major field of study in an American university with few penalties, since most earned credits can be applied to the new degree field or at the new university. But drop-outs from science, especially students who switch from science to business, are much more common. This occurs even though there are more awards in the form of partial scholarships for science and engineering undergraduates than for students in other major fields.

The articles in *U.S. News and World Report* divide the institutions of higher education in the United States into nine categories. Rankings were done by votes from deans and presidents of institutions in each category. The top-ranked science programs are listed by category below. You should not be surprised if you have never heard of half of these institutions. One of the enduring strengths of the much-criticized American educational system is the existence of many centers of excellence, departments or programs where a student can gain an excellent research education in a friendly environment.

CATEGORY	COLLEGE
National Universities	Massachusetts Institute of Technology
National Liberal Arts	Oberlin College (Ohio)
Smaller Comprehensive	Montana College of Mineral Science and Technology
Southern Comprehensive	University of Alabama in Huntsville
Eastern Comprehensive	Rochester Institute of Technology (N.Y.)
Western Comprehensive	California State Polytechnic University San Luis Obispo
Western Liberal Arts	Alma College (Michigan)
Southern Liberal Arts	Virginia Military Institute
Eastern Liberal Arts	Saint Joseph College (Connecticut)

In the model case presented by the AAAS president, only 66 students out of the initial 4,000 ninth graders received Bachelor of Science degrees. The projection from other data indicates that about 26 enter graduate school and six eventually received doctorates. There is also the dimension of foreign students to consider. Philip Abelson, a deputy editor of *Science*, explains the financial facts of life and describes non-American students who come to the United States for graduate school after receiving their undergraduate training in another country, often in another language.

> About 90 percent of individuals obtaining a baccalaureate degree in engineering in the United States are citizens. However, only 41 percent of the small number of Ph.Ds are native-born Americans. The typical holder of a baccalaure-

> ate degree finds employment in industry at an annual salary on the order of $30,000. Fewer and fewer U.S. citizens are willing to forego such salaries in favor of several years of graduate student poverty and expense [sometimes including debt] that will yield a few thousand dollars more in annual starting salary. In the meantime, other members of the same age cohort may have received substantial boosts in pay.
>
> *Science* 242 (Oct. 28, 1988) p.493

The same conclusion is reached by a National Research Council Report published in January 1988 (*Scientific American* 258, May, 1988, p. 16).

Table 1. Federal research support to American academic institutions

Institution	1986 Total Funding[a] Ranking	1986 Total Funding[a] Amount (million $)	1987 Research Funding[b] from N. I. H.[c] Ranking	1987 Research Funding[b] from N. I. H.[c] Amount (million $)
Applied Physics Laboratory: John Hopkins University (Maryland)	1st	313	-	
Massachusetts Institute of Technology	2nd	188	-	
Stanford University	3rd	180	5th	96
University of Washington	4th	147	4th	102
University of California at San Diego	5th	133	-	
John Hopkins University (not APL)	6th	133	1st	129
Columbia University	7th	127	8th	88
University of California at Los Angeles	8th	125	6th	95
University of Wisconsin at Madison	9th	121	-	
University of California at San Francisco	-		2nd	117
Cornell University	10th	113	-	
Yale University	11th	112	3rd	104
Harvard University	-		7th	95
University of Pennsylvania	-		9th	84
Washington University (St. Louis, MO)	-		10th	81

[a]Science **239** (January 8, 1988) p. 140. [c]N.I.H. = National Institutes of Health
[b]Science **242** (November 11, 1988) p. 869.

The total Federal support for academic institutions in fiscal 1986 was $11. 6 billion. More than half ($6. 538 billion) was for academic research; most of the rest was for student support through grants of various types.

Table 1 shows the academic institutions which receive the greatest amount of federal funding for academic research. The numbers and rankings are slightly different when medical research is included. The total amount of federal support for academic research in fiscal year 1986 was $6.5 billion, with the top 10 institutions receiving 25% of the total. Many writers complain that there is not enough funding for the stipends of graduate students and young postdoctoral researchers. In all events, most Americans move to industry and many talented non-Americans flock to good universities and are glad to receive whatever stipend they can get from the Federal government or other organizations.

Young Americans with a Ph.D. or D. Eng. degree would be free to identify their profession or employment category as engineer or scientist. They would be considered upper-middle-class and would be expected to have progressive or personal satisfaction value systems. How would they get along in ordinary middle-class American society? I disagree with the composite of negative statements compiled by Walter Gratzer of King's College, London, but this is what his survey of 35,000 American students produced as the standard male American scientist stereotype:

> He neglects his family--pays no attention to his wife, never plays with his children. He has no social life, no other intellectual interests... He bores his wife, his children, and their friends... He is always running off to his laboratory. He may force his children to become scientists also.
>
> *American Scientist* 76 (Sept.-Oct. 1988) p.442

My graduate school experience was in Washington, D.C., which the author of *The Nine Nations of North America* rightly considers a special category, along with New York City, Alaska, and Hawaii. My experience was that the general reaction of non-scientist neighbors to scientists and engineers was one of respect, esteem, even admiration. Whether the scientists and engineers were working in academic, governmental or industrial laboratories, they would generally be considered as valuable neighbors. The other professionals who lived nearby, whether they were lawyers or physicians or stockbrokers, would value the cooperation of the scientists and engineers in local projects.

Funding for Applied Research

In the United States several different institutions provide money for scientific research. Both the Federal government, and state governments are directly involved, along with industrial corporations, benevolent foundations, and universities. The Federal government has constitutional responsibility for defense-related matters and for interstate matters. These include safer transportation systems and protection of the environment, Economic competitiveness motivates both the federal government and some rich states to fund research and development of new materials or systems.

The Federal government is divided into three distinct branches: the legislative, the judicial, and the executive. Most involvement in scientific research is through executive departments and agencies, but the other two branches are also involved. The legislative branch must pass and review laws which set up and fund agencies within the executive branch. There are at least six subcommittees which are directly concerned with scientific research.

There is a great deal of overlap of areas of responsibility among the functions of the Executive Office of the President, the sections of the thirteen Cabinet-level departments, and the independent executive agencies. This is not necessarily bad for the promotion of research, since a team of investigators has several potential sources of research funding. The situation becomes more confusing when there is a question of taking responsibility for accidents or mismanagement or of planning for the prevention of such problems. Thus the area of environmental protection seems to have the greatest areas of administrative overlap.

The traditional alliance of values between research scientists and military professionals seems to break down when it comes to Defense Department bureaucrats. Jerome Wiesner, president emeritus of the Massachusetts Institute of Technology, offers the following caustic evaluation in a recent issue of *Scientific American* (260, Jan., 1989, pp.18-23):

> Most cabinet officers, however, are so overwhelmed by the job of running their departments that they rarely have the time or energy to understand the president's special problems, particularly those that relate to science...
> Another difficulty is that departments have their own fish to fry. The Department of Defense, for example, is an enormous, self-perpetuating bureaucracy that regards its own survival and growth as its top priority. The Secretary of Defense has little control over it. Entrenched bureaucracies may try to thwart the deployment of new technology because it threatens some political or social status quo. (p.19)

Wiesner's criticism may result in less funding from the Department of Defense to Massachusetts Institute of Technology research projects, but the institution can afford the loss better than most. Within the Department of Defense there are the secretaries of the army, the navy, and the air force. Each of these secretaries has several high-ranking assistants, who are also appointed by the president and subject to confirmation by Congress. The American military establishment will go to any length to avoid using the same nomenclature in each of the three main services. Thus the secretary of the army has an assistant secretary for research, development and acquisition; the secretary of the navy has one assistant secretary for research, engineering and systems, and another assistant secretary for shipbuilding and logistics; the secretary of the airforce has no assistant secretaries, but instead he has a deputy chief of staff for logistics and a head of the office of space systems. The taxonomy of the American armed services is kept as complicated and unique as possible, perhaps in the hope that confused congressmen will vote more money for personnel and weapons.

Research and development spending in the United States includes money spent at laboratories controlled by the funding agency as well as money given as grants to research organizations. Most funding from the departments of Defense and Energy goes to classified projects at laboratories such as Los Alamos or Sandia in New Mexico. The scientists who work in such facilities must undergo a security clearance check conducted by the Federal Bureau of Investigation or some similar military security agency. Some research is not classified and available for publication, but most results are weapons-related and unpublishable. Small percentages of the total research budget, but big amounts of cash nonetheless, are made available to outside research groups such as universities through linking agencies like the Defense Advanced Research Projects Agency. One example of unclassified research conducted within the Federal government is the National Bureau of Standards, where a great deal of unclassified basic research is undertaken under the funding of the Department of Commerce. Non-Americans are welcomed as researchers in these non-classified projects and are especially in evidence in the medical research projects conducted by the National Institutes of Health with internal funding from the Department of Health and Human Services. A lot of friction between the United States and Japan is caused by the absence in Japan of similar government laboratories which might welcome non-Japanese researchers. The National Academy of Sciences recently opened an Office of Japanese Affairs and the special seminars at the annual meeting of the Association for the Advancement of Science in January 1989 in San Francisco included an introduction to newly established joint R&D program opportunities (*Science* 237, July 31, 1987, pp. 476-478 and 241, Sept. 30, 1988, p. 1834).

Frank Press, the president of the National Academy of Science, thinks there are 15 different federal departments and agencies which are involved in the funding process (*Science* 240, May 6, 1988, p. 713) while *Science* magazine itself breaks up the funding sources into 19 separate major departments and agencies (Feb. 26, 1988; p. 965f). For basic research funding, the six most important federal funding sources are, in order of importance: the National Institutes of Health, National Science Foundation, Department of Energy, National Aeronautics and Space Administration, Department of Defense and the Department of Agriculture (*Science* 242, Dec. 9, 1988, p. 1368ff).

If applied research and development are included, which include the weapons development and atomic power plant research, the ranking shifts. The category "defense-military functions" controls more than

60 percent of the research and development funding (*Scientific American* 260, Jan., 1989, pp. 18-23). Second comes the Department of Health and Human Services, which funds the National Institutes of Health. Third comes the Depertment of Energy, then the National Aeronautics and Space Administration. The National Science Foundation falls to fifth place, since NSF funds practically no applied research. The Department of Agriculture remains in sixth place. Other funding groups include the Department of the Interior, the Environmental Protection Agency, the departments of Transportation and Commerce, the Veteran's Administration [mostly hospital-related research], the Agency for International Development, the remaining Cabinet-level departments except for State and Treasury, the Tennessee Valley Authority [which produces electricity], the Smithsonian Institution, the Corps of Engineers, and the Nuclear Regulatory Agency.

The amount of money spent in the United States on scientific research is confused by the government funding poured into secret programs to develop better weapons. In fiscal year 1986, the annual spending from all sources on research and development was about $110 billion. About half of this came from federal funds, and about two-thirds of the Federal funds went to weapons research. Science reported in early 1988 in an analysis of recent spending on secret research:

> For the first time in the Reagan years, the share of the federal R&D budget scheduled to go to military programs is set to decline lightly, from 67 to 66 %. The Department of Defense (DOD) is planning to spend $38.7 billion on research, development, testing and evaluation next year, of which $ 906 million -- a mere 2.3% -- is designated as basic research. In fact, DOD's basic research budget is slated to increase by only 1.5%. In addition, the Department of energy (DOE) is planning to spend $2.4 billion on weapons related R&D, about the same as in fiscal year 1988.
>
> Mark Crawford, *Science* 239 (Feb.26, 1988, p.967)

Military R&D spending was roughly half of the total during the

1970s, but shot up to two-thirds of the total during the years that President Reagan controlled the budget of the federal government. Recent discussions by prominent leaders in science policy in the United States have focused on the need for setting priorities in funding projects, since there is not enough federal money available to do all the worthy projects which are being proposed (*Science* 240, May 20, 1988, p.965 and *Scientific American* 259, July, 1988, pp.8-9 and *American Scientist* 76, Nov. - Dec., 1988, pp. 599 - 603). This creates a crisis in values, with the personal success value of the scientists colliding with the Progressive and Collectivist value presumption that truth should be discovered as soon as possible.

As I wrote above, the federal government provides half of the funds spent each year in the United States on scientific research and development. Another third of the total comes from industrial sources: some of this money is consumed internally, at the excellent laboratories at the Bell or General Electric companies, for example, and some is given to universities for research projects of mutual interest. New sources of research funding are the state goverments, which have increased the amount of funds used "to create jobs, to support innovation by small companies, and to facilitate university-industrial collaboration. At least 10 different types of programs have been devised, such as research parks, incubators, and provision of venture capital, but the major activities involve research or industrial extension services. Appropriations are usually leveraged by contributions from industry that match or exceed those from the state." (Phillip Abelson, *Science* 240, April 15, 1988, p.265)

In summary, the research money in the United States comes from the following sources:

Federal Government	50%
Industrial Sources	33%
Other Sources	17%

(State Governments, Foundations, Universities, etc.)

In Japan the table is much simpler: government 20 percent, industry 80 percent. In the United States, about 12.5 percent of R&D expenditures goes into basic research, while in Japan, only 3 percent does (*Science* 237, July 31, 1987, pp.476-478). A detailed criticism of the Japanese funding practices was given by Kiyonori Sakakibara of Hitotsubashi University in a two-part column for *The Japan Times* newspaper published May 14-15, 1988. He criticised Japanese universities for not taking research seriously. He expects the new source of funding for American R&D will be Japanese industry.

The top 100 institutions in total R&D spending for fiscal year 1987 are listed in a table obtained from the National Science Foundation and published by the *Chronicle of Higher Education* on Nov.23, 1988. As usual, John Hopkins University is at the top of the list because its Applied Physics Laboratory, which is actually a pseudo-academic institution doing mostly weapons-related research, received more total funds for R&D than any other American research institution. John Hopkins University falls to about 16th place if the Applied Physics Laboratory is treated as a separate institution. These numbers mix physics, chemistry and engineering research money with medical and biomedical grants. The top 10 total spenders would be:

Massachusetts Institute of Technology	$264 million
University of Wisconsin at Madison	254
Cornell University	245
Stanford University	241
University of Michigan	225
University of Minnesota	222
Texas A&M (Agriculture and Mining) University	220
University of California at Los Angeles	199
University of Illinois: Urbana-Champaign	189
University of Washington	187

The total funding for all institutions for fiscal year 1987 was slightly more than $12 billion, of which the top 100 institutions and the Applied Physics Laboratory accounted for almost $10 billion.

The federal government operates hundreds of government research laboratories. The most famous of these would be the National Institutes of Health. Until recently the patent rights for inventions developed in these government laboratories were retained by the managers of the laboratory for the government. New laws and directives are trying to make it easier for companies to get access by licensing to some of these inventions that may be profitable. Until 1980 the common sense was that since tax money had been used to develop the invention, it should be available to everyone for free. This noble sentiment was fatal for product development because "one thing on which industry is unanimous is that what's available to everyone is worthless" (Alex Zucker, acting director of Oak Ridge National Laboratory: *Science* 240, May 13, 1988, pp.874-876). Oak Ridge has negotiated 27 licensing agreements so far, of which four are making money for private companies and the laboratory and the individual inventor. Examples include a steel which is plastic and a new material, nickel aluminide, which gets harder at higher temperature rather than softer. (*Scientific American* 256, May, 1987, p. 68) 「Future Cooperation in Applied Research between Japan and the United States」

Prime Minister Takeshita and President Reagan signed a new science pact during the summit in Toronto on June 20, 1988. The tensions and criticisms which marked the negotiations to rewrite a 1980 agreement are well described in two *Science* articles written by Marjorie Sun (237 July 31, 1987, pp.476-478 and 239 Jan.1 1988, pp. 13-14). The controversial request of presidential adviser William Graham to force the Japanese government to subsidize new positions for American scientists in Japanese laboratories was included in the agreement. *The Daily Yomiuri* on July 10, 1988, published a report from its Washington bureau that 200 American scientists would come to Japan in the fall of 1988. According to the *Yomiuri* correspondent:

> Through the program, which was organized at the request of Japan, the Science and Technology Agency prepared posts for 50 researchers in national research institutes--20 from the NSF(National Science Foundation), five from the U.S. National Institutes of Health(NIH), 10 selected by other U.S. research organizations and the remaining 15 to be invited directly by the Japanese institutes. The Education Ministry has allotted posts for 50 U.S. researchers in national

> research institutes and universities. The candidates will be selected by the NSF and NIH... According to NSF officials, 75 to 100 American researchers will also be sent to Japan under a $4.8million program set up by the Foreign Ministry.

The Science and Technology Agency will provide orientation and language programs in Tsukuba, where many U.S. researchers will be assigned.

There is mixed evidence concerning the number of American researchers who actually want to come to Japan. Charles Wallace in the National Science Foundation, said in 1987 that he had rejected 40 proposals to do research in Japan which were ranked high priority by another branch of NSF (*Science* 237, p.478). But Hiroshi Inoue, former dean of the Faculty of Engineering at the University of Tokyo and a hero to American scientists because of his efforts to negotiate away legal, attitudinal, and traditional barriers to the employment of foreign scientists in national universities and government laboratories, suggests from his experience that American scientists have little or no interest in coming to Japan for research. He mentions expensive and cramped housing, low stipends, and poor job opportunities for spouses as some non-scientific barriers to such applications. *The Japan Times* editorial on June 28, 1988, which welcomed the signing of the new agreement, pointed out that it would be hard for scientists from American competitors to be welcomed in the industrial laboratories of Japan, where 80 percent of the funded research is carried out. The insufficient Japanese language skills of many researchers will hamper real interactions, though there are quite a few second-generation Japanese in research positions in California universities and laboratories. "There is the perception among some [American researchers] that a period of time in this country [Japan] may not serve to advance their career prospects." I would guess that sentence refers to the limited number of publications that would result from a period of research in Japan.

I have uncovered a contradiction or two in the materials coming from America and commented on by the Japanese. First, this demand for reciprocal access to laboratories has the unspoken assumption that all scientists and engineers are agents of their government or at least agents of the companies where they work. Yet many Japanese scientists such as Professor Tonegawa never go back to Japan after establishing themselves as successful researchers in America, so what difference does it make what passport such a scientist happens to carry ? Many American scientists and engineers are likely to change jobs or positions several times during their research careers and may end up at some point working for a Canadian or British or Dutch multinational research corporation. This appeal to patriotism seems likely to fall on deaf ears in both America and Japan. The second contradiction can be summed up in a question: Why leave the No. 1 county in research to work in the third ranked nation ? A White Paper issued in Japan in December 1988, includes the results of a survey of Japanese researchers. Responding to a questionnaire, these Japanese high-technology researchers ranked the United States ahead of Japan in research in life sciences, materials, information and electronics, oceanography and geology. They ranked Europe ahead of Japan in the first and last category, gave a tie ranking for materials research, and only ranked Japan's research ahead of Europe's in the area of information and electronics. This may just be a reflection of the Japanese way of speaking, where delicious meals are referred to as scraps and beautiful spouses and children are derided as hopeless. But if the rankings are correct, then the Japanese researchers must wonder why any first-string American researchers would want to come to participate in Japan's research activities (*The Asahi Evening News*, Dec. 24, 1988, p. 3).

I am confident that Japanese scientists will make much greater efforts to welcome visiting researchers than the Japanese teachers in junior or senior high school have made to welcome government-sponsored English-language teachers. But visiting and doing research are different activities, and it is doubtful that many American researchers will be able to survive in Tsukuba or any place else unless they learn minimum Japanese language before they start their research.

I am more confident, however, that American industrial production managers will be to learn from the Japanese companies about how to introduce innovations (*Science* 241, Sept. 30, 1988, pp. 1769-1774). I expect that American companies will defend their patents more aggressively, as Andrew Pollack pointed out in a New York Times article picked up by *The Asahi Evening News* (July 9, 1988). For example, "The Inter Corporation is locked in a battle with Japan's NEC Corporation over the copyrightability of microcode used in microprocessors." And I think that Professor Sakakibara is quite prescient in suggesting that American research universities will seek and gain funding relationships with Japanese companies for applied research leading to patents and marketable products (*The Japan Times*, May 14-15, 1988).

The roles of private universities in Japan will probably continue to be minimal in conducting applied research or in welcoming researchers from the United States. They can do a good deal in helping Third World scientists to improve their skills, however, and I am quite proud that Sophia has been chosen by the Japanese Society for the Promotion of Science to conduct exchanges of scientists between the Philippines and Japan.

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