Science, Technology, and Society

By Murakami Yoichiro

Science and Technology

It may not be a subject for discussion at this late date, but looking back at the previous century, hitherto unheard of accomplishments have been made in the fields of science and technology. When we examine this phenomenon closely, it is possible to discern several stages in the process of its development. For example, exactly 100 years ago now in Europe, the birthplace of modern science and technology, there was still minimal exchange between the fields of science and technology. Listing some of the individuals who contributed greatly to the birth of modern industry – Andrew Carnegie, king of the steel industry; Henry Ford, king of the automobile industry; Thomas A. Edison, driving force behind the development of electricity and electric power; Gottlieb Daimler and others – we see that none of them received any higher education, let alone university training. Though university education in Europe by the latter half of the 19th century had at last begun to include science education, and the institutionalization of science, then beginning to take shape, had begun to influence it, it should be noted that the development of modern industry took place almost completely independently of the science education offered at the universities of the time.

Looking at this from the point of view of science, it can be said that an understanding that scientific research should be pure in its motivation – that is, that science researchers should not pursue their work with expectations of profit or benefit but instead only out of curiosity and the desire to solve nature's mysteries – had become an established principle in the field.

This type of thinking had taken shape by the time science had become organized in Europe by the 19th century. Scientists with common interests formed scientific communities. These researchers published their results in the form of technical papers with readership limited to their members; that is, researchers with the same interest shared their ideas only among themselves. The accumulated knowledge noted in these journals was distributed among their membership and used and evaluated exclusively by them. Originally, the only reward for their efforts was what is termed the "eponym." "Eponym" refers to the custom of attaching the discoverer's name to his or her find, as in the "Schrodinger's Wave Equation," the "Heisenberg's Uncertainty Principle," etc. This was a form of acknowledgement from the researcher's peers, the concept behind it being that the valuable discovery of the researcher should be given his/her name. This acknowledgement was in itself a great reward for outstanding research results. It can also be said that the Nobel Prize, a system designed to publicly award research – first awarded in 1901 and firmly established today – was also initially awarded based on this same principle of "peer review."

To summarize, the field of science with its beginnings in the 19th century was centered on the self-contained intellectual activity of the scientific community, where knowledge was produced, accumulated, circulated, used, digested, and evaluated. Or, to put it another way, it can be said that the community had the distinguishing characteristic of not sharing the results of its work with the outside world; that is, it did not have any "clients" outside of its own circles.

The sole exception to this rule was organic chemistry: extensive scientific research in this field was used in the development of artificial fertilizers, dyes, and compounds used in medicines and chemical substances. In other words, transfer of knowledge to clients outside of the scientific community took place relatively early on in the field of organic chemistry than in other fields.

The term "linear model" can be used to describe the situation where scientific research is directly linked with industrial technology, as in the case with organic chemistry; that is, science is "linearly" (directly) applied to uses in industry. With the exception of organic chemistry, the link between science and technology cannot be explained in terms of the "linear model" for the period spanning the 19th and early 20th centuries.

Changes in the Quality of Science

This situation began to gradually change, however, around the time of World War I, and one reason for the change was the fact that the industrial world began to take notice of the potential benefits and uses of scientific research around this time. An example of this was the development in 1935 at Du Pont of the famous man-made fiber, nylon, under the guidance of Wallace Hume Carothers, a scientist who had obtained a university degree and who also had teaching experience at universities. He was hired by Du Pont and given the task of developing fibers, his work resulting in the development of nylon. It was starting from this period that major companies began to set up their inhouse laboratories, hire scientists, and assign them research and development projects.

It goes without saying that another reason for changes with regard to the institutionalization of science can be attributed to modern warfare. Governments had begun to realize the potential of scientific research for use in warfare, and with the advent of

World War II, this tendency became firmly established. Though the level differed depending on the country, every nation that was involved in the war put great efforts into mobilizing scientific research into weapons development, with the work of the United States being the best organized and most thorough. President Roosevelt and Vannevar Bush collaborated to form an organized exploitation of scientific research by government. The "Manhattan Project," for the development of nuclear weapons, was one "successful" (though I hesitate to use the word) result of this collaboration.

The "linear model" type of relationship between science and technology thus solidified considerably over the latter half of the 20th century. Prior to that time, the entire research process was carried out only by and within scientific communities. Results of their research, as mentioned above, were enjoyed, evaluated, and utilized exclusively by these same specialists, and only fellow researchers perused one's research results compiled in the form of theses. Use of results as the basis for further research was also confined to these groups of researchers. The scientific communities of the time were comprised of groups of scientists who carried out their research with such intensity that outsiders must have indeed wondered what on earth was so absorbing. Today, half of the scientific research being carried out still maintains this form.

However, with the development of the "linear model" type of relationship between science and technology, the process of pinpointing interesting research, and evaluating and using the results, is no longer in the hands of specialist researchers, but has been appropriated by people connected with the military, industry, and government.

Scientific research is no longer a self-contained activity. To illustrate, let us take the example of research topics. Under the old system, it was of course researchers themselves that determined their own topics: the subjects researchers found interesting automatically became topics of research.

Photo : Kyodo News

Former Prime Minister Murayama Tomiichi (center) at the Council for Science and Technology in 1995

However, under the current system, research topics are determined by clients outside the scientific community. Researchers are given assignments; that is, they are commissioned to work on specified projects.

Changes have also taken place with regard to the form in which research is carried out. Though under the old system many researchers collaborated to produce results on specific research projects, those collaborating belonged fundamentally to the same field of research. Under the new system's concept of "project research," however, since the assignments are not given by anyone inside of the specialized field, an array of researchers – sometimes including individuals from outside the field of natural science – from various fields are needed to carry out the required research.

Beginning in the latter half of the 20th century, science began to establish organic links with general society in various forms, and was no longer fundamentally self-contained within the scientific community separate from society. It is my opinion that structural changes in science, or changes in the quality of science research, should be analyzed in this context.

Science, Technology, and Society

Dramatic changes in the relationship between science and technology and society began to surface at this time. Previously, scientific research had been perceived by society at large as a type of cultural activity, not all that different from opera or ballet, theater or art, though this may seem now a rather odd comparison. General society took the view that the researchers were devoting themselves to research they found interesting – though people on the outside had no concept of what they were doing – and that this was one example of a human or cultural activity worth maintaining, thereby worthy of some financial assistance. This was the way scientific research was looked upon by the outside world.

The situation is completely different now. At present, this phenomenon is illustrated in phrases used in Japan such as, "scientifically and technically advanced country," or as indicated in the Science and Technology Basic Law – established by the national assembly in 1995 – "science and technology" is an issue determining the fate of the nation, and a political issue concerned with the very fate of Japanese society. For better or worse, we as members of

Photo : AP/WWP

Former U.S. President Bill Clinton, Craig Venter (right), the president of Celera Genomics Corp. and British Prime Minister Tony Blair (on a TV monitor) jointly announce that the International Human Genome Project and Celera Genomics have completed the first rough map of the human genome on June 26, 2000

society are directly affected by scientific research. The system of society where scientific researchers' work – whether or not the researchers themselves are conscious of it – "linearly" affects the lives of the people came into existence at the end of the 20th century.

The effect on our day-to-day lives is clear: for example, biological research, such as on DNA, affects not only treatment for illnesses, but is also having a significant impact on the life insurance system. The decision by the British government in October 2000 to approve release of individuals' genetic information regarding Huntington's disease for use by insurance companies shocked the world. Huntington's disease is a serious illness caused by irregular genes in DNA strands encoded in human chromosomes. There is no cure for the disease, and the prognosis for recovery is not good; an individual carrying the factor for the disease will become ill by the age of approximately 35. The Human Genome Project, a project with the goal of deciphering the entire structure of human DNA, is scheduled to be nearly complete in 2001. Medical examination of genes, which is related to this undertaking, has become extremely accurate. The British government's decision was designed to avoid insurance-related problems: it will prevent individuals who have been advised that they have Huntington's disease from hiding the disease and secretly taking out huge insurance polices, and, on the other hand, will prevent insurance companies from wrongly denying insurance policies to family members (who do not carry the factor) of individuals diagnosed with Huntington's disease. It can be said, meanwhile, that researchers responsible for the analysis of DNA did not, at the outset, necessarily expect that their work would affect society in such ways.

I would like to note here that the situation in the United States is such that, even with the completion of the Human Genome Project, extreme caution will be taken to protect individuals' privacy with regard to public use of individuals' genetic information thus obtained.

This is but a very small example. Even if the research in progress today were to have its starting point under the old-type system, where researchers' motivation was purely to unlock nature's mysteries, the results of their research would still have tremendous effect on the structure of our society and the lives we live: this is the position that science now holds in our society, and is something of which I believe scientists and lay people alike should be fully aware.

View to the New Century

This link between science and technology and its effect on society will only grow stronger in the 21st century. Yet there are still many aspects of our society lagging behind the times, unable to deal with this tendency. To illustrate, let us look at the example of problems in the field of education.

In my opinion, scientific education today still retains the characteristics of the system created under the assumptions of the old-style organization of science. In other words, it is thought that science education from elementary and junior high school to university is geared only toward students with a keen interest in science. I do not believe, however, that teachers are neglecting students without any particular interest in science, as they do attempt to make the material interesting to such students. They indeed make the effort on every scene. The related problem of the current tendency for young people to be "away" from science will not be discussed here.

Substantial efforts by education professionals have been made until now to ensure that students do correctly understand and take an interest in modern science. While such efforts are certainly necessary, I believe that what should be seriously considered now is the question of whether that alone is a sufficient science and natural science education.

Education that provides people with knowledge about the science and technology that inevitably affects their lives, even to those who will have nothing to do with science throughout their lives or who will not be involved in scientific research, will be indispensable in our future world. There is no need to learn about extremely detailed laws of science or chemical compounds, but the type of education which provides for understanding, in essence, of the relationship between scientific research and one's life, and creates the ability in

individuals to make decisions and take action with regard to this relationship, is required.

This is only one side of the issue. Looking at another aspect of the issue, education designed to train people to become scientists must include training to make such individuals aware that the research they may become involved in could very well have a serious impact on their own lives, as members of society, as well as those of the descendants they will never see. The education provided to such individuals must also equip them to ponder this issue, make appropriate decisions and take proper action. The current reorganization of education in Japanese universities is merely serving to minimize science education given for humanities majors, and humanities and social education given for science majors, a phenomenon which goes completely against the times. Now, as we stand at the beginning of the 21st century, we are faced with the challenge of setting the goal to implement this new type of education, including elementary and secondary education.

Considering the Issue in an International Context

The emergence of science and technology as a leading national strategic issue, comparable to diplomacy, defense, education, medicine, and social welfare, has resulted in several new developments on the international scene.

Firstly, research and development has become an indispensable building block for national competitiveness. The process of deciding which areas of research are to receive what degree of priority, and of ascertaining which areas require competition with other countries, is now of the utmost national strategic importance. In contrast to the system under which science was previously organized, where nationality and national borders were irrelevant, modern scientific research and development is now carried out with regard to what benefits it will bring to the country concerned.

The concept of international cooperation in science is also in flux. Research communities were originally unconcerned with nationality, and many specialist associations did not take the nationality of their members into consideration. There was no need to emphasize the concept of "international cooperation"; indeed there was no meaning to the term.

However, from the present time onwards, international cooperation influenced by the various central governments behind it will be on the rise, and with this type of cooperation, there is always an undercurrent of competition among countries, and national pride hangs in the balance. Also, there is a great deal of sensitivity concerning the sort of social and national benefits to be obtained. In contrast to the old-style cooperation system of scientific research, where it was carried out in placidity, priority is now placed on efficiency and producing concrete results. A research process carried out in a manner similar to that of business management is now becoming the norm. It is not my intention to say here, however, that these new circumstances are entirely negative.

Photo : Kudan Junior High School in Chiyoda City

Educational reforms are needed in order to deal with the current tendency for young people to lack interest in science

Science as a Peaceful Intellectual Activity

In conclusion, I would like to convey the following message regarding the future of research and development. The purpose of research and development is, of course, to be of service to society and the nation, but science as a peaceful intellectual activity should also be treated with respect. The bliss experienced by facing the natural world with devotion and quietly opening the doors to its mysteries is worthy of preservation. At the same time, it is my hope that scientists remain constantly alert as to whether the mysteries of nature they solve pose risks to the welfare of all mankind (as was the case where nuclear research led to the development of weapons of mass destruction), and that they will also have the courage to return to nature any such secrets of potential destruction they may unlock. Perhaps it is time for us to consider the following words of Goethe once again.

Das schönste Glück des denkenden Menschen ist, das Erforschliche erforscht zu haben und das Unerforschtliche ruhig zu verehren.

(For the thinkers of the world, the ultimate bliss is understanding as completely as possible that which can be understood, standing in quiet reverence before that which cannot.) JJTI

Murakami Yoichiro is a Professor at International Christian University and a Professor Emeritus at the University of Tokyo. He specializes in Science/Technology Studies and the History of Science and Technology. He is also a member of the Pontifical Academy of Social Sciences.