What Makes "Science" Science?

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1. Prologue

To begin with, read the following, although it is a bit long.

"First of all, a clear distinction should be made between science and technology. This is a very important distinction which so many people are not making, including many of our politicians, and it is at the basis of much misunderstanding between scientists and the public.

As far as science is concerned there is, in my opinion, no way in which we can concentrate more money and more scientists for long-term benefits to the nation and to mankind. The reason is that nobody ----not even scientists----can predict what discoveries in science will be made in the next 10 or 50 years, nor can they predict what the importance of these discoveries will be for benefits to the nation and to mankind. The important point is that we should give our scientists---- and I don't mean technologists ---- the freedom to tackle what they consider to be significant problems, and we may have a chance to reap benefits in economic terms from their work. If we don't give them freedom, then no new discoveries will be made and no resultant long-term benefits will accrue."

This message sounds quite contemporary. But this is an excerpt from an interview with Dr. Herzberg at the occasion that he was awarded the Nobel prize which appeared in, I guess, "Weekend Magazine" of Globe and Mail, a Toronto newspaper on June 10, 1972[1]. Conflict between bureaucrats (and politicians) and scientists is not new, and that is a conflict between the people who place more value to maintain or perfect the current system and the people who like to break the current situation to create something completely new. Herzberg was a staunch fighter against bureaucracy.

2. Act 1

1420405751.786 Hz. This is the transition frequency of the 21-cm line of H (hydrogen atom). This is the transition between the F=1 and F=0 hyperfine levels of the ground 1s state. It is an extremely important astronomical probe into physical conditions of the Universe. It was N. F. Ramsey that determined the frequency very accurately by devising a hydrogen maser. This has been one of most accurately measured physical quantities that human beings have ever achieved, together with a more recent measurement of the Rydberg constant by Hänsch. For this remarkable achievement, Ramsey was awarded the 1989 Nobel Physics Prize. This maser line is now serving as a frequency standard and we are benefited from this everyday as the frequency standard of GPS.

There is an interesting table which lists the historical development of measurements of the Rydberg constant in a book "Hydrogen: The Essential Element" (Harvard University Press) written by Rigden[2]. The first determination of the constant was made by Rydberg as the name suggests and we all know. It was in 1890 that Rydberg determined the value to be 109675 cm^{-1}. A most recent measurement listed in the table was done by Hänsch and coworkers and the value is 109737.31568639(91) cm^{-1}. This measurement is awesome. He was awarded the Nobel Physics Prize 2005 for "the development of laser-based precision spectroscopy". This kind of extremely accurate measurements is only made possible by "fanatic" persistent pursuit of innovation of experimental technique developed over years by John Hall and others, and naturally Hall was also awarded the Prize together with Hänsch. This is completely my own speculation, but I cannot keep this thought within my mind. If Ken Evenson had been alive, he might have been awarded the Prize either. He pursued higher and higher accuracy for measurements of the speed of light, and eventually led to the international agreement of defining the speed of light. He played a central role in that movement. We all knew that he really liked to work in the laboratory for himself. Such fanatic pursuit of accuracy and development of instrumentations and methodology which make such extreme accuracy possible are not quite appreciated in this country. This kind of fanatic research is the essence of natural science to unravel the mystery of Nature. The fact that it is not regarded highly is indicative of ignorance of general public and in particular some influential science policy-makers about what natural science is.

Tycho Brahe (1546.12.14-1601.10.24) was born in Denmark[3]. He was said to be an astronomer, but his occupation was rather heavily involved in astrology. He was not satisfied with the accuracy of the measurements prevailed at that time. Astrologers at the time lived on inaccurate shoddy data. (It does not really matter, does it?) He was determined by any means to

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attain the highest accuracy conceivable without telescope (!!). Every night (weather permitted) he went up to his observatory and recorded the positions of stars and planets with astonishing accuracy. (Remember, in Japan the battle of Sekigahara took place in 1600.) Analysis of vast amount of data accumulated over 16 years was assigned to his followers. In particular, data on Mars was given to Johannes Kepler (1571.12.27-1630.11.15). He meticulously analyzed the data and determined the orbit of Mars, then that of Earth. The results were striking. For long time, the orbits of the planets had been believed *a priori* to be a perfect circle. He discovered that the orbit was not a perfect circle but an ellipse. In classes, I usually write a much flattened ellipse on board to represent the orbit of Earth. In fact if we draw the earth's orbit on the floor with 1m radius, the difference between the major axis and the minor axis is only 140-μm. It cannot be perceived (by ordinary people) as an ellipse. High precision of Tycho Brahe observation enabled Kepler to conclude the orbits of planets are ellipse not perfect circle.

Joseph Fraunhofer (1787.3.6-1826.6.7) was born to a glass craftsman in Bavaria. Often he is cited as a German physicist, but he was more a glass craftsman himself. He wanted to check the quality of his glass prism by dispersing the Solar light. Then he found dark lines in the spectrum which now we call "Fraunhofer lines". He recorded 576 such lines in the entire visible region. It was in 1814. It was an era of Napoleon in Europe. Beethoven was at his prime of composing, and Berlioz was eleven years old. Imagine there were no spectrometers with electric or electronic recording devices or photographic plates. So he must have recorded all the spectral lines by hands. His beautiful spectra did not mean much at all to his contemporaries including himself at that time. There was no way to understand them. It was almost a century too early for the Fraunhofer lines to be fully understood by means of quantum mechanics. In between, works by such giants as Kirchhoff and Bunsen, Ångstrom, Balmer, and Bohr, made tremendous progress before reaching Heisenberg and Schrödinger. We scientists all understand that even works by those giants must have been benefited from many other steps made by investigators like us (sorry for people who do not belong to "us".) whose names were not usually surfaced. That is the nature of science.

When we look back history, it seems at first glance that everything has come out naturally or very orderly fashion. However, Tycho Brahe had never carried out his persistent observation day and night by anticipating future progress in which Kepler discovered now we call Kepler's three fundamental laws, which together with Galileo-Galilei led to Newton. Fraunhofer could predict in no way that his work later was regarded as the beginning of astrophysics and spectroscopy, which eventually led to discovery of quantum mechanics. Life is similar. No one can predict his/her fate even for immediate future.

3. Act 2

Of course there are research areas which aim at improving or inventing useful devices based on already known principles. Such research is no doubt important and its significance is relatively easily recognized. Such area of research is technology or engineering. It would be easier to assess importance of such applied research and to decide which should be funded how much. However, the ultimate objectives of natural science are to unravel fundamental principles or mechanism that Nature presents to us, and to accumulate or establish knowledge which can be shared by all humankind. Such basic science intrinsically has characteristics of unpredictability and no one can tell if it leads to some useful consequences or useful devices. It would be a great tragedy, if public were not quite educated about how science or our civilization had been developed. Majority of people may have a notion that scientific discoveries were made by geniuses who could foresee the consequence, could plan ahead, and pursued exactly what they wanted to do. This is a largely wrong notion. That is why science education is important. Development of science is unpredictable, similar to our own life. We have to become a story teller on how science evolved. The law of gravity was not discovered suddenly by Newton by looking at a falling apple.

We have to establish the notion that science is a culture, like music, opera, and literature. The utmost mandate of universities is to produce torch bearers to pursue such science as a culture. Forcing natural science to be short term mission oriented research is not fit to basic science. Unfortunately, policy-makers, politicians, bureaucrats often are preoccupied by completely wrong notion that science should be directed by making detailed planning. Of course every scientist actually has ideas and plans to pursue. However, we all know and have experienced that the plan is often not realized as it was planned. If everything went well exactly as planned, what a boring thing it would be! Research should not be evaluated by looking at how many of the initial objectives have been achieved. This kind of evaluation criteria is the one that bureaucrats or bureaucratic scientists would like. If this kind of evaluation prevails, it eventually ruins not only basic science but also applied science which has its base on basic research. Rather it should be evaluated depending on if interesting unexpected

results have been obtained, even though they were not mentioned at all at the initial plan. This is the way science evolves. Research fund should be granted basically to individuals not group of people. Once decided who should be funded, give them complete freedom. Behind recent project oriented science policy, there haunts phantom of bureaucratic scientists. We should keep it in mind that evaluation criteria are naturally different for basic science and for applied science or engineering which could have clear objectives. In basic science it is less important whether it achieved the initial goal as it planned, but it is more important if it yielded very interesting and exciting results.

4. Act 3

Is the Japanese situation peculiar to this country? Not particularly, but definitely something very unique feature is lying deep underneath our culture. I have no way to describe it clearly. However, even with my very limited experience, I can say that a great deal of the problems which are peculiar to this country originates from the notion of education which deeply rooted in culture. At the center of this country's education there is the entrance examination system. Entrance examinations are pain in the neck for majority of people. Extremely few people have ever thought abolishing the current examination system completely. There is at least one country which does not have entrance examinations at all, so far as I am aware. That is Canada. There may be other such countries or states or regions, but I have not done enough home work to list them all.

In Ontario a central office handles all the applications to all universities in Ontario. Applicants usually indicate his/her 1st, 2nd, and 3rd choices in the application. The university which is listed up in the application as either one of the three choices is all notified with all the relevant information, which includes the grade average mostly in the last one or two years of the high school with grades on individual subjects together with special comments on extra curricula activities or specific merits of the applicant. Selection process is done by Dean's office, in case of Waterloo. This is a kind of many body processes. Applicants wait for offer(s) from either one of the three choices. Universities try to entice best students available by examining the data sent from high schools. Often even though the student lists University A as a third choice, if the Dean's office thinks he/she is an excellent student not to be missed, then try to steal him/her by enticing him/her by offering good scholarship or something attractive offer. It would be natural that grade average fluctuates from one high school to another, but universities have accumulated calibration factors. So differences in academic levels among high schools have been rarely an issue.

The current Japanese situation is highly alarming. One time I thought grade average or recommendations from high school should be weighted more. Then colleagues of mine at the time alarmed me that such data from high schools were not reliable, often modified to look better. It was really astonishing to hear such comments openly. Then I realized such things were already in public domain. Even a newspaper[4] reported that students admitted through high school recommendations and interviews by universities are behind in "academic level" compared with students who were admitted through the entrance examination. Whatever this "academic level" means, it appears that high schools usually try to send students through a channel of admission by recommendations who were not quite up to certain level for the competition to universities. So, according to the newspaper article[4], several cram schools such as Kawai-juku now offer classes for such students to make up their academic levels before entering universities. The classes are said to be held on behalf of universities in between the graduation from high schools and the entrance to universities. For several weeks???!!! Don't university professors and high school teachers get angry about this? No one seems to be thinking deep enough and critically. This kind of situation together with various "irregularities" that surface from time to time is a vindication of total failure of the current education system in which the entrance examination occupies a gargantuan post. If the mark-ups or alteration of grades in high schools were a general practice, they would be a perjury, a serious criminal offence.

In short, the current examination system in Japan distorts the entire education. Some people genuinely believe that, because of this "strict" examination, the Japanese students excel in many areas in particular in science and mathematics. On the other hand, many people think that now the education in Japan is not working, so the level of proficiency of students is rapidly declining. But this kind of comments has been always around us. Our generation was also to blame for declining level of performance at the time. My limited experience tells me that Japanese students are in general not a deep thinker, rather a superficial congenial thinker. It is understandable, because deep skeptical thinkers may not succeed in the current system. Education in the current form might have worked well to regenerate workers who could perform well in carrying out what was told to do. (Nowadays some signs of failure of such routine tasks may be becoming noticeable). My short conclusion is that abolishing the current examination system is urgent. The sooner, the better. The Canadian system can

be a model.

5. Act 4

The nature of the position *JOSHU* is now in the majority of universities reviewed and has been altered. *JOSHU* appears to be mostly called *JOKYO* (What an odd naming!). And the English translation of *JOKYO* is, I am told, assistant professor. Fine, finally. But looking into the situation a little deeper, then I realize that this may not be quite equivalent to an assistant professor of US or Canadian universities. I can speculate why they use such an odd naming as *JOKYO* rather than *JOKYOJU*. They (who?) do not like to treat *JOKYO* entirely like a professor, but like them merely to give courses. So in a way that its English translation is assistant professor is mean and sneaky. I wish my speculation be wrong, but I cannot help mentioning this. Probably *JOKYO* in majority of universities is not quite independent faculty member who operates an independent research group.

It is long overdue to make a drastic change in the system. *JOKYO* and other junior faculty members would not speak out. Speaking out under the current situation is very likely a suicidal act. That they are silent does not mean that they are content. It is exactly why established senior faculty members should take drastic action, not this lukewarm ambiguous changing naming *JOSHU* to *JOKYO*. Why not simplify the system. Professor, associate professor and assistant professor (and may be lecturer) are equal in the sense that they all equally operate their own research group, and all should enjoy equal opportunity for applying for research grants. This kind of revision of the system should be initiated by established senior members.

Established senior professors used to be a junior faculty or alike and must have felt a kind of aspiration at some stage of their career at early stage in pursuing research activities on their own. Senior establishments should make all efforts at any cost not to regenerate and impose similar frustration that they experienced to young generation. Quite a few research scientists have experiences to have spent some extended period of time in outside the country, mostly in US, Canada, or European countries. Majority of them must have felt a great sense of liberation in outside the country. The most compelling difference is the way to treat young scientists.

Certainly the system has been changing constantly, but the change has been too little too slow, and often incoherent.

6. Epilogue

In various aspects of daily life, we are exposed to all sorts of micromanagements. Micromanagements often act as a hindrance in promoting individual's free creative activities. The line of commands in Japan is arranged vertically, so we usually encounter many middle managements between us and those higher up. The middle managements do little in decision making and simply pass on the issue to one step higher. This is largely the source of frustration and inefficiency. As a result, routine procedures which yet have no precedents are difficult to deal with.

The university administration system is by no means an exception. It is embedded in the “Kasumigaseki”. Each country has its own red tapes, but at least my experience tells me that administration here in Canada is more transparent about which administrator deals with what and what authority he/she has. So, when we encounter some dispute, it is much easier and more straightforward to solve the problem and it is much faster.

Whatever the reason, then-National universities are now transformed to an independent (from the Ministry?!) organization. However, upon the transformation, as far as I am aware and I witnessed, not a small number of universities took a careful measure to minimize the change by adopting how they were doing and what they were. Surely the current administration system has not been conceived with simple and efficient supporting system for faculties in education and research in mind. Under powerful and innovative leadership, it would be possible to implement a drastically different administrative system. If it works and democracy can be trusted, almost all the faculty meetings and committees would be unnecessary. In the current system, it appears that the leaders, presidents, deans, and department chairs, are largely directionless, sitting at the center of mass which is undergoing Brownian motion. Everyone knows this system is the real hindrance in doing education and research in many respects. Yet in the past many decades no significant improvements have been realized.

It is really neither a purpose of this short article nor within my capacity to discuss more about how to revise or improve the university administration in some length. However, at least I would like to say here that a system should be created, in which professors do not have to treat junior faculties, postdocs, and graduate students in daily operation of the group as if they were secretaries or technicians, in which senior professors can concentrate themselves on their own education and research without worrying about the administrative burdens which are under current system mostly unnecessary and seem to be complete waste of time. So, when a more reasonable system were to be implemented, we would never hear again such an outrageous comment as “Professors usually do not know the

details of research done by their young staff members. Professors are in charge of larger scale planning of the research. So it is not surprising to hear that the professor did not know what his assistant (*JOSHU*) was actually doing"[5].

I thank Carol Huber for making newspaper and magazine clips about Herzberg available to me. Conversations with my colleagues, in particular, with R. L. LeRoy are greatly appreciated.

References

(1) *Globe and Mail*, June 10, 1972.

(2) Rigden, J. S. *Hydrogen. The Essential Element*; Harvard University Press: New York, 2003.

(3) Historical development and physical insight are presented in a book by Tomonaga, S. *What is Physics?*; Iwanami Shoten: Tokyo, 1979.

(4) Nihon Keizai Shinbun, February 8, 2007.

(5) *Close-up GENDAI*; NHK, January 10, 2007. The program was transmitted in Japanese. Therefore this English translation is by no means an official transcript, and I am solely responsible to this translated content.

(Accepted: April 10, 2007)

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