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INTRODUCTION

The last twenty five years have witnessed enormous advances in scientific understanding and technological application in biological, physical and geophysical sciences. We are now on the brink of the most revolutionary technical challenges, in a world that also is undergoing rapid change in its political and economic structures. As never before, we need wide understanding of the interrelated impacts of these changes - by the general public, by political policy-makers, and by scientific specialists.

The public is bombarded by daily headlines of catastrophe and risk, and these simplifications are a dubious basis for optimized policies. Education along many lines is needed.

The political establishment is generally poorly organized to receive the most objective and competent scientific advice. Senior officials have neither the background nor the time to learn all of the technical complexity; but they surely can know the main elements of technical choices.

The scientific establishment is preoccupied with the intellectual excitements of discovery and invention, and with the accomplishment of narrowly defined technical tasks. That specialization makes it difficult, and often unrewarding, for the scientist to play a useful role in important matters of public policy. It is challenging for an individual scientist to have comprehensive and decisive knowledge on a key policy choice. It is even more difficult to have the detachment, the ability to separate one's personal ethical and political biases from the presentation of the policy choices that remain open for decision by legitimate authority. Finally, many of these dilemmas are very painful ones -- where any choice entails risk or hurt -- and in the very process of being objective, the scientist faces the risk of being blamed for invoking the pain of decision!

Having indulged in discussions of such problems for 25 years in the U.S.A., it is with some trepidation that I enter them here in Japan. Yours is a country that I deeply admire; but having visited you just once before (22 years ago!) I cannot pretend to close knowledge of your own national dilemmas, of your value systems, or your methods of decision-making on matters of science in policy. While most of my comments concern what I believe to be essentially universal issues, I may be insensitive to some of their applications in a Japanese context, and it is as a humble student -- in hopes you will show me where I may have strayed -- that I continue this discussion. I look forward during my present visit to learning much more of what is distinctively Japanese in your approach to these problems of science policy. With your extraordinary success in global technological competition, there is no doubt there is much we can learn from your approaches to problems we all share. The peoples of our countries are friends, and our governments are close allies; so I also look forward to contributing to the traditions of Japan-U.S. cooperation.

Much of my discussion will concern trends in the applications to public health of new biological science. While human biology is a universal, the vital statistics are unique to each country. My experience is limited to the U.S., and so I ask your patience if I draw conclusions from the U.S. experience that differ from your own at this time. In addition to the revolution in the biological sciences, I will have brief remarks about the trends in computers-communications and in the exploration of space.

THE BIOLOGICAL REVOLUTION

The modern biological revolution refers to the unmasking of the role of DNA as the biological code, and then to the development of DNA-splicing that produces a biotechnology as means of exploiting the scientific knowledge. There are many implications:

- (a) Practical means of manufacture of myriad new substances important in the diagnosis and treatment of disease; for example:
- * human insulin, interferon, lymphokines, plasminogen activator (thrombus-lysing enzyme)
 - * diagnostic probes for prenatal diagnosis of genetic disease (sickle hemoglobin; thalassemia Huntington's chorea, cystic fibrosis...)
 - * rapid diagnostic probes for infectious agents STD's; AIDS virus; other viruses and bacteria

New means for preparing vaccines for immunization against virus infections and parasitic diseases; but there are potential problems with vaccines for malaria (trypanosomes..)

- (c) Direct intervention in genetic composition of crop animals is on its way (mouse-rat 'gene-hybrids'); but this is unlikely to be reliable or desirable in the human.

There has been an enormous amount of discussion about the ethical problems raised by technical innovations like in vitro fertilization. It is bizarre, however, that far more publicity attends the fate of one frozen embryo than to the death of 5 MILLION children per year from diseases preventable by vaccination. Where does the true responsibility in the ethics of science lie?

- (d) New crops should increase productivity of agriculture; open up previously barren lands; many specialty crops.

- (e) Design of artificial organs, and mitigating barriers to

organ transplantation.

- (f) Deeper understanding of mechanisms of cancer, heart disease and other disturbances of human physiology. (Uses of DNA probes). More rational assessment of the health hazards of new (and old) environmental chemical and physical agents.
- (g) Biochemical dissection of the brain: discover the diversity of cell types, their connections, their disturbances in neurological and psychiatric disease; genetic variation among individuals.
- (h) The problem of embryonic development remains as the deepest challenge to biological science.

But these remarkable opportunities pose problems for us as we deal with the consequences of success. Such problems include:

- * prolongation of life span; health costs of maintaining older population. Ethical dilemmas when the termination of life becomes a medical technical option
- * increased efficiency of agriculture in more advanced countries may worsen competitive problems of developing countries. Decrease in natural variability of crops makes them more vulnerable to plant disease outbreaks.
- * human population will be denser and there is rapid global transport: so we also may still be vulnerable to viral or microbial pandemics. AIDS is a warning example of new disease, but one (happily) not so readily transmitted. Many species have been exterminated by disease; using new tools we have a chance to stay in race against natural evolution of new infectious agents.

THE COMPUTER - COMMUNICATIONS REVOLUTION

Here I offer briefer comment on the informational unification of the world with advances in computers, communications, and transportation. These technologies do leave important productive tasks for human intelligence. The issues include:

- (a) Artificial intelligence:
 - makes orphans of its successes
 - rapid advances in expert systems: but continuity with previous work. Valuable new programming tools,

- great difficulty in 'common-sense' systems: limitations of lack of direct world experience, and tacit learning, on part of computers.
 - learning systems have hardly moved in 20 years: need enormous enhancement of computer power just for experimentation.
 - highly parallel systems, with thousands or millions of processors, needed to mimic the human brain
- (b) Need intercommunication of knowledge bases, ability to read and assimilate world libraries.
- (c) Computer based communication systems:
- At least people should be given more timely access to one another with electronic mail, and file access. Prototype of intelligent computers interacting.
 - Intrinsic problem of telephone (simultaneous availability) accentuated by time-zone difference, but fundamental even for colleagues at one location.
 - Obstacles purely political: should be cleared away soon for science to facilitate equal participation on global basis, including LDC's.
- (d) Hazards of computerized world with great system complexity:
- Complexities transcending human judgment
 - Vulnerability to fraud and sabotage
 - Most important function of expert systems to assure computer program reliability and accountability.
- (As compilers allow efficient production of programs)
 (Decompilers to assure those programs are transparently subordinate to functional aims)

THE SPACE REVOLUTION

In opening the circum-terrestrial, lunar and planetary estates, our space programs have posed many choices for science in public policies. Even a casual tour of this subject must recognize themes such as:

- (a) What space is good for: its geography
- Perspective on earth.
 - Meteorology, communications, peace-enhancing intelligence all enormously useful.
 - The celestial bodies
 - Moon, planets -- only beginning of exploration planetary evolution bears on earth's history
Moon - sterile; Mars - ???

(b) Nevertheless, public involvement in visible human activity has led to a great emphasis on sending people (astronauts) rather than scientific instrumentation into space missions. Relevant considerations include:

- inherently stressful
- more costly life-support
- imperatives of returning to earth
- add some flexibility of repair, improvisation
- enormous expense
- robots, teleinstrumentation not quite up to task as yet; but for comparable investment, these will offer increasing competition, certainly for extended planetary missions.

CONCLUDING REMARKS

All three of these domains of science and technology have grave military applications. If pursued in secret, the work can enhance insecurity and tension in world. So we need to maximize openness of communication and provide reassurance that fundamental aims are shared by all nations in the pursuit of science.

The roles of basic science are crucial. In U.S., many businessmen have had a tendency to follow an exploitation model: that the whole value of science is in feeding technology. By that logic, it doesn't matter who does the science, for the results will be common knowledge and readily exploited by those who then develop products and market them. That may be true in short run. But that model totally disregards the function of scientific research in the education, not only of the scientists, but the engineers and the practical men and women who may be the scientists' students.

In the U.S., mature industries have created no new jobs (net) in the past decade. Small new businesses have accounted for the larger part of our economic growth; and there is a close association between the mentality of basic research and of the aggressive entrepreneurship that has sustained the economic viability of the U.S.

I suppose that such issues are among the fundamental questions in science and economic policy facing Japan today. Your country will be congratulated if it enhances the balanced view that combines its recent extraordinary practical success with the forward look of the most basic sciences. As this has been the mission of my own institution, we will follow your continued progress with the greatest-of expectations, and with the earnest desire to participate with you in building an ever more robust and interconnected world science.

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