CHAPTER 3

Scientific Advances and the ever more Complex Challenges facing Society

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INTRODUCTION

Every year in December, the editors of *Science* select the ten most important discoveries of the year. Genomics led the year 2000 ranking, probably not a great surprise to most of us. That year, several milestones had been achieved in deciphering genomes from drosophila to plants and, finally, to man.

Number two in the ranking was the elucidation of the structure of ribosomes, as well as the confirmation of a hypothesis of the catalysis of the polymerisation of amino acids by RNA and not by proteins. Furthermore, the discovery of two well conserved cranes from south of Trifles were ranked, because they permit to conclude that our ancestors left Africa for Eurasia some 1.7 million years ago. Remarkable progress was achieved with stem cells, a very important domain of cell biology with a great theoretical as well as medical potential. Also of interest was the announcement of cloned piglets. In this connection, it was shown that cloning methods can be useful to avoid the extinction of endangered species.

A final biological discovery concerned nuclear receptors. These elements play an important role in the regulation of the functions of genes. From a medical point of view, nuclear receptors are instrumental for the understanding of diseases of the cardiovascular system, as well as of cancer and of the side effects of drugs.

Besides the winner in the field of biology, important discoveries in quantum physics, organic semiconductors and supraconducting polymers with exciting properties were distinguished. Last but not least, research on planets showed, among other aspects, that our neighbouring planets might well hide some water reserves and that some four billion years ago, water could have been present on planet Mars in the form of lakes. Research in astronomy as well as in cosmology led to new insights.

This short description of the ranking list illustrates the dominance in interest in biology or life sciences over other scientific disciplines and shows growing interest in the physical sciences, in particular solid state physics and quantum physics, as well as astrophysics and cosmology. In conclusion, all the selected discoveries belong to knowledge-oriented, long term basic science. Several discoveries have an obvious potential for application. The selection made by the *Science* editors underlined not only one of the strong points of the past century, but pointed to the new century in which life sciences and information technologies might continue and even reinforce an important megatrend. As a matter of fact, this megatrend continued in the year 2001 at more or less the same pace (*Science*, 2001a).

Science is a key element of modern human societies. As it consumes considerable amounts of public money, it is influenced by science policy and political bodies. President Bush's first research budget was set to favour life sciences, with all its unforeseeable consequences for other scientific disciplines. The tragic events of September 11, 2001, however, had a deep impact on his second budget.

The European Union (EU), on its side, is making strong efforts to restructure the highly fragmented European scientific community. In addition, priority areas were identified and agreed for the sixth Research and Development Framework Program: Information technology, Genomics and biotechnology, Sustainable development and global change, Nanotechnology, Intelligent materials and new production processes, Aeronautics and space, Food safety (*Science*, 2001b). Whereas the EU programme is probably less focused on life sciences than US research, there is a major difference in funding. The EU nations invest 1.8 % of their Gross Domestic Produce in R and D, a very modest figure in comparison with the United States' 2.7 %, or Japan's 3.1 %.

Nevertheless, there are common traits between these nations or groups of nations belonging to the science- and technology-driven industrialised world. Since World War II, science and technology have been dominating the tertiary sector, whereas humanities, social sciences, or even economic sciences have been playing a minor role.

To conclude this introduction, let me pose a question. Since the time of Francis Bacon, human beings have had the idea that technical progress will provide happiness through unlimited mobility, freedom through unlimited communication, and the prolongation of life. The latter has been achieved in the course of the last centuries. But are we happier than before and do we have less problems?

SCIENCE AND TECHNOLOGY — MAJOR DRIVING FORCES OF MODERN CIVILISATIONS

The world we live in today is defined as post-modernist, or in a more simplistic way, as a '*Knowledge Society*' or '*Risk Society*' (Nowotny, Scott & Gibbons, 2001).

On the macro level, the following characteristic traits are worth mentioning:

- Profound changes in the world of labour
- Dematerialization of products
- Quantitative and qualitative enhancement of service activities
- Application as important as knowledge production and, as a consequence, an enormous increase in the speed of innovation
- The sources of scientific and technological knowledge are completely reshaped by processes of internalisation and globalisation.
- Changes in production systems, increased flexibility (just in time), lean organisations
- Increasing importance of information technologies (IT)
- Primacy of the economy, in other words, the market dominates the meaning of life.
- Innovation addiction and risk aversion characterise our hedonistic and pluralistic world.
- Despite a continuous oscillation between public hysteria towards risks, fear of science and certain technologies, indifference and attempts to reform, there is no serious awareness or will in politics and governments to counteract quantitative growth with its foreseeable negative impact on a sustainable development of our world. President Bush's decision to renege on his pre-election promise to regulate emissions of carbon dioxide is a saddening warning as to the low importance given to environmental and sustainability issues (*Nature*, 2001).
- Last but not least, the idea that knowledge is dangerous is deeply embedded in our society.

On the micro level of science and technology, several trends have appeared during the last fifty years or so. Science has moved increasingly from a knowledge-driven to a utility-driven system. As a consequence, the diversity of the scientific system has been reduced. This might lead to budgets becoming out of balance, as is seemingly the case with the US administration's science budget, which favours to a great extent life sciences at the expense of other disciplines. Or, far-reaching specialisation of a university may have a negative impact on its potential for future and as yet unknown developments.

During the past years, scientific organisations were accused of being resistant to change and of inefficient management, as well as of being reluctant to collaborate with industry. These criticisms are partially justified and they have to be taken seriously. The same is true for the ivory tower attitude. It is obvious today that a scientific institution is no longer external to society. As a matter of fact, it is part of it. The time is over when the communication between science and society was unilateral. Today, society asks questions to science, with an ever-increasing intensity. Indeed, nothing is more needed for science than to win public confidence.

To conclude this discussion of the present situation, let us consider briefly a problem internal to science: the relation among disciplines. Whereas the scientific and technological world have long learned out of necessity to communicate with each other, the situation is very different concerning communication between science, technology on the one hand, and humanities and social sciences on the other. As mentioned earlier, science and technology have shaped the modern world. Their creative power is such that strategies for exploring implications have to be developed. In other words, to solve a practical problem or to acquire knowledge with far-reaching and often unknown consequences once applied, demands dialogue with people who have explored different ways of thinking and focused on questions of concept, methodological theory, epistemology, ethics and social impact. In view of the ever-increasing complexity and unpredictability of science- and technology-driven societies, the humanities must become partners of science and technology, in order to contribute to ethical norm-setting, as well as to pre- and post-action reflection on possible repercussions.

SCIENCE AND TECHNOLOGY FOR THE FUTURE

It is Frank H. T. Rhodes (2000) who wrote: *Universities are communities of enquiry, discovery and learning, created and supported by society, with the conviction that the growth and diffusion of knowledge not only enrich personal experience, but also serve the public good and advance human well-being.* This statement reflects in a pertinent way the goals and characteristics of the modern university. It is quite different from Wilhelm von Humboldt's vision of the university, which is centred on the idea of the formation of individuality as the final goal of the universe (Rebe, 1995).

Without any doubt, in modern universities, science and technology play a dominant role. Real science, in the broad sense of the definition, will always produce ideas about how the world works. On the other hand, ideas in technology will result in usable objects. Nevertheless, technology is more and more science-driven and the relationship between science and technology becomes closer and closer and less hierarchical. What will the future pillars of the science and technology systems look like?

Basic or Knowledge-oriented science

Basic or knowledge-oriented science will still play a major role. It is part of our cultural inheritance. It cannot be planned and yet it is an important part of our value system. Notwithstanding its unpredictable nature and very loose goal orientation, this kind of science has to accept adequate criteria of productivity via appropriate quality assessment systems. Probably there will be a natural tendency to do research at the interfaces between the disciplines, with the consequence that in-depth knowledge will have to be combined with a horizontal language that allows communication with neighbouring disciplines.

In future systems, basic science will interact much more with the humanities, as well as with the social sciences. A good illustration is given by the neurosciences. In this field, in particular in brain research, very basic questions such as free will and personal responsibility will be discussed between philosophers and neurobiologists.

Finally, the contextualisation of knowledge production will become important (Nowotny, Scott & Gibbons, 2001).

Problem-oriented or applied sciences

If openness is already important in basic sciences, it becomes even more important and more complex in applied sciences, which by definition lay the ground for technological solutions to practical problems. Strategies for the exploration of implications will be of paramount importance. Interaction between scientists of various disciplines and belonging to the "two cultures" must thus become much more intensive than in the past.

New systems of participation and involvement—even from the public—will have to be considered. This part of the scientific enterprise depends heavily on public confidence. In view of the development and socio-economic and ecological state of our world, there is an urgent need to develop criteria and conditions in order to foster a sustainable development. In other words, universities of the future will have to go beyond their traditional tasks and participate in addition in the search for solutions to major problems of human societies. After all, humans are the world's greatest evolutionary force and it is part of our responsibility and accountability as scientists to contribute to the understanding of the consequences of our actions on future developments.

As Nowotny *et al.* (2001) mention, knowledge societies will have to become learning organisations in order to develop their human and intellectual capital. Universities will play a major role, provided that they are adaptable organisations and comprehensive institutions rather than highly specialised niche players. If we accept the opening of the university internally as well as externally by re-thinking the culture of communication and creating a new relationship with our partners from industry and society as a whole, we may create the prerequisites for a socially credible institution, able to alleviate people from the belief that knowledge is fundamentally dangerous.

Science is not only an activity leading to knowledge and, finally, to innovation. It is above all a cultural achievement of human creativity. Universities are places where science can develop its greatest potential. Their most important impact on society can be achieved through science-supported education. Therefore, research and education have to remain united. Nevertheless, there is an urgent need, in particular in Europe, to improve the concepts of education. We often forget that in a learning institution teachers as well as learners are learning. It might be necessary to re-evaluate and adapt this important process. It is important to leave the unidirectional teaching process and also to adapt to teaching interdisciplinarity in an interdisciplinary research environment without losing scientific quality.

Last but not least, many European universities are faced with an outdated concept of governance. The future university needs a great deal of autonomy coupled with a new communication culture and a new perception of accountability. The future research and education university will certainly have to face limited financial resources. It is therefore of paramount importance that concepts are developed in order to increase its productivity.

In this context, Europe offers interesting opportunities. There is a high degree of cultural diversity within a relatively dense distribution of qualitatively good institutions of higher education and research. This situation can be favourably exploited for the creation of complementary networks, provided the notorious particularism of the single institution can be overcome. Networking has another advantage, because it allows us to assemble monodisciplinary excellence within a high-performing transdisciplinary system.

CONCLUSION

Even if the university of the future will maintain its concept of research-supported education, it has to adapt and develop substantially in order to face successfully future challenges and needs.

The science of the future, applied or basic, must be based on reflections going beyond the sciences. This is where a true cooperation with humanities, social sciences and also economics and ecology will emerge. Beside its traditional tasks to create knowledge, to educate and to lay the basis for the responsible ecological, social and economic wellbeing of human societies, science has to act as an early warning system. This important task can be achieved only if a new contact between science and society is established.

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