What to do with the 20th Century in the History of Science and Technology?

(Problems of historiography of science and technology)*

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1.1. 20th century, without doubts, contributed most significantly to theoretical, as well as practical applications of the science and technology, which had great and global influence on the life of the whole human society and mostly to its benefits.

There is a whole range of registers of important discoveries and inventions, which – from time to time – appear also in different journals and books.[1] It is tempting to analyse, though only superficially, the register of discoveries made by collaborators of the prestigious Encyclopaedia Britannica in its Almanac from 2003.[2] The latter comprises an alphabetically arranged moderate selection of about 345 discoveries and inventions, furnished with the year of the discovery, name of the discoverer or inventor, and the country of his/her origin (there is nobody from the Czech Lands).

Regardless the selection criteria, one can see that:

- ***69%*** of all data ***fall within the years 1850 – 2000***
- ***14,8 %*** of discoveries took place ***in the years 1750 –1850***
- ***The period from the beginning of the list up to 1750 comprises only 16%*** of the total number of discoveries.

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[*] Text of the introductory lecture presented at the International Conference with the same title held in the National Technical Museum in Prague, 2005.

[1] There is a chronological history of science, technology, medicine, and natural sciences in dates published in Czech, including recent (2000) translation of the book The Timeline Book of Science by Ochoa and Corey. It is interesting to compare the concept of the selection of published data with the scope of the list (see footnote 3).

[2] Let us put aside the fact that bikinis, chewing gum, coloured pencils, Christmas cards, *etc.* are listed among the important discoveries; that the steel plough is mentioned in 1836 and John Deere is named as its inventor, or that radar – connected with Ch. Hülsmeyer's name – is assigned to the year 1904. Why the Veverka cousins and ideas of their predecessors are neglected in one case and why in the other case only the idea of radar is mentioned, while the real experiments with the radio locators fall rather into the second half of the 1930s? This can be explained by mixing selection criteria of the topics, *e.g.* by retrospection of the principles of later inventions, or by stressing commercial or other aspects of the inventions; the impact of the level of knowledge of the authors and their tacit inventions cannot be excluded either.

It is interesting that 165 discoveries of the list (*i.e.* 50 % of total) originated in the USA, which country, however, enters history actually as late as the 17th century, and more intensely after the Civil War, in the 1860s. On the other hand, in the principal European Countries (England, France and Germany) occurred 25 % of inventions in sum and in other 82 countries of the world remaining 25 %.[3]

The data presented indicate that the vast majority of achievements of the science and technology, without being overestimated, fall within the last 150 years of many years development of mankind. Moreover, this conclusion was treated by Derek J. de Solla Price (1922–1983) in his theory of exponential growth of scientific findings, as early as the 1950s. Neither the choice of the middle of the 19th century as a starting point was accidental. At that time, the schooling system in Europe acquired the first intense development and the network of the middle schools and universities broadened. Technical education achieved a higher level and both the number of the university lecturers and specialists with the university education and experience, gained by study-stays in prominent world establishments, simultaneously increased. Without any doubts, there was a contribution by the developing industrial society, where each technical success meant further advance in knowledge. For example, the second half of the 1960s, with the Soviet Sputnik, meant a shock to the whole schooling system in Great Britain and new colleges were established, which had not been initially accredited; only during next decades their level was enhanced, helping thus in creating the next stronger generations of specialists.[4] No wonder, considering that science

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[3] A solely quantitative comparison of the identical time periods in surveys of history of science, of technology and of medicine in dates, as compounded and published in *Mladá fronta* and *Avicenum* in Bohemia at the end of the 1970s and in the middle of the 1980s:

year of register edition	1979	1977	1985	2003
branche	science	technology	medicine	Enc. Brit.
period	%	%	%	%
1850 – 1975	50.8	45	57	69 (up to 2000)
1750 – 1850	14.5	21.8	18.5	14.8
up to 1750	34.6	33	26.8	16

(A greater attention paid to the achievements before the middle of the 18th century in the lists published in the Czech literature indicates prevailing of the historical standpoint).

[4] Let us note that the Czechoslovak network of universities started to increase

and simultaneously technology, gained a proper speed of development in the 20th century, in connection with the development of civilization, its social needs and stimuli. After the intense run-up from the industrial revolution in the second half of the 19th century, the 20th century entered history with a break-through caused by new, more efficient and especially "transferable" energies.[5] The new resources made it possible to bring to reality many ideas, which have arisen much earlier and remained only in the form of plans and designs.

1.2. When observing carefully the time period around the beginning of the 20th century, one can see several basic and progressively improved inventions, which gave character to the whole first half of the century:

- **Combustion engine** (Lenoir 1859–60, Benz 1885–86, Daimler 1883–86, Diesel 1893–97) and its visualization — for a broad public — in the form of a car and its industrial and serial production (Ford 1903–07), before the outbreak of the WWI, and similarly in the form of a plane (Wright brothers 1900 and their industrial successors, such as Junkers 1910).
- **Powerful steam and water turbines** (Francis 1849, Laval 1883–89, Pelton 1884, Parson 1884, Kaplan 1912) open the **age of electricity** with all its attributes, namely the energy source, restricted neither by location, nor by output, for a long time.
- **Railway, road and air transport and shipping** prop themselves upon these inventions.

In this connection new demands arose, concerning ore mining, metallurgy, fuel exploitation, and finally product machine tools-industry.

In these areas, much of that what had been known in the early development was combined with the primary ideas of mechanicians, who are managing the overall technology needed for an invention to be implemented (let us recollect again the names above), which is then leading to a success through many more or less successful experiments.

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at the beginning of the 1950s, then again in the middle of the 1980s, gaining an unprecedented extent at the end of the 1990s; *conf.* Chapter 1.2 "Conditions of the Development of Science and Technology in Czechoslovakia in 1945–1992", in "Studies on Technology in the Czech Lands 1945–1992" (in Czech), vol. 1, Prague National Technical Museum, 2003, pp. 60–68.

[5] Steam, combustion and electrical engines and their applications in all sorts of human activities; machine drives and development of machine tool industry; railway, road and air transport and shipping shortened distances and allowed transfer of large loads, raw materials and commodities; gas and electric lightning prolonged workday; increasing demands on mining and processing of mineral ores, coal, oil, *etc.*

It looks as if everything started with those skilled mechanicians; however, the real beginnings are undoubtedly younger by several decades and they prop themselves upon the results of the scientific research and experiments: Let us recollect the Papin's and Guericke's experiments with the steam pressure, with air and vacuum, experiments with gun powder, Vinci's efforts for making use of aeromechanics, many years' experiments with electricity and electric machines leading up to Siemens and his successors, *etc.* They did not mean any longer performing odd phenomena in the aristocracy drawing rooms, but a pursuit of creating an important and efficient means for certain prospective work activities. At the beginning of the 20th century, this concerned mainly applications of mechanics, dynamics, and their consequences. Also, the character of the scientific work has changed. At the turn of the 20th century, important inventions can be credited to Siemens, Otto, Daimler, Benz, Diesel, Laval, Pelton, Parson, Edison, Tesla, Marconi, Wright brothers *et al.*, and significant discoveries can be attributed to individuals such as Mendeleev, Pasteur, Pavlov, Rutherford, Maxwell, van der Waals, Koch, Boltzmann, Planck, Löffler, Behring, Hertz, Wien, Roentgen, Skłodowska, Jansky, and others. In the course of the 20th century, however, research is carried out in work teams and becomes more anonymous.

The beginning of the 20th century meant a further significant change in spreading achievements of the science and technology. If (book)printing meant a significant break through in spreading the knowledge in the previous centuries, then the information technology enters the 20th century, it is gradually accepted and in the second half of the century it culminates: telegraph (1840), teleprinter (1850), intercontinental communications cables (1866), telephone (1876), wireless radiocommunication (1900), phototelegraph (1904) TV information (1930). Starting the 1970s, the information revolution culminates foremost in the military security and information systems (ARPA, 1968), later in the information systems of great research institutions (CERN, 1980) and in the public Internet (1980). Satellite world monitoring is a consequence of this trend. At the turn of the 21st century, the public Internet meant again significant changes in the system of spreading, utilization and publication of all sorts of information, including publicly released research results.[6] Such explosion of information means, methodically, to a historian an increased watchfulness on accepting facts and a deeper

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[6] Industrial and military research has always been subject to concealment. The results, mainly of an applied character, reached public with a delay, often an inten-

criticism of sources handled in this way, because non-prereviewed publications appear, which might contain imprecise, distorted, or even false data.[7]

1.3. A somewhat detached observation of the development of technology shows that there are certain stages in which several products play a decisive role in the overall level and trends of technology, when compared with the other products. Let us look at the main trends and achievements of the 20th century technology development:

- **Beginning of the 20th century — car industry.**
- **End of the 1930s — airplane industry** and increasing demands on **fuels, synthetic fibres, plastics, and pharmaceuticals.**
- **From the 1940s — chemical industry**, followed by progress in **long-distance survey** (radar — end of the 1930s), **computing technology** (MARK I — 1944), **nuclear research** (atomic bomb — 1945; nuclear power-plant — 1954).
- **From the 1950s — telecommunication technology and miniaturization** (transistor — 1948–53), **space rockets, satellites and space probes** (1957).
- **Towards the end of the 1970s — intense progress in genetics and its applications,** culminating by **decoding the human genetic code** around 2000.

A great variety of specializations and speed of the development lie beyond the possibilities of handling by a single historian of science and technology.[8]

The same holds, of course, for the separate fields of science and technology. Specializations become more profound, forcing the specialists to narrow their fields of interest. Individuality of discoverers begins to vanish and almost anonymous research centres, development laboratories and design offices prevail after the middle of the 20th century; the prominent experts from different branches of sciences are concentrated

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tional one, after the more comprehensive research reports from independent university laboratories had been published.

[7] Even pre-review, however, often does not catch all errors.

[8] Indeed, when browsing the latest issues of the ISIS bibliography one can see as if the generation of daredevils with the broad scope of contemplations, such as Bernal, Koyré, Price, Taton, Hahn, Kuhn, Kline, and Popper – shining from the middle of the 1950s up to the middle of the 1970s – vanished and left behind only a few big names, such as Cohen or Holton, for the next decades.

there and work often on parts of large-scale projects, often secret ones, for military, global-political, or commercial-competition reasons. Several examples: Nazi Peenemünde, American Manhattan project, the whole NASA research, Soviet Atommash and vast nuclear research connected later only with the names of Kurchatov and Sakharov, similarly as the Soviet spacecraft research with Korolyov and German and American one with von Braun. Similarly, the research is carried out in many secret and unnamed factories and also in traditional design offices, *e.g.* Messerschmitt, Tupolyev, Antonov, Mila, Sikorsky; despite the large work teams of designers, the names of the leading designers persist, similarly as in Boeing, Airbus and other car, electro-technical, chemical, metallurgical, and machine works.

In the 20th century, new science disciplines appear which are progressively utilized both in the technical and research establishments, and which, eventually, manifest themselves in mass production in many unthought-of applications. Both the Planck quantum hypothesis, which originated from the problems of optics, and the Einstein relativistic physics, born from cosmological impulses, had to wait first to be verified and accepted by the scientific community; nevertheless, they became later basis for the newest technical inventions of the 20th century. Starting with the discovery of radioactivity, science focuses its efforts on the problem of structure of matter and the individual research results lead to more and more accurate models of atom and its nucleus. In the 1940s, the early hypothesis of the release of energy in nuclear reactions is proved experimentally. Unfortunately enough, the first applications were negative, *i.e.* of a destructive character.

De Vries's, Correns's and Tschermak's revival and completion of Mendel laws at the very beginning of the 20th century, together with the development of genetics, led to decoding of the genetic code towards the end of the century. Chemistry mastered syntheses of compounds with desirable properties, as well as their industrial use, and in unexpected way launched production of pharmaceuticals. Geology succeeded in surveying structure of the earth crust and in unveiling mineral resources of the Earth. Experimental survey of the bodies of the Solar system started and became widely developed. Technical devices were launched, reaching larger and larger distances in space. Starting at the end of the 1960s, medicine has mastered transplanting perhaps all organs of vital importance.

All that represented a great variety of technical produces; each of the discovered principles started its own life, bound to the further progress of other technical branches, of scientific knowledge and social needs.[9]

2.1. The 20th century should also deserve a special attention in the studies of historians, too. One cannot say, however, that historians pay a little attention to the history of science and technology in the 20th century.

Let us search a little through the present bibliography of works from the history of science and technology, as it is given annually in the fifth volume of the ISIS sponsored by the American History of Sciences Society. When adopting classification as given in this bibliography, we can see that the number of studies dealing with the 20th century amounts annually from 19 to 24 % of the total, which corresponds to about one fifth to one third of the interests of the present historians of science and technology.[10]

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[9] Selection of the main achievements of science and technology is given, for example, in *Natural sciences, technology and medicine in the 20th century in dates* (in Czech), by Jaroslav Folta and Pavel Drábek, *Dějiny věd a techniky* 33 (2000), No. 5., ISSN 0300-4414, pp. 1–72.

[10] In the Current Bibliography of ISIS **2001,** 568 (*i.e.* **19.8 %**) studies of the total of **2869** deal with the 20th century. These works are itemized into 9 groups — one of them is "general, including philosophical problems of history of science and technology" (43) and the remaining groups are specialized. The last one is devoted to the historians of sciences (20) and the last but one — devoted to technology (128) — is without any specialities, similarly as medicine (61) and social sciences (80). Henceforth individual other branches are given: *mathematics* (16) — both pure and applied, mathematical logic and statistics; *physical sciences* (102) — including astronomy, physics and chemistry; *Earth sciences* (9) — geology, geophysics, geography, cartography, geodesy, oceanography, travelling, navigation, mineralogy, crystallography, meteorology; *biological sciences* (72) — zoology, botany, anatomy, physiology, physical anthropology, genetics, evolution, ecology, applied biology, including certain aspects of agriculture, such as plant and animal cross-breeding, economic entomology, *etc.*

The new Editor changed and refined structure of bibliography; for example, from the total number of **2492** studies given in CB ISIS **2005,** 597 (*i.e.* **24 %**) deal with the 20th and beginning of the 21st centuries, and they are further classified into two main groups: (**1** the works up to 1950 (431) and (**2**) the works after 1950 and beginning of the 21st century (166). These main groups are further divided into subsets.

Further we give the number of studies from the group (1) over the number of the studies from the group (2): *general history of science* — 2/1, *national circumstances* — 3/1, *information sources* — 1/1, *linguistic studies and studies of visual aspects of science* — 0/1, encyclopaedias and other reference works — 1/0, *general works on science* and its social and cultural interactions – 2/0, science and morality — 3/0, science and politics, law and economics — 7/10, science and art and literature —

As mentioned above, the attempts of bringing out the overall development of science and technology become scarce. Such projects exceed possibilities of an individual, regarding both his expertise and volume and preparation of materials. A broader team of researches could perhaps solve such task step by step.[11]

2.2. Why small countries, such as Holland and the Czech Lands, succeeded in completing characteristic and analysis of their overall technical development? The Dutch motivation should disclose the Dutch colleagues.[12] As for the Czech motivation, let us recollect the efforts for the overall covering of the development of the science and technology in

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6/3, science and media and communication of science — 0/1, science and popular culture — 1/0, science and race and ethnic — 9/0, science and gender — 2/0, science and religion — 0/1, science and war — 11/6, scientific institutions — 3/2, scientific instruments and mensuration — 0/1, teaching of science and educational institutions — 4/3, professional activities of scientists including their correspondence and publications — 3/1, history of philosophy and history of ideas — 7/0, *mathematics* — 21/7, music — 0/2, astronomy and cosmology — 11/3, *physics* and general works on exact sciences — 45/4, chemistry — 11/5, *Earth* and atmosphere sciences — 22/4, geography, cartography and research — 12/1, natural history — 2/0, ecology and environmental sciences — 15/6, palaeontology — 6/1, *biological sciences* in general — 8/9, botany and plant sciences — 4/0, zoology, anatomy and physiology — 9/0, heredity, genetics and evolution — 24/9, microbiology, molecular biology — 3/8, physical anthropology — 2/0, neurosciences — 5/1, psychology and comparative psychology — 20/4, *social sciences* in general — 5/1, sociology — 2/0, cultural anthropology — 9/0, archaeology — 1/4, *medical sciences* in general — 46/13, psychiatry, medical and clinical psychology — 15/3, health, nutrition and public health — 15/2, pharmacy — 7/4, clinical medicine — 0/1, *technique* in general — 24/13, computer and communication technology – 8/15, agricultural sciences — 2/1, aerial and space technologies — 11/13.

[11] There have been attempts for enyklopaedically and alphabetically ordered sets of entries related to the development of technology in the 20th century made by Taylor & Francis Ed. in "Encyclopedia of Twentieth-Century Technology" (2004, Colin Hempstead and William Worthington, eds.). Harwood Academic Publisher induced a direct attempt for synthesis of the "Science in the Twentieth Century" (1997), John Kriege and Domenique Pestre, eds.), on which 40 specialists participated. Surveys on the development of mathematics (Development of Mathematics I. 1900–1950, II. 1950–2000, Birkhäuser 1994/2000, 2100 pages) and physics (Twentieth Century Physics, Vol, I–III, Institutes of Physics London, Bristol, Philadelphia and New York, 1995, 2059 pages of text) were created and published in the form of collective works. The works on matematics and physics were initiated by J.-P. Pier and by L. M. Brown, A. Pais and B. Pippard, respectively. The survey of physics appears to be much more balanced.

[12] J. W. Schot, H. W. Lintsen, A. Rip, A. Albert de la Bruhèze (eds.), *Techniek in Nederland in de Twintigste Eeuw.*, Vol 1.–7. (1998-2000).

the Czech Lands from the middle of the 20th century, which started as early as the first decades of the 20th century.[13]

Size of the territory played apparently certain role in both cases, namely viewing state as an economical unit; in larger countries, such direct and complex pursuit of the scientific and technological level of the industry and research and of their development cannot take place. Moreover, in small countries each radical economical change affects the whole society, leads to almost complete conversion of productions and breaches international contacts, agreements and markets. And this is why pursuit of the overall scientific and technological development is much more up-to-date and more detailed. In large countries, great enterprises have mostly international and global character and their branches are scattered over the world.

Also, both the scope and depth of the scientific research and technological development and applications represent a great obstacle in studying most of the domains of the latest history of the science and technology. This makes special demands on the historian of science: it is not enough for him to possess knowledge of the general history, but he must understand basis of the scientific or technical discipline in the epoch he is dealing with.

Both latter remarks indicate the reason why a historian of the 20th century — even being well prepared in a certain scientific or technical field — has to narrow field of his interest and confine himself to problems which are close to his specialization.

Let us point out that the large social changes and catastrophes of the 20th century — which formed the overall character of the science and technology and affected their aims — made the work of historians of science and technology often more difficult. Two hot wars and forty years of a cold war, accompanied by a steady military tension in certain territories, manifested themselves in fundamental changes of production and research but also in significant losses of documents, despite perfect archive legislative. In the Czech Lands it happened after two basic transformations of the economics, after 1948 and after 1989. This con-

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[13] A research project on the development of technology on the territory of the Czech Republic up to the end of the 20th century was carried out and the results were stepwise published. The last three volumes of that opus (2877 pp in total) were published at the end of 2003 and awarded by »Gloria Musaealis«. It is the final part of a compendium (10 volumes) edited in the years 1973–2003; more than 200 experts collaborated on the last three volumes.

cerned not only production enterprises, but also those research centres, which — due to the changes of social structures and participation in international market — lost both their prospects and financial resources and whose production premises were often sold in an open competition to organizations of a quite different type. Records offices of such institutions had to be often cleared out within a few days and, in case that there were no free rooms available, their funds could not be preserved.

At the same time, the general public is greatly interested in the latest development of technology and research, as well as in their peripetia.

The method we used in the Czech Lands, after a long contemplation, has something remotely common with oral history. The research project is carried out by a historian, who decides on the project conception, proportions of individual topics (chapters), as well as on the leading (dominant) subject to be eventually dealt with. The conception is then discussed with a panel of experts, who have a good knowledge of their disciplines and this is how the authors' team starts to be formed.[14] Theses of the designed book, together with the completion of the authors' team, namely the leading experts in given fields, represent the next step. In collaboration with the project leader, the proportionality and balance of the individual chapters has to be enforced and interferences in interpretations given by individual authors have to be eliminated. Also, some internal subjective opinions of individual authors are trimmed away step by step through consultations. In contrast to the "retrospective" oral history, the authors work here with technical literature and archival resources. One has to say that they enter the methodology of the historical studies without any difficulties, even on the first encounter. No doubts, this is one of the ways to arrive at a complete picture of the development of decisive fields of technology in periods of interest. Let us add that there were only four professional historians among the 180 authors of the above mentioned last part of the Czech compendium of the history of technology (1945–1992); most of the authors, however, were leading specialists in their fields. It is clear that this is not the way

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[14] There is dissimilarity from the up-to-now understanding the oral history. A participant of the historical process – in his recollections and portraying own experience – is lead by a clear chronological and thematic framework. On the other hand, the classic oral history uses and treats verbal or written communications, which have been made without any leading plan; this is ;+why they contain often irrelevant and immaterial information or some information can be missing, because importance of the facts considers the telling person.

to compile the history of technology in a large national or even a world scale. One will have to use a more general view, skipping the peripheral phenomena.

2.3. There are, however, other questions in the history of science and technology concerning the 20th century development, namely more general views of the scientific and technical development.

For one single epoch of the 20th century, a part of the historiography of the science and technology was dealing with generalization of the last 150 years of the developments of the following phenomena. Terms *scientific revolution, industrial era* and *industrial revolution* were starting points for the next stages of similar revolutions, namely the *second a third industrial revolution*, but also the *technical-scientific and scientific-technical revolution*; in a way, analysis of *Kuhn's paradigmatic stages* appeared also in studies of the history and technology, both theoretical and applied ones, provided that the classification of different phenomena of the scientific and technological development with theses structures can be regarded as an application.

In recent years, however, these problems slip away the general subjects of the historians of the science and technology and only pronounced convulsions remain, such as scientific revolution of the 16th and 17th centuries, and industrial revolution of the 18th and 19th centuries. As for the general conception, paradigms appear in some studies to illustrate something stable, to which the studied topic is related, or which it contradicts.

The following problems are in a permanent interest of historians:

- Science and technology as a social process
- Nodal points of the social development and science and technology
- Science as an immanent process
- Science and technology in the process of development of state formation
- Development laws of the science and technology as a starting point for prognoses of further development in these fields, as long as both phenomena can be linked together at all.

These are, however, rather *philosophical contemplations* supported by examples; their managing requires sufficient research erudition. Nevertheless, one should not give them up, because they might serve as resources for secondary-school teachers. Without solid knowledge of the history of a given period, an excessive and meaningless generalization or obscure and foggy philosophical conclusions may arise.

We have already touched on the problem of the development of science and technology of the 20th century in the education of the secondary schools. This question has not actually been solved yet and it makes significant demands on the pedagogues. It is connected with a question whether teacher is prepared (from the university) to explain the development of science and technology and whether he devotes space enough to these problems. To leave this subject to specialities teachers (mathematic, physics, chemistry, biology, geology, *etc.*) at the secondary schools would mean to give up the complex view of the development of the scientific knowledge, of technological progress and of the significant social consequences, internal, as well as external. I am not convinced that this aspect is being stressed enough during the education of historians, neither that increasing influences of this domain upon the social and political decision-makings are shown. By the way, let us assess contents and low demands upon the interpretation of the development of science and technology in the history text books of both the secondary schools and universities; though not indicators of the extent of teaching and requirements on students, they show evidence of underrating significance of studying this domain of history.

Let us note that only a few faculties at the Czech universities carry out programs of history of a certain field of natural science, but there is not a single department of the history of science. On the other hand, Wikipedia gives a partial list of 37, mostly Anglo-American universities, which carry out a general program of the history of science and technology; as for continental Europe, only Bern and Utrecht are listed by an anonymous author. This difference is striking.

2.4. Teaching and culture-educational activities are connected with the exposition-visualization of physical artefacts documenting development of science and technology in the 20th century. We are not going to deal here with the problems of the museum presentations, let us just call attention to some aspects of documents collecting and preserving. No doubts that visual familiarization with technical achievements (or with arrangements of scientific experiments) contributes to understanding and remembering theoretically conveyed information. That concerns both adults and youth. With the latter, this might enhance their interest in these fields and contribute to the formation of their life's careers.

Technical museums were established in the second half of the 19th century, originally as "show halls" with most modern technical achievements, aimed at enhancing the overall level of skills and technique. The 20th century, of course, augmented significantly technical achievements. On one hand, large series of individual product types were developed (*e.g.* cars, motorcycles, engines, aircraft), some of them awaking a great interest of public. Not all items, however, can be assembled in classical museum buildings; as long as they do not prevent public projects, either they have to stay in place (factory halls, iron works, mines, and sizable equipment), or they have to be expensively moved (protected bridges, footbridges, water mills). In some cases — when liquidation appears to be too expensive — special open-air museums are established in the form of "objects decaying under control"; some of them find use in the form of work opportunities after the full employment has been lost there. In the case of large enterprises, documentation is usually filed in archives, becoming so a good resource. In the case of small establishments, which are shut down completely without any follow-up production programme, the loss of filed documents is usually great, if not absolute.

In the times of so called "conversion programmes", the obsolete technological equipment is very often sold up at a very low price or just simply liquidated (to be used as raw materials later). Such circumstances favour collecting different items and creating collections on different levels. Historically valuable material is preserved in this way in any case.

There are many more problems concerning studies of the development of the 20th century science and technology connected with very broad general technical activities, narrow specialities of professionals and difficulties of specialized historians who are lacking any natural-scientific or technical education needed for grasping broad problems of the latest development of science and technology. On the other hand, knowledge of the development of science and technology in their global manifestations, of their mutual influences and their subordination to the social development is needed by the society authorities and serves also the general education of the next generations.

I would like to close my reflections by statement that it is necessary to embark upon these problems. Question is, however, how to organize the research, which is beyond the possibilities of an individual, and how and where to start.

Wherein lies the revolutionaryness of the scientific-technical development in the twentieth century?[1]

Mikuláš Teich

Just before the radical political changes in 1989/90 the renowned London weekly *The Times Literary Supplement* asked fifteen distinguished historians to describe the books or project they would most like to see undertaken. I found Eric Hobsbawn's contribution of particular interest. Briefly, Hobsbawn wished to see the history of the world written since the Second World War. "To the best of my knowledge", he wrote, "there has not been another period when human society has been so profoundly transformed in a mater of decades ... What has taken place in the world since the war really has been extremely hard to understand ... It is rather important for those about to enter the twenty-first century to see the second half of the twentieth century in historical perspective"[2]

There is no way to get to grips with the important matter raised by Eric Hobsbawn without going back to the chain of scientific and technical developments such as nuclear fission, electronic computers, or the genetic code, set in motion with the discovery of the nuclear atom and rediscovery of Mendel's work since the turn of the century. To denote them the term "Scientific-technical Revolution" in the twentieth century came into infrequent usage but, for all the expansion of social history of science since the 1960s, it has as such commanded virtually no attention in historical debate. It may well be that Kuhn's seminal and influential work *The Structure of Scientific Revolutions* (1962, 1970) helped to weaken the appetite for the study of the relation of science and technology to social change. To all intents and purposes, it pays na attention to socio-historical context. There is a need study and understand the Scientific-Technical Revolution as a historical product and factor in the social transformations in the world since the beginning of the twentieth century. It is theme that forms the subject matter of this paper.

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[1] I draw a good deal on my previous writings on this theme which would be fastidious to refer to.

[2] E. Hobsbawn, *The missing history — a symposium*, The Times Literary Supplement, 23–29, June 1989, 690.

It is the historical experience of the atomic bomb, microelectronics and genetic engineering rather than analysis that lies behind the virtually undisputed view that, in comparison wit the nineteenth century, a qualitative change in the relations between science and technology has taken place. It has found expression in terms such as "science-based technology" or "science-related technology" which however, do not do justice to the ensued fundamental transformation in the complex relationships between scientific discovery, technological development, practical application and social consequences. Following J. D. Bernal, it is possible to denote it as the Scientific-Technical Revolution in the twentieth century. First employing the term in 1957, Bernal wished to underline "that only in our time has science come to dominate industry and agriculture".[3] The physicists Bernal (born 1901 in Ireland and deceased 1971 in London) was not only a brilliant scientific polymath but also a creative thinker in matters concerning scientific an social evolution. Against Bernal Hobsbawn's charge cannot be levelled of failing to be aware of what was happening in his lifetime. It was the Great War, the economic crisis of the 'Thirties, and the advent of fascism which impelled Bernal, in the first place, to examine critically the function of science in society. It led to the publication in 1939, on the eve of the Second World War of Bernal's seminal book which is relevant to the topic under review.

Take Bernal's assessment of the application of scientific knowledge to war: he allotted a separate chapter in the book to it. Then Bernal explained that the close historical link between science and warfare was not due to any mystical affinity between science and war but because the urgency of war needs was greater than of civil needs, and that in war novelty is a premium. The Great War, according to Bernal, altered the situation profoundly, because in his words "scientists found themselves for the first time not a luxury but a necessity to their respective governments".[4] At the same time Bernal pointed out, this conflation of science and war had created problems. For one thing, there were millions who came to blame scientific developments for the sufferings they experienced during the Great War and therefore they rejected that science intrinsically was beneficial to mankind. One consequence was that among the younger gener-

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[3] J. D. Bernal, *Science in History*, 2nd ed. (London, 1957), p. 690.

[4] J. D. Bernal, *The Social function of Science* (London, 1939), p. 171.

ation of scientists there were not a few who questioned an involvement in military research a something entirely alien to the spirit of science.

Bernal being a Marxist place history firmly as the centre of his analysis of what science is about. “To see the function of science asd whole”, he wrote, “it is necessary to look at it against the widest possible background of history”.[5] He continued by identifying three major changes which mankind has experienced since its relative late emergence on earth. The first and second changes, the foundation of human society and civilization respectively, occurred before the dawn of recorded history. As to the third change, Bernal associated with it, as he put it, “that scientific transformation od society which is now taking place and for which we have as yet no name”.[6] Bernal traced its origins to thwe related processes of the rise of capitalism and the birth of modern science in the middle of the fifteenth century. In discussing thi two-way relationship. Bernal argued, though[7]

> capitalism was essential to the early development of science, giving it for the first time a practical value, the human importent of science transcends in every way that of capitalism, and, indeed, the full development of science in the service of humanity is incompatible wit the continuance of capitalism.

In effect what Bernal did in the concluding chapter of the *Social Function of Science* was to divide world history into three stages of humanity whereby stressed that the third stage hat still to be achieved. The following formulation in the concluding chapter of the book, published more than 65 years ago, may help to bring out the author’s significance as one of the twentieth-century creative thinkers about society, man and nature:[8]

> We must realize that we are in the middle of one of the major transition periods of human history. Our most immediate problem is to ensure that the transition is accomplished as rapidly as possible, with the minimum of material, human and cultural destruction … belonging to age of transition we are primarily

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[5] Ibid, p., 408.

[6] Ibid.

[7] Ibid, p. 409.

[8] Ibid., pp. 409–10.

> concerned with its tasks, and here science is but one factor in a complex of economic and political forces.

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There is no way to get to grips with the important matter raised by Eric Hobsbawn without going back to the chain of scientific and technical development set in motion since the turn of the last century. Thus take the radical rethinking about the structure of matter and space-time the beginnings of which go back to the turn of the century. From here developments tied with military needs, economic expectations, technological feasibilities, political interests and other interlinked factors led to radar, the atomic and hydrogen bombs, electronic computers, automation, space navigation and so forth. The penetration into the micro- and macrocosmos has provided mankind with the means, in the context of nuclear and space war, to destroy itself. Alternatively, it has provided impetus for governments of the USA and USSR, irrespective of their unlike social systems, to look for non-military solutions to international problems. Being aware of the real danger of self-annihilation through the use of nuclear weapons both sides stepped back. Does is not suggest that the impact of nuclear weapons on the maintenance of peace a comprehensively thorough historical analysis? It is not without historical interest that the early history of electronic computing intertwines with radar and atomic bomb development during the Second War. The first electronic computer, designed in 1943 and built for the United States army, became operative by 1945. It became known under the acronym ENIAC (Electronic Numerical Integrator and Computer). The computer set up in connection with the construction of the hydrogen bomb received the name MANIAC, apparently reflecting what some of the participants in the project thought about it. ENIAC contained 18 000 electronic valves, it weighed 30 tons and consumed 50 000wats. Forty years later a computer containing a 25 square millimetres micro chip and performing similarly was 100 times quicker and 10 000 times more reliable but used up only 1 watt of electrical energy.

That was the consequence of the discovery of the transistor in the Bell laboratories in the USA (1947–8). It ushered in a development regarded by many as the greatest revolution in the history of technology. Be that as it may, the alterations in manufacturing techniques by employing microelectronic devices are comparable with the consequences of novel production technologies, introduced and developed during the Industrial Revolution in the eighteenth and nineteenth centuries.

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As far as I know, it was in Czechoslovakia, from 1965, that the most searching endeavour to investigate the Scientific-Technical Revolution as a social and historical phenomenon was undertaken on an interdisciplinary basis by a group formerly attached to the Institute of Philosophy of the Czechoslovak Academy of Sciences. It was headed by the philosopher Radovan Richta whose first discussion of the problems of modern technology in wider social context appeared in 1963. May I add that, at that time, I also began to be interested in the subject matter. The interest was a by-product of my coordinating activities of a team working on the history of technology in Czechoslovakia. Eventually Richta's team (which i joined in 1966) did include 60 men and women active not only in philosophy but also in other fields: economics, sociology, psychology, political science, history, medicine, the theory of architecture and environment, several branches of science and technology. By the spring of 1968, the material embodying the results of their collective labours was assembled and appeared in print in July of the year.[9] What is impressive is that over 50 000 copies of the Czech and Slovak editions were sold out immediately, demonstrating the broad and intense degree of concern in the country for the issues explored in the volume. Recognized abroad as a significant contribution to the literature on the social and human dimensions of twentieth-century scientific and technological development, it was translated into several languages. In order to acquaint the foreign reader with the climate in which the book came to be put together, a short explanatory section was added to the Introduction from which the following passage is taken:[10]

> The work was conceived in an atmosphere of critical, radical discussion on the way forward for a society that has reached Industrial maturity while passing through a phase of far-reaching socialist transformation. In the light of theoretical enquiries, we saw and image of all modern civilization. The choice advanced in our hypothesis emerged as a practical problem.

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[9] Cf. R.Ṙichta and a research team, *Civilization at the Crossroads: Social and Human Implications*, translated M. Šlingová, 3rd expanded ed. (Prague, 1969).

[10] Ibid, p. 21.

To readers, especially to the younger generation, this passage may appear rather remote and therefore, perhaps, a brief comment is in order. To say that the team was somehow consciously participating in the preparation of the events that are known as the "Prague Spring of 1968" would be misleading. Nevertheless, its work constitutes an integral part of the latter's history (which has as yet to be written). In that the analysis, produced regarding the social and human impact of the twentieth-century scientific and technological developments, led to poignant critical questions about the Czechoslovak social environment and the perspective of building socialism and communism in Czechoslovakia respectively. Moreover, it critically especially emphasized the need to take into account the fulness of man's inner life:[11]

> Hitherto individual socialist endeavour has tended to be put at a disadvantage … individual initiative has been curbed by a mass of directive … An urgent task in this field, in which scientific and technological advance can make an especially hopeful contribution is to bring into operation a variety of ways by which the individual can share in directing all controlable processes of contemporary civilization and to do away with some of the restricting, dehumanizing effect of the traditional industrial system.

The changed political climate, following the entry of military units of the Soviet Union (and Poland, Hungary, German Democratic Republic and Bulgaria) on 20 August 1968 into Czechoslovakia, put paid to this promising effort of the team to understand historical process in which science and technology under capitalism as well as socialism had become cardinal. As to inquiries by scholars in the West into the nature of the scientific-technical progress in the twentieth century, they are valuable and much information may be gleaned from them. But the reality is that critical contributions to the problematic of the Scientific-Technical Revolution in its social context failed to appear.

Similar to the Scientific Revolution in the sixteenth and seventeenth centuries and to the Industrial Revolution in the eighteenth and nineteenth centuries, the Scientific-Technical Revolution in the twentieth century is both a product and a factor of far-reaching social transformations. The radical difference in the situation lies in the unprecedented global

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[11] Ibid, pp. 284–5.

influence of the chain of scientific and technical developments since the turn of the twentieth century on society.

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Let us take the Internet, much talked about for its signally pervading impact on a variety of social, economic, political and cultural activities. To a historian it is, or should be of interest that its origins go back to the US government's concern, following the launching of the Sputnik (1957), to safeguard its communication system revolving around a few isolated supercomputers. Not for the first time in history a radical technical novelty, such as embodied in the "network of networks", has attend a quasi-religious connotation. But the "techno-gospel"[12] of easing poverty, making democracy stronger and bringing peoples of the world to get her seems to fall by the wayside. Indeed, it may be that the sands are running out. As the Technology Correspondent of the well-known Sunday paper *The Observer has pointed out recently:*[13]

> The boom era of the internet ... will coon be a thing of the past unless coordinated action is taken to improve security, Microsoft has warned ... Other internet security specialists believe the crisis is urgent. Richard Cox, chief information officer of anti-spam campaigner Spamhaus, said: "If you can't go to a website without risking your computer being compromised, if you can't open your e-mail box because so much of it is junk, what's left? In three years the internet could be unusable."

Then there was the Human Genomeproject which impinges on legal, commercial, ethical and a host of other matters. Here too, as in the case of the Internet, the post-1945 involvement of an American government agency — the Department of Energy — in human genetics is of historical interest. Asking questions about genetic effects of radiation in the wake of the bombing of Hiroshima and Nagasaki eventually evolved into the multi-partite and multi-stage project which established the sequence and comprehensive analysis of an estimated 3 billion base pairs in the human DNA. Those who spoke for the Human Genome Project maintained grandiloquently that it will lead to "the understanding of the essence of man" and of the "determining force behind historical events". They

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[12] Cf. M. Slouka, *War of the Worlds Cyberspace at the High-Tech Assault on Reality* (London, 19969), p. 81.

[13] Cf. D. Smith, *Spam and scrams 'could make internet unusable'*, The Observer, 18 September 2005.

were less keen on examining what one among them, Robert A. Weinberg, Professor of biology at Massachusetts Institute of Technology and member of the prestigious Whitehead Institute for Biomedical Research, had said. Weinberg pointed to the danger of misusing genetic information by insurance companies threatening persons looking for employment or indeed planning to marry. He concluded gloomily:[14]

> As a biologist I find this project a bitter pill, The biological revolution of the past decades has proven extraordinarily exciting and endlessly fascinating, and it will, without doubt, spawn enormous benefit. But as with most new technologies, we will pay a price unless we anticipate the Human Genome Project's dark side. We need to craft an ethic that cherishes our human ability to transcend biology, that enshrines our spontaneity, unpredictability and individual uniqueness. At the moment I find myself and those around me ill-equipped to respond to the challenge.

Contemporaneously and not unrelated to the ventures into the nucleus of the atom and the cell has been the growth of various, private and public forms of economic socialisation. After the collapse of the Soviet-type of societies, it shows most visibly in the commanding position in the world economy of trans-national (mutinational) companies. In the early 1990s, according to a United Nations study, these accounted for one third of global output. It is estimated that they are currently responsible for 40 to 50 per cent of fundamental and applied research worldwide. Inevitably the question arises whether and to what extent money distorts scientific reseach fields.

In a lecture at the Salzburg festival in 1994 George Steiner, a critical commentator on contemporary cultural life, censured the barrenness of European culture at the end of the millennium by stressing, among others, that the landings on the moon haver not inspired the creation of a single great poem, picture or metaphor. Not know for being an advocate of radical societal transformation, Steiner exclaimed despairingly:[15]

> The only manifest energies are those of money. Money has never smelt more sharply, it has never cried more loudly in our public and private concerns . . . there are at present fewer

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[14] R. A. Weinberg, *The dark side of the genome* in A. H. Teich, *Technology and the Future*, 6th ed. (New York, 1993), p. 328.

[15] G. Steiner, *Modernity, mythology and magic*, The Guardian, August 1994.

> and fewer voices which articulate a philosophy, a political or social theory, an aesthetic which would be both in the European heritage and of world relevance.

The twentieth-century Scientific-Technical Revolution, in order to come into its full human and humane heritage, calls for a type of society very different from forms of societal organizations known so far, and in that lies its revolutionariness.

One of the Great Conundrums of the 20th Century Science – Ionizing Radiation: Radiation Processing and Applications in the Czech Lands

Igor Janovský

Abstract

Period from the end of the 19th century up to the middle of the 20th century – with all the discoveries and achievements related to ionizing radiation and radiation sources – can without doubt be classified as the „golden age of physics“. It is closely followed by observations of a large variety of radiation effects, culminating in the years 1950-1970, which period can be called the "golden age of radiation research". Practical applications of ionizing radiation in different fields were also not long in coming and "radiation industry" lives through a pronounced "boom" in the 1970s. Examples of successful applications are evident also in the Czech Lands, such as radiation sterilization of medical products, polymer modifications, preservation of objects of art, semiconductor modifications, and use of radiation in agriculture or for foodstuffs disinfestation.

1. Introduction

By definition, ionizing radiation is any kind of radiation in which an individual particle, e. g. a photon, electron, alpha particle, etc., carries enough energy to ionize an atom or molecule, that is, to completely remove an electron from its orbit. [1] In this respect ionizing radiation differs from UV radiation which does not posses enough energy for such event to occur. It is well known that these ionizations can be destructive to living tissue with lethal consequences. On the other hand, the same entity can be life preserving, as we know from the radiotherapy of cancer. This dilemma, with its pros and cons, with beneficial and possible adverse effects of radiation, extends also to other application fields called "radiation processing": ionizing radiation is applied either for obtaining a new product or for preserving or modifying properties of already existing one. Radiation which is used in radiation processing does not allow for a nuclear reaction to occur, in other words the irradiated material does not become radioactive. Applications of UV radiation are also sometimes referred to as radiation processing, but these are not subject of this paper.

Sources of radiation, which are used for radiation processing, are either artificially produced radioisotopes (mostly ^{60}Co) or electrical generators (electron accelerators) and this is why the history of radiation processing ensues the history of radiation itself and of radiation sources.

2. Milestones in the early history of radiation and radiation sources – "golden age of physics" [2,3]

1895 – Wilhelm Conrad Roentgen discovered X-rays when studying cathode rays
1896 – Henri Becquerel discovered emissions of radiation from uranium salts through blackening photographic emulsion and classified emissions according to their penetrating powers
1897 – J. J. Thomson discovered electron
1898 – Pierre and Marie Curie discovered the first radioactive elements: polonium and radium
1899 – Ernst Rutherford discovered alpha and beta radiation
1900 – P. U. Villard discovered gamma rays
1912 – Max von Laue demonstrated that X-rays are a form of electromagnetic radiation
1913 – Hans Geiger unveiled his first radiation detector (point counter)
1929 – Van de Graaf invented electrostatic machine for acceleration of electrons and heavy charged particles
1930 – Ernest O. Lawrence and Stanley Livingstone designed the first cyclic accelerator (cyclotron) of charged particles
1931 – Ernest O. Lawrence and David Sloan constructed and operated a linear accelerator
1932 – J. Chadwick identified neutron
1934 – Frederic and Irene Joliot-Curie discovered artificial radioactivity
1938 – Otto Hahn and Fritz Strassman demonstrated nuclear fission and Lise Meitner and Otto Frisch named the process and gave its physical explanation

1938 – John Livingood and Glenn Seaborg discovered ^{60}Co
1939 – Varian brothers invented high-power microwave amplifiers called klystrons, which are vital components of linear accelerators
1940 – Donald Kerst built the first betatron
1942 – Enrico Fermi with coworkers created the first controlled chain reaction in a nuclear reactor
1946 – commercial production and distribution of radioisotopes begun
1947 – Bill Hansen and coworkers built the first linear electron accelerator
1954 – AECL (Atomic Energy of Canada Ltd.) commissioned a powerful reactor with a high production capacity of ^{60}Co

3. Radiation effects - early observations and further development [1–3]

Besides the blackening of photographic plates, the very first radiation effects observed were probably human injuries from X-rays, reported shortly after their discovery, and in 1904 first human death from X-rays was reported. On the other hand, at the very beginning of the 20th century the therapeutic effects of radium were already attempted: in 1901 radium was placed in contact with TB skin lesion and in 1903 Alexander Graham Bell suggested placing it in or near tumors and George Perthes proposes the use of X-rays. In 1904 S. Prescott publishes at MIT (Massachusetts Institute of Technology) studies on bactericidal effects of radiation, in 1905 U.S. and British patents are issued for use of radiation to kill bacteria in foods [4] and by the 1930s a logarithmic radiation dose-inactivation relationship for microbiological systems was revealed. Other early radiation effects observed were formation of ozone in air besides ionization, formation of oxygen, hydrogen, sometimes of explosive gas and of hydrogen peroxide in water and later oxidation of Fe(II). As early as 1910 the first paper on water radiolysis was published by a student of Mme Curie. [5] Regarding solid state effects, darkening of glass under irradiation and coloration of crystals of radioactive salts (chlorides, bromides) were observed. At the beginning of the 20th century (1902-1903) stimulating effects of uranium on plant growth were reported in Japan and allegedly in 1912 the Czech agrochemist Prof. Stoklasa already reported on the stimulating effects of radioactive water from Jachymov mines. It was soon realized that ionizing radiation can act as a mutagen: J. H. Müller observed in 1927 mutations in fruit fly

Drosophila induced by X-rays and at nearly the same time also plant mutations were induced (tobacco, maize and barley). [6]

Knowledge on various effects of ionizing radiation increases significantly especially after the world war II., mainly as a result of the development of nuclear weapons and nuclear technology, work with high concentrations of radioactive substances and strong radiation sources, namely nuclear reactors, ^{60}Co and microwave linear electron accelerators.

Development of new experimental techniques, such as electron spin resonance (first measurement was performed by Evgeny Zavoisky in Kazan State University 1944) and especially pulse radiolysis with ultrafast optical spectroscopy (J.W. Boag in the late 1950s and early 1960s in the UK), made it possible to investigate short-lived transient species generated by radiation and subsequent reactions. Radiation research then changes from somewhat obscure field into one of major importance and the period 1950-1970 becomes its "golden age". Extensive investigations were carried out in newly formed branches, namely radiation chemistry, radiation damage to materials and radiation biology, and many important discoveries were made during this period. They include understanding of mechanism of water radiolysis, identification of hydrated electron and many other reactive free radicals, establishing mechanisms of their reactions, techniques of radiation polymerization, the structure of coloured centers in solids, role of DNA in radiation biology, etc. [1]

A revolutionary discovery was made in early 1950s by Charlesby, when it was observed that irradiated ethylene polymers no longer melted at elevated temperatures, but exhibited rubber elasticity, due to the formation of a three-dimensional network of macromolecules called "crosslinking", i. e. instead of material degradation, its properties were significantly improved. [7] Also, so called "memory effect" with irradiated polyethylene was discovered. The latter consists of three-step material processing: irradiating polymer material, mechanical deformation (stretching) at a high temperature and subsequent fast cooling. When such material is heated again it tends to resume its original form: so-called "thermo-shrinkable" or "thermo-setting" materials.

Basic research both in radiation chemistry and radiation biology was closely followed by the technological applications of radiation in various fields. Radiation processing can be performed on a large industrial scale, but sometimes it is put into practice on a semi-pilot or on a small laboratory scale only. The first radiation processing plants appear in the mid-1950s and “radiation industry” lives through a pronounced “boom” in the 1970s. Various technologies spread out very quickly, starting with the strongest world economies and the rapid growth is demonstrated by the production increase in the USA: [8]

year	1964	1970	1975	1977	1979
product worth in million US$	70	150	750	1250	3000

In 1967, there were 27 ^{60}Co gamma-ray facilities (source activity above 20 000 Ci) of pilot or semi-pilot character installed in 13 countries. [9] Today, there are about 200 gamma-ray facilities (mainly ^{60}Co) operated for radiation processing worldwide, with a combined inventory of about 8 EBq (220 million curies) and the number of accelerators operating worldwide is close to 1200. [10–13]

4. Scope of radiation processing

The broad range of radiation-processed materials is well demonstrated in the monograph “Dosimetry for Radiation Processing [14]”: *Indeed, in the developed countries of the world, it is likely that almost every member of the public will come into contact with radiation processed articles every day, without being aware of it. One may encounter radiation-processed materials in a car, or in the tires of a car, at the doctor, or dentist, or at the hospital, in plumbing and electrical insulation, in permanently-creased trousers or shirts, and even the ink on paper money might be cured by radiation. Other common examples of irradiated materials include plasticized milk cartons, plastic bottles for carbonated beverages, cling-film and coating on non-stick frying pans. In the future, we all may be grateful for a cleaner, safer environment because of the radiation treatment of hospital, airport and aircraft waste and sewage, or because the emission of sulphur and nitrogen oxides from the oil- and coal-fired power stations is reduced with the help of radiation scrubbing of the effluents gases.*

Based on various radiation effects, the radiation applications can be classified as follows:

- **utilization of “biogenative” effects of radiation**
  radiation sterilization of medical and pharmaceutical materials
  radiation treatment of cosmetics

pathogen elimination/decrease in food and spices
elimination/decrease of trichinosis in pork
disinfestation of grain and citrus fruits
shelf-life extension of perishable food
delayed ripening of fruit and vegetables
inhibition of sprouting in potatoes, onions and garlic
insect population control by male-insect radiation sterilization
water purification,
recycling wastes
preservation of objects of art and relics attacked by¨wood-worming insects, moulds, fungi

- **“biotechnological” applications**
  seed stimulation
  mutation breeding of plants
  treatment of peat material as carrier for culture of bacteria
  immobilizations of enzymes in or on polymer materials
- **radiation polymerizations**
  curing of plastic coatings
  curing of printing inks
  fabrication of composites (wood-polymer, fiber-reinforced (carbon-, epoxy))
  fabrication of hydrogels
- **radiation modification of polymers**
  rubber vulcanization (tires, silicone)
  crosslinking (PVC, PE, wire insulations, tubes)
  production of heat-shrinkable plastics (“spaghetti“ insulations, films)
  grafting (textiles)
  monomer elimination in polymers
- **modifications of semiconductor materials** by introducing solid-state defects
  diodes, thyristors
- **ecological applications**
  scrubbing of gaseous effluents
  degradation of PCBs and other harmful compounds
  polymer degradation
- **radiation syntheses of organic compounds**

Three application domains – radiation sterilization, polymer modification or polymerization and food irradiation – can be designated as the most important, the first of them being world-wide most spread and the last one most controversial, especially regarding its public acceptance and legislative problems.

Industrial radiation sterilization of medical items was introduced first in 1956 by Ethicon Inc. (a Johnson & Johnson company) and in 1992 there were already about 120 gamma-irradiation plants and about 30 electron accelerators, located in more than 40 countries, applied for radiation sterilization. In the mid-1990s about 40 to 50 % of medical production, mainly of disposables, was sterilized by radiation. [15]

Food irradiation started in the early 1960s in Canada, France (potatoes), England (eggs) and in the Soviet Union (grain). By 1994 irradiation of foodstuffs was permitted already in 38 countries and pilot and production plants were operating in 27 countries, for radiation treatment of potatoes, onions, garlic, tomatoes, beans, seasonal vegetables, spices, strawberries, citrus fruits, apples, mangoes, dried fruit, grains, rice, poultry, fermented sausages, shrimps, dried fish, frozen frog legs, etc.[15]

Radiation crosslinking of polyolefins was introduced first in the USA in the 1950s and the present list of countries in which this process is applied, mainly in the cable and wire industries using electron accelerators, includes Japan, UK, France, Germany, countries of the former Soviet Union, Czech Republic and several others. [15] Similarly, radiation processing of thermo-shrinkable plastic (polyethylene) films and tubes, which are used for food wrapping and fastening cable or tube connections, respectively, was introduced first of all in the USA, Soviet Union, France, Japan and Hungary.

Radiation polymerizations of monomers and their mixtures is utilized mainly for the purpose of hardening of thin layers of coating compositions, such as paints etc. An American patent [16] dates back to 1952, but the technology could not actually be developed until production of necessary low-energy electron accelerators started in 1970 in the USA. In 1990 there were already about 350 laboratories, pilot plants and industrial plants throughout the world carrying out radiation hardening of paints, varnishes, adhesives, metalised materials, printing inks on many surfaces such as wood, metallic, ceramic, paper, magnetic discs etc. [15]

Regarding radiation treatment of gaseous effluents, a pioneering contribution was made by the Japanese researchers in the early 1970s and the technology was later further elaborated in the USA, Germany, Poland and China. It allows simultaneous removal of nitrogen and sulphur oxides with high efficiency and the byproducts generated can be applied as fertilizers. The industrial installations of a pilot- or demonstration scale, equipped with low-energy electron accelerators, have been already constructed in the named countries. [15]

5. Radiation processing in the Czech Lands

Research in radiation chemistry and/or radiation processing, has been performed in Czechoslovakia since the late 1950s and brief accounts of some earlier projects are given in several reviews. [17–19]

Main research centres are:

- Nuclear Research Institute Řež (ÚJV Řež),
- Institute for Research, Production and Application of Radioisotopes Prague (ÚVVVR Prague)
- State Textile Research Institute - Radiation Technology Centre Veverská Bítýška (SVÚT-CRT, earlier SVÚT Brno).

Besides these, several other – mainly specialized laboratories – were involved:

- Faculty of Physical and Nuclear Engineering Prague (FJFI)
- Research Institute for Alimentaries Bratislava (VÚP)
- Institute of Chemical Technology Prague (VŠCHT)
- State Wood Research Institute Bratislava (ŠDVÚ),
- Research Institute for Veterinary Medicine Brno (VÚVEL)
- Research Institute for Rubber and Plastic Materials Gottwaldov (today Zlín) (VÚGPT)
- Research Institute of Pure Chemicals (Lachema) Brno
- Institute of Experimental Botanics of the Academy of Sciences, Department of Radiobiology
- Central Research Institute of Food Industry Prague
- Research Institute of Synthetic Resins and Paints

In the period since the mid-1970s through 1980s, most of the applied research was concentrated within state research projects sponsored by the Czechoslovak Atomic Energy Commission and partly by industry and coordinated by the ÚJV Řež.

There was a large number of topics and projects, as already the names of the research institutions listed above indicate; however, not all of the planned technologies were really put into practice.

The main projects are reviewed briefly below.

5.1. Radiation sterilizations of medical items

Research started in the early 1960s in the SVÚT Brno, where a 1.8-MeV Van de Graaff electron accelerator TUR (Transformatoren- und Roentgenwerk Dresden, former Siemens facility) and later pilot equipment furnished with a conveyor for passing the material through the electron beam, were installed. [20] (The accelerator was developed by Manfred von Ardenne.)

Automatic irradiation line in the SVÚT-CRT in Veverská Bítýška (today BIOSTER, a. s., privatized in 1994) was installed in 1972 and has been in operation since 1973. [21] It was the first industrial radiation processing plant in Czechoslovakia. Process equipment (Irradiator Type J-6000 with ^{60}Co, nominal activity about 15 000 TBq (408 kCi)) was supplied by the Atomic Energy of Canada Ltd. (today MDS Nordion) which is the largest among the world producers of gamma sources. Material is irradiated in standard cartons ($46 \times 36 \times 46$ cm^3) on a conveyor in a continuous mode and maximum sterilization capacity is about 20 000 m^3/year (every 10 minutes one carton with sterilized material leaves the irradiation room). The plant was built near the RICO factory (today Hartmann-RICO), producer of the cotton wool and bandage materials, and chief part of its production has been sterilized by radiation. Much valuable work was done in the SVÚT-CRT on the radiation sterilization process for medical products: methods of assessment of radiation compatibility of plastics in use were developed, initial contamination of different items and radiation resistance of various microorganisms thoroughly studied, and a number of new products introduced, such as several types of haemostatic Traumacel, mammal implants, diagnostic aids (Uritest set), surgical aids as artificial finger-joint from high-density polyethylene, special bandages, etc. [19]

Since 1996, the Bioster has been certified in compliance with the EU standards, and in addition to radiation sterilizations it offers today other irradiation services, both to domestic and foreign customers.

Since about the mid-1960s, radiation sterilization of medical and pharmaceutical materials with ^{60}Co gamma-radiation has been carried out also in the ÚJV Řež and since the early 1970s already on a quarter industrial scale, when a special ^{60}Co irradiator "ROZA" (nominal source activity 500 TBq) was installed there. Materials were irradiated in four rotating cylindrical containers, and a great advantage of this unit was the versatility of materials that can be treated. The service was exploited by more than 50 medical and health-care institutions in Czechoslovakia. The irradiation facilities of the ÚJV Řež played a vital role when several new Czechoslovak medical products were implemented, e. g. coils for dialysis machines, electrodes for pacemaker, preproduction batch of single-use disposable syringes, etc. Also, radiation decontamination of various pharmaceutical substances, such as enzymatic (pancreatin, chymotrypsin) or organo-preparations (thyreoglobulin, thyreoidea), was performed here after proper irradiation conditions had been established, since other classical procedures, such as thermal sterilization, proved to deteriorate these materials significantly. [22]

5.2. Radiation processing of cable insulations

Within a collaborative project of the ÚJV Řež and Kablo Kladno Vrchlabí Works Concern (since 1992 Kablo Electro, Inc.) two technologies were developed and put into practice. [23, 24]

In 1983, a production line for radiation vulcanization of silicone-rubber wire insulations equipped with a linear electron accelerator ELV-1 (electron energy 1 MeV, power 25 kW, made in the Institute of Nuclear Physics in Novosibirsk) was put into operation, after many technological issues had been resolved: selection of the optimum silicone rubber composition, preparation of the wire core and designing irradiation technique to secure homogeneous irradiation of insulation. The latter device – a special wire positioner — allows rotation of the cable along its axis. [25] Radiation vulcanization, when compared with the classical peroxide vulcanization, yields material with a better quality and at a lower cost. By the middle of 1984, 30 000 km of radiation-vulcanized cable worth over 50 million Kčs was produced. The production capacity amounts to about 10 000 km/year (wire haul-off rate up to 250 m/min). Besides silicone, PVC, polyethylene and EVA (ethylene-vinyl acetate) insulated wires are also irradiated. It was the first industrial line equipped with an electron accelerator installed in Czechoslovakia and it was modernized in the years 2001-2002 (modernization involved individual parts of the production line besides the accelerator itself).

Another irradiation line, designed primarily for radiation crosslinking of domestic polyethylene insulations (Bralen KB 2-11), was put into operation in 1991 and presently it is exploited in compliance with the market needs. The line is equipped with a self-shielded ILU-8 electron accelerator from the same producer (electron energy 0.4-0.9 MeV, power 20 kW). Electron beam exits through two scanning horns which allow two-sided wire irradiation to be performed; the wire haul-off rate of the production line is up to 450 m/min.

5.3. Radiation preservation of objects of art and relics

In the Central Bohemia Museum in Roztoky nr. Prague a unique gamma-ray conservation facility was built and opened in 1982, within the collaborative project between the Museum and the ÚJV Řež. [23, 24] The project was preceded by thorough investigations of various possible deteriorative radiation effects e. g. on polychrome, as well as by about ten years of experience of radiation treatment of valuable artworks in the ÚJV Řež (e. g. paintings by Lucas Cranach on wood). This irradiation facility was the worldwide first in that it was operated by a museum and/or a cultural establishment, yielding to Czechoslovakia at least one primacy, regarding the radiation processing plants. Irradiation chamber of a size of $4.5 \times 4.5 \times 3.6$ m^3 is equipped with a centrally located ^{60}Co gamma-ray source of a nominal activity of 200 TBq.

Mostly radiation disinfestation of wooden objects of art attacked by wood-worming insects (woodworm, sawyer, powder-post beetle) is performed, but also other materials — e. g. leather, textile, paper – can be treated there. The facility provides centralised irradiation services on commercial basis with about 2000 medium size articles (70 dm^3)handled per year. Large size of the irradiation chamber makes it possible to irradiate rather bulky articles, e. g. church pulpits, winding stairs, benches or organs. Also new furnitures (e. g. Rattan) imported from India and Indonesia are treated with radiation there.

In the ÚJV Řež, further effort was directed towards development of a mobile irradiator for *in situ* applications, based on the experience of the irradiation unit HWK-3 ("Holzwurmkanon"), operated in GDR in the late 1970s and tested in Neues Palais in Potsdam-Sansoucci. [26] However, much more sophisticated device – a sort of computer-operated Robot — was developed within the collaboration of the ÚJV Řež with the Nuclear Fuel Institute Prague-Zbraslav in the late eighties. [27] The irradiation source consisted of two ^{137}Cs elements with activity of

120 TBq each, placed in a container made of depleted uranium. During the irradiation, the source moved according to an irradiation program on a vertically mounted frame with dimensions up to 2 m (width) × 6 m (height), placed in front of the object to be irradiated. The irradiator was tested in the Castle of Hrádek nr. Nechanice (a wooden porch at the entrance to one of the halls was treated with radiation). However, further experiments and/or applications were terminated due to the new and more strict legislation regarding the assessment of the radiation protection of the public.

5.4. Radiation modifications of semiconductors

Since 1986, Polovodiče a. s. Prague company (earlier ČKD Polovodiče) is in possession of a Tesla–4 MeV linear electron accelerator (power 1.2 kW) and irradiates semiconductor power devices to produce defects — i. e. recombination centers — in the bulk material. (The initial irradiations and technology development were performed with the Tesla–4 MeV Linac installed in the ÚJV Řež). Such defects accelerate the commutation process in matrix and serve to regulate (shorten) turn-off time and reverse-recovery time of thyristors and silicone diodes, respectively. The modified devices meet the demands of frequencies higher than commonly used 50 or 60 Hz, which results in miniaturization of other construction elements, such as transformers and impedance coils. This eventually saves material and enhances progressive construction of the final products (e. g. welding machines). [28]

At present, about 10 % of the manufactured components are irradiated. A significant fraction of the production is exported. Since 1995, the Swiss ABB Semiconductors has been the company's largest business customer.

5.5. Radiation syntheses of organic compounds

Radiation syntheses belong to those applications which - in most cases round the world — did not step off the laboratory scale.

In the ÚVVVR Prague in the 1960s and 1970s several projects were handled. Synthesis of an important Halotane anesthetic (1,1,1-trifluoro-2-bromo-2-chloroethane), based on the radiation-induced addition of hydrogen bromide to trifluoro-chloro-ethylene, was developed up to the stage, when the British company ICI was willing to buy the license with all rights for 110 thousand British pounds, probably in order to protect its own technological procedure. [19] Some other processes — radiation isomerization of maleic to fumaric acid and synthesis of methyl chloroform and benzotrichlorid by radiation chlorinations — were developed only up to the laboratory stage and ended with the technological designs; for methyl chloroform a technology with a production capacity of 15000 tons per year was developed but not implemented. Only one of the investigated processes, namely combined radiation-thermal bromination of p-xylene yielding tetrabromo-xylene (TBX), was tested on industrial scale in Povážské chemické závody Žilina (Slovakia) in the early 1970s. [18, 29] The TBX was supposed to be used as a flame retardant for polystyrene foam and the planned capacity of the facility was 140 tons per year. However, only a few batches were produced and after many difficulties the facility was permanently closed in 1984, by decommissioning the gamma-ray source. There were several reasons for this failure, among them alleged existence of a competing flame retardant (tetrabromocycloctatetraene) and radiation psychosis contributed as well.

In the mid-1960s in the Research Institute of Pure Chemicals (Lachema) Brno, radiation synthesis of dibutyl-tin-dibromide — a substance necessary for synthesis of PVC stabilizers – was developed but the industrial process was not established.

At the turn of the seventies, several other projects were also investigated in the ÚJV Řež. Radiation-initiated reaction of maleic acid with alcohols yielded polycarbonic acids (terebic acid) and their esters. These products could serve conveniently as plasticizers and detergents, and for textile preparations. Also, terebic acid can be an industrial substitute of citric acid. Regrettably, lack of interest by producers and partially import nature of maleic acid prevented construction of pilot production plants with planned capacities of 100 tons per year, for each of the developed technologies. [18, 30] Similarly, the investigated processes of radiation telomerization of halogenated olephines with alcohols yielding fluoro-alcohols were not implemented, though the products could have been used as inflammable hydraulic liquids, mould release agents, or tenside additives. [18, 30]

5.6. Food irradiation

Research started in about 1960 and the early studies comprised experimental irradiations of various foodstuffs (potatoes, onions, mushrooms, cereals, meat, poultry, strawberries, peaches and fodders) and testing their wholesomeness; irradiations were carried out mainly in the ÚJV

Řež. [31] National health-authorities (chief health officers of the Czech and Slovak Republics) permitted in 1976 irradiation of experimental batches (up to 10 tons) of potatoes, onions and mushrooms, for sprouting inhibition or ripening delay. The aim of these studies carried out within a collaborative project of the ÚJV Řež and VÚP Bratislava — building an irradiation plant — was not fulfilled. [19, 32] The results obtained with onions and mushrooms were satisfactory and promising, however potatoes, the main anticipated commodity to be treated, showed after irradiation accelerated rotting and moulding, caused by their damage on harvesting.

Also another project, aimed at radiation disinfestation of cereals by using an electron accelerator, was not successful owing to the very high costs, when compared with the chemical treatment. [19, 32]

On a commercial basis large amounts of only spices (mainly pepper and caraway), dry vegetables and herbs have been irradiated with the ^{60}Co gamma-ray source (PERUN in Artim s.r.o. Prague) to reduce pathogens such as *E. coli* since the early 1990s, in amounts shown below. [33] Actually, only these commodities can be irradiated in compliance with the current EU regulations.

Table: Amounts of the foodstuffs irradiated in the Czech Republic (mainly spices, dry vegetables and herbs). [33]

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Tons	130	250	480	750	850	930	1000	800	800	571	854	1046

5.7. Applications of radiation in agriculture and gardening

Radiation-mutation plant breeding has a rather long tradition. An outstanding semi-dwarf spring barley cultivar Diamant was derived from the cultivar Valtický by X-ray mutagenesis in breeding station Branišovice (allegedly dry cereal grains were irradiated to a dose of 10 000 R (100 Gy) with a dental X-ray apparatus). [34–37] This cultivar was registered in the period 1965 to 1976 and was intensely used in breeding programs, owing to its high yield, short straw and excellent malting quality. In the years 1970-1972, Diamant yield was on the average 5.5 metric centners/hectare higher than other cultivars. Diamant varieties were planted on 92 % of the total barley-seeded area in Czechoslovakia and according to a conservative estimate this yielded a surplus production corresponding to one thousand million Kčs (Czechoslovak Crowns). More than 120

European spring barley varieties registered worldwide, among them 42 in the Czech and Slovak Republics, trace back to Diamant.

A "Gamma field", serving the needs of the radiation-genetic research and mutation-breeding praxis and operated by the Forestry and Game Management Research Institute in Zbraslav-Strnady was established in 1961. [38] It was equipped with a ^{60}Co gamma-ray source (15 TBq) with fully automatic remote control (dose rate from 10 mr/h to 10^4 mr/h). Irradiation regime was arranged into 18- to 20-hour irradiation cycles. The plants were placed in circles around the source and formed sectors with radius of 90 m and arc lengths from 104 cm (near the source) to 1042 cm (field circumference). Within the 15 years after the field opening in 1962, it was exploited in total at 89.6 % (at 37.5 %, 22.0 % and 23.3 % for produces of fields, fruit cultivars and forest-tree species, respectively). [39] Among others, the first low-erucoic (or no erucoic) varieties of rape in Czechoslovakia were breeded there. [40] The facility was permanently closed in 1979 for economical reasons, by decommissioning the gamma-ray source.

Within a collaboration of mycologists (Mycologic Station Prague) with the ÚJV Řež a new field mushroom strain *Agaricus bisporus* MS 211 was developed by radiation mutation (irradiation of germinated spores) in the 1970s, characterized by larger sporocarps. About 400 tons of this radiomutant were grown in the years 1978–80 by the Žampiony Jaroměř company; this represented an increase of about 12% in the production at the same cost. [18]

In the Dairy Research Institute Prague, new mutants were obtained by irradiating strain *Streptococcus lactis Lactoflora* 71/1 with ^{60}Co gamma rays, which increased the production of the nisin antibiotic by a factor of four. Dry milk nisin powder is used as an additive to increase the quality and durability of the processed cheeses. Production of this material started in the Industry of the Milk Nourishment in 1975 and within a year the output reached 50 tons. [40]

Within a collaborative project of the ÚJV Řež with the Oseva Stránčice agro-company a method for radiation sterilization of peat carrier for preparing Rizobin seed inoculant (contains *Rhisobium bacteria* strain) was developed in the late 1980s. [41] *Rhisobium bacteria* can fix nitrogen from air, thus decreasing the need of using nitrogen fertilizers; Rizobin is an ecological fertilizer for growing wetch fodders and leguminous plants. This technology is protected under a patent and currently the material is prepared by the Selecta company and sterilized by radiation by Bioster a.s. in quantities of several hundred thousand hectare dosages per year, which are applied both in the Czech Republic and abroad. [24]

Radiation-mutation breeding of dahlia flowers has had a long tradition, dating back to 1970s. Such mutations were carried out in breeding stations in Turnov and later in Heřmanův Městec and many varieties cultivated today date back to that period. Presently radiation-mutation breeding of dahlias is carried out — on a small scale only — in Silva Tarouca Research Institute for Landscape and Ornamental Gardening in Prague-Průhonice. Dahlias tubers are irradiated during the rest period with a low dose of gamma radiation and further bred from cuttings; besides colour changes, mutations of plants growth size, tubers quality and shape of individual flowers occur. [42] Also, apex cuttings of chrysanthemum are irradiated with a low dose of gamma radiation; plants cultivated from the cuttings taken from the offsets (grown from basal buds) of the irradiated cuttings show mutations in colour (e. g. white to yellow, rose to white or bronze).

5.8. Radiation regeneration of water wells

Delivering capacity of underground water-wells can be significantly diminished by so called ochre-clogging, which — in some cases — has a biological origin; it is caused by bacteria like *Thiobacillus ferroxidans* and *Gallionella* responsible for the redox reactions of the ions Fe(II), Mn(II), etc. and formation of insoluble hydrolytic products. Radiation kills these bacteria thus preventing clogging and borehole aging. The technology was invented and widely applied in GDR in more than 600 water wells. Based on this experience, four ^{60}Co sources (total activity of 52 TBq) were installed in a well near Veselí nad Luž. in 1979, within a shared research project of the ÚJV Řež, Water Research Institute Prague and Water Resources Prague. Owing to the favourable results, two other wells in southern Moravia were equipped with ^{60}Co sources in the early 1980s. Despite the technology proved to be generally successful, it is not employed currently and radiation sources had to be removed (in GDR immediately after the reunification of Germany). [18, 43]

5.9. Radiation degradation of polychlorinated biphenyls (PCBs)

In Czechoslovakia large amounts of toxic PCB-based materials (about 21 000 tons) were produced in the years 1959–1984, more than half of them for the domestic use. Method of degradation of PCBs, based on a radiation-induced dechlorination chain reaction in isopropanol, was investigated in Canada and a mobile irradiation unit with a ^{60}Co gamma-ray source with a capacity to dechlorinate about 25 000 kg of PCBs per year was designed. [44] The possibilities of the disposal of PCBs and perchloro ethylene in the Czech Republic *via* such radiation degradation process have been intensely investigated in the Department of Nuclear Chemistry of the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague, in collaboration with the ÚJV Řež and TESLA V.T. MIKROEL since the mid-1990s. [45] The principal advantage of this process consists in converting chlorine from organic to harmless inorganic form, which can be separated from the irradiated solution; other reaction products - acetone and biphenyl - can be utilized further. A through-flow apparatus for irradiation with TESLA Linac was designed, constructed and tested. This equipment made it possible to handle a volume of approximately one hundred liters of the solution. Results obtained showed a real possibility of the practical use of this technology, and a new project aimed at pilot-plant testing, is under study now.

5.10. Radiation colouration of glass for decorative purposes

The New Scene of the National Theater in Prague was finished and opened in 1983 (centenary of The National Theater). Façades of the new building are covered with glass units (shape of a TV screen with dimensions of $80 \times 40 \times 20\,\mathrm{cm}^3$) — securing noise-insulation — which were made of Simax glass in Kavalier glass works (Sázava). The original glass had somewhat unsightly greenish colour and for the factory's operational reasons it was not possible to change the composition of the melt because it was used also for a range of other products. Thus, the individual glass units (7700 in total, weighing about 40 kg each) were irradiated with ^{60}Co gamma-ray source "Perun" of the ÚVVVR Prague. The gold-brown tone acquired by irradiation fulfilled the architectural rendering better than the original glass colour. [46]

Similarly, the walls in the Metro Station Jinonice (earlier called Švermova, opened in October 1988) are covered with specially moulded pieces of Simax glass irradiated with ^{60}Co gamma in ÚVVVR Prague; the semicircular glass bricks were designed by František Vízner and were used (unirradiated) earlier also in the Metro station Karlovo náměstí (opened 1985). [47]

5.11. Some other applications

In the SVÚT CRT Veverská Bítýška there was a low-energy ESH electron accelerator (Dürr, Stuttgart, 250 kV, scanning width 60 cm) installed in about 1984 and operated up to about 1999. [48] It was equipped with an irradiation line, which was used mainly for producing cable shielding foils at a semi-pilot scale. The foils were fabricated by laminating aluminum films (9 to 90 mμ thick) and PET films (12 mμ thick) via electron irradiation in inert nitrogen atmosphere. Another application was lamination of materials to be used for packaging in food industry.

There are several other applications of ionizing radiation, often subject to patent protection, which, however, were not implemented at a large industrial scale.

In the ÚVVVR Prague and in the ÚJV Řež abrasive materials for material machining have been irradiated since the early 1980s. The irradiated tools kept better original shape and were more resistant towards abrasion.

In the ÚVVVR Prague methods of preparing wood-plastic composites (based on unsaturated polyester resins, styrene, polymethyl methacrylate and PVC) have been investigated since the 1960s. Also, techniques for fabrication and irradiation of small products were designed (e. g. for use in the musical-instrument industry). In the 1970s, there was a collaborative project with the State Wood Research Institute Bratislava, for installing an experimental production line (700 tons/year) for wood-plastic flooring (mosaic parquet from beech or other wood species impregnated with polyester resin-styrene or methylmethacrylate), with properties surpassing significantly those of the conventional oak flooring. None of the technologies was put into practice. [49]

5.12. Problems connected with the implementation of radiation processing

The main problems encountered during the research and technology development and implementation in the field of radiation processing in Czechoslovakia, as analyzed by a former executive of the Czechoslovak Atomic Energy Commission [19], fall into three areas:

- technical: lack of irradiation sources and materials for testing technologies, difficult collaboration among professionals from different fields, and low technical level of the implementation fields,

- human factor: radiophobia, priority being given to classical technologies,
- economic: high cost of investments and unfavourable economic climate in Czechoslovakia.

These might explain why many of the projects – some of them even not mentioned here – sooner or later failed.

6. Conclusion

The history of ionizing radiation and of its use coincides almost exactly with the 20th century. It is demonstrated here that ionizing radiation, despite having a bad reputation which perhaps it gained owing to the misuse of nuclear weapons and some radiation accidents which actually could have been prevented, played an important and positive role in the 20th century technology. Ionizing radiation — with a large variety of its effects — is a very powerful tool and when handled with care it can be considered a very safe tool as well. Ionizing radiation can deliver some new and useful products and prevent deterioration of existing ones. In the Czech Lands many obstacles had to be overcome when pioneering new technologies; nevertheless, quite a few applications of ionizing radiation in various fields proved to be successful.

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Appendix

Lists of large irradiation sources – both for laboratory and industrial purposes – which have been installed in the Czech Lands

^{60}Co gamma-ray irradiators for radiation research/processing in the Czech Lands

(all irradiators — except for those from the AECL — are of domestic design and construction)

Activity (nominal)	**User, installed (year)**	**Irradiation chamber**
ca. 15 TBq ^{60}Co	Military Academy AZ Brno ca. 1958	$20 \times 20 \times 50$ cm^3
ca. 9 TBq ^{60}Co	Res. Inst. for Rubber and Plastic Materials Gottwaldov (today Zlín), 1958	annualar space diam. 150/40, height 150 mm
ca. 9 TBq ^{60}Co	Nuclear Research Institute Řež, ca. 1959	270°-sector radius 45 cm, height 45 cm
190 TBq ^{60}Co Gammacell 220, AECL	Inst. Res. Production and Appl. of Radioisotopes Prague, ca. 1960	diam. 150, height 200 mm
70 TBq ^{60}Co	Res. Inst. for Rubber and Plastic Materials Gottwaldov (today Zlín), ca. 1962	diam. 40 cm, height 25 cm
500 TBq ^{60}Co	Nuclear Research Institute Řež, ca. 1965	diam. 1 m, height 77 cm (ca. 500 dm^3)
500 TBq ^{60}Co ("ROZA")	Nuclear Research Institute Řež, ca. 1971	four rotating containers (each diam. 35 cm, height 65 cm)
15 000 TBq ^{60}Co Type J-6000, AECL	State Textile Res. Inst. Veverská Bítýška*), 1972	automatic continuous irradiation line
ca. 3000 TBq ^{60}Co ("PERUN")	Inst. Res. Production and Appl. of Radioisotopes Prague**), 1980	$3 \times 3 \times 5$ m^3
200 TBq ^{60}Co	Central Bohemia Museum Roztoky near Prague, 1982	$4.5 \times 4.5 \times 3.6$ m^3
ca. 800 TBq ^{60}Co ("RADEGAST")	Inst. Res. Production and Appl. of Radioisotopes Prague**), 1983	

*) Today BIOSTER, a. s.

**) Today Artim s. s r. o. Prague

Electron accelerators for radiation research/processing in the Czech Lands

Type of accelerator (producer)	User (installed)	Parameters
Van de Graaf TUR (Transformatoren- und Roentgenwerk Dresden)	State Textile Research Institute Brno	0.7-2.0 MeV, 0.4 kW
Linac UR 4/1200 (Tesla Res. Inst. of Vacuum Electrotechnics, Prague)	Tesla Research Institute of Vacuum Electrotechnics (1969)	4 MeV, 1.2 kW
Linac UR 4PR (Tesla Res. Inst. of Vacuum Electrotechnics, Prague)	Nuclear Research Institute Řež (1976)	4 MeV, 0.1 kW
Linac UR 4/1200 (Tesla Res. Inst. of Vacuum Electrotechnics, Prague)	Nuclear Research Institute Řež (1980)	4 MeV, 1.2 kW
Linac ELV-1 (Institute of Nuclear Physics Novosibirsk)	Kablo Works Vrchlabí (1983)	4 MeV, 25 kW
ESH (Dürr Stuttgart, licence of Polymer-Physik GmbH, Tübingen)	SVÚT-CRT Veverská Bítýška (ca 1984)	250 keV, 5 kW
Linac L 4/1200 (Tesla Res. Inst. of Vacuum Electrotechnics, Prague)	Polovodiče a.s. Prague (1986)	4 MeV, 1.2 kW
Linac L 4/1200 (Tesla Res. Inst. of Vacuum Electrotechnics, Prague)	Synthesia Works Semtín (1991, very soon shut down)	4 MeV, 1.2 kW
Linac ILU-8 (Inst. of Nuclear Physics Novosibirsk)	Kablo Works Vrchlabí (1991)	0.4–0.9 MeV, 20 kW

How to get Information by Viewing

Peter Schreiber

The presentation of the history of science and technology in a museum as well as the choice of illustrations in books and papers on this matter needs a theoretical foundation that considers the manner in which people recognize and digest optical information. As such a theoretical basis I propose a new and growing interdisciplinary science, in Germany named "Bildwissenschaft", in which elements of geometry, logic, psychology, neuroscience, computer science, philosophy, history of arts, and others work together. (For general information cf. [Sachs-Hombach], [Tufte] and [Mallot] from the references.) At the same time this Bildwissenschaft (I prefer the term optoinformatics) may serve as further example for the formation of new interdisciplinary topics at the change from the 20th to the 21st century (cf. the contribution of A. Guran).

The term picture in the following denotes the optical signal (may be moving) received by the human retina or by a scanner, camera,… that may be generated by a two-dimensional picture in narrower sense or else by looking at a three-dimensional scene. For shortness and simplicity we neglect here that the information transmitted by such a picture may denote a process, a question, an emotion,… and concentrate on the case of terms and statements (shortly: expressive pictures). In deed, there are strong analogies between the logical structure of text and that of pictures. Hence that part of optoinformatics treated here may be denoted by picture logic. First we have, as in classical logic, to distinct between syntax and semantics. The first one has to do with all notions and processes related to the material existence of a picture (and hence may be recognized or produced by a machine). The second one concerns the manifold of possible interpretations resp. meanings of the picture and all notions grounded on this.

As in classical logic there are terms, i.e. strings denoting objects, and expressions, denoting statements. Terms are simple, i.e. names or variables, or they are composed by simpler terms and functors in a hierarchical manner. In a text e.g. *1, 2, Peter* are names, *animal, girl* are variables, *…'s father* and *the face of…* are functors, so *Peter's father* is a term and *the face of Peter's father* is a more complex term. Simple expressions are builded from terms by the help of n-ary relators (strings denoting n-ary predicates) with different numbers n. In a text e.g. . …*is a prime number,* …*has fair hair* are unary relators, <, …*is married with*…. are binary relators,…*is a child of*… *and* …. is ternary.

Hence *2 is a prime number*, *Peter has fair hair*, *Peter is married with Jane* are expressions. More complex expressions are builded from simpler expressions by logical connectives as *and, or, not,*… or by quantors *For all*…. *It exists*… So e.g. *All girls have fair hair. For all men exists a woman that is married with him,* are more complex expressions. The examples show that the possibilies of syntactical composition may be formulated in rules and that they are independent of the meaningfulness and truth of the expressions. Both notions belong to semantics.

The analogous structure we find in expressive pictures. Some parts of a picture are names or variables. (If a picture of a man shows a special man, eventually known to the observer, then his picture is an (optical) name for him. If it shows any man, e.g. in a traffic signal, then it has the nature of a variable.) *The borderline of*…, *the common border of*… *and* … are syntactical functors, …*has a symmetry axis*…, … *is surrounded by*…, …*is similar to*… are examples of syntactical relators. Note that we have no or at least no short linguistic descriptions for most of the syntactical relations between parts of pictures. We „see“ them and re-cognize them in other pictures. So the examples written in italics are not themselfes optical syntactical relators but only a clumsy trial to describe them. Note also the important difference between syntactical and semantical notions. *The roof is red* refers to a meaning of a picture of a *roof*, hence it is a semantical interpretation. *Looks like a roof,* …*looks red* refers to the syntax of the picture. *Looking red* may be caused by being red but also by red light or by a mistake in printing.

Classical logic is founded on the fact that the same word (syntactical unit) may have many different meanings: A statement B is a logical consequence of the statements C, D iff A is true in all intepretations in which also C and D are true. But except of rare cases the syntax of a text seemingly is uniquely. In contrary in pictures mostly also the syntactical structure is not uniquely. E.g. a photomosaik portrait of Lincoln by R. Silvers we can describe in terms of the rectangular raster of the little picture parts, neglecting the face of Lincoln, but also in terms of eyes, nose etc. of this face, neglecting the raster structure of the whole portrait [Silvers, p. 13]. The same phenomenon was used as early as by G. Arcimboldo in his famous portraits composed from fruits and plants and it is repeated in all digitalized pictures without irritating us. In everyday situations this fact is hidden because we at once do aside all syntactical possibilities which we value as irrelevant in a given situation and enviroment. But in psychological tests and also in some kind of entertaining pictures the syntactical and also the semantical doubtfulness of special pictures plays an important role.

For more details on classical logic I must refer to textbooks, for more details on picture logic on my German papers *Mathematik und Logik* in [Sachs-Hombach 2005a] and *Bildlogik* in [Sachs-Hombach 2005b]. Here I have to focuss on three aspects of the matter which are relevant for the aim of the conference. The first of them ist the interplay between local and global information, the second one the interplay between pictures and written information, the third one the role of portraits in the history of science and technology.

Recognizing a text, usually we read it sequentially. So we get lots of *local* informations by single words and sentences. Only at the end of reading we have perhaps some *global* information as e.g. what is the essential contents of the text, what wants the author to say, which kind of people he may be. Some other global information as e.g. stylistic properties is hidden and may be unveiled only by extended statistical analysis. But also in the case of text some very local information sometimes can be neglected, e.g. single misprinted letters or in some texts also whole sentences. On the other hand, there are many tools helping to catch the global information before reading the whole text, e.g. division in chapters and §§ with titles, table of contents, but also some techniques of "diagonal reading". In contrary, looking on a picture in most cases we get at once a global information about the contents of the picture and the transmitted information before looking on details, and some of the details, particularly the degree of brightness and the color of a single pixel of a digitalized picture, are totally unimportant. Because of everydays experience we tend to recognize pictures with respect of their hierarchical syntax "from outside to inside". How deeply we go inside into this hierarchical structure depends on the viewer and his aim. Often also bigger details than pixels may be not interesting and not necessary for understanding a picture.

A very good example ist the graphical display of the sun activity during the years 1877–1902 (x-axis), sorted according to the parallel circles of the surface of the sun (y-axis) (fig. 1). We see at once two very important informations: The activities are globally periodical and they are symmetrical with respect to the equator of the sun. The same information would also be contained in a sequential table of values

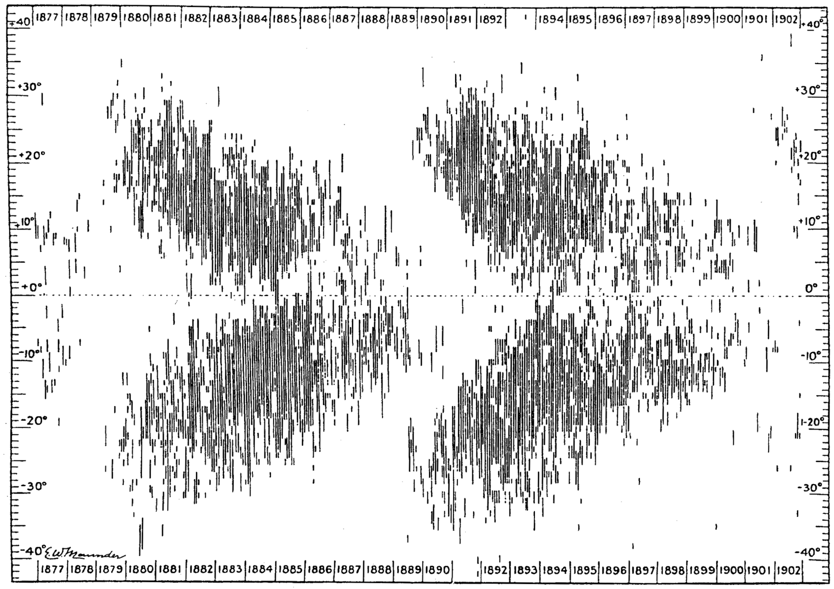

*Fig. 1. From*E. W. Maunder*: Notes on the Distribution of Sun-Spots in Heliographic Latitude 1874 to 1902.* Royal Astronomical Society, Monthly Notices 64 (1904)

but only to catch by extended processes and most probably remain unexplored. Of course one may take from the diagram also the activity of a single year on a special parallel circle, but this is not interesting for the majority of the viewers. In contrary, graphical time tables of railway routes present no global information. The aim here is the use of the diagram as a tool for avoiding conflicts. Maps present always a lot of local information. A global oversight is given only if the map contains wellknown coast profils, border lines, rivers, or main cities. In the historical map of a part of France (fig. 2) displayed here all such hints are missing and hence it gives only small information for most viewers though it contains so many details.

Let me mention that in some cases (e.g. handwriting, old prints, calligraphic texts) the optical nature of texts plays a role that can't be catched by classical computer science and information theory which always start with the assumption that there are strings builded from well

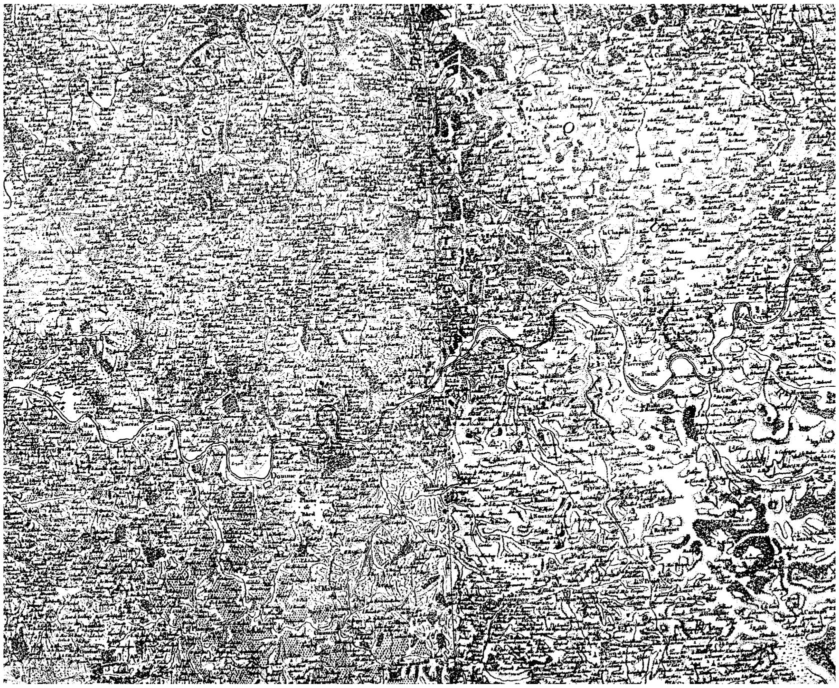

Fig. 2:.Map from the midpart of France, about 1760

distinct signs of a fixed finite given set of signs. Another case in which the optical character of text plays a role is the interplay between image, text, and labelling, especially in scientific and technical information devices. There are texts hardly to understand without illustrations and also pictures hardly to understand without explanation inside and / or outside the picture. My personal experience was often: too many pictures without sufficient explanation in books and papers and too less or bad organized explanations in exhibitions. Such explanations should support the human tendency of recognizing optical information from outside to inside, e.g. commentary of the whole should be written in bigger letters than commentaries of details and arrows may indicate in which order the visitor should read the texts. A general demand of the temporary history of science and technology says: Take historical pictures as an independent matter of research, exploring their making, original function and use, and show them never without sufficient explanations and commentary [Nikolow, Bluma].

At the end we will discuss the role of portraits in the history of science and technology from the viewpoint of picture logic. In my opinion the curious need to show portraits of everybody is much greater than the wants of the public to see them. May be, it is a relict from the role of the pictures of gods and saints. May be, it is often the simplest way to show anything, pep up a text by some pictures. The picture of an individual is in the syntactical hierarchy from outside to inside first a single object, in the next level consisting of eyes, nose, hair,... and parts of the clothing. A single object can be only in one-place relations. He looks old or young, nice or not so nice, friendly or strong,... Without label or knowledge of the viewer the portrait would have the character of an optical variable. With label, i.e. with a name in letters, it is an "optical name", and storing it in the brain makes sense only if there is an expectation that the same "name"' later on will occur also in other connections. If it is a portrait from older times than the observer can from the next level of the syntactical hierarchy get information how the people in this time were looking, which clothes, which hair-style, which beard-style,... If it is the portrait of a contemporary we learn only that he is a contemporary. By the way, there are many horrible examples of famous people from which exist so very different portraits that nobody can have an impression how they looked really. Modern psychology and medicine confirm that our perception system takes much information from the mimicry, the moving face (and understanding the manner in which this works is a recent research matter) but never from a single fixed photo. (This is also the cause why most first dates, if founded on an exchange of photos, are frustrating.)

My short paper could only give some hints from a very new viewpoint and perhaps awake more attention than before for the questions What will we show, why will we show it, how should we show it so, that our aim will be satisfied.

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Zur Entwicklung der theoretischen Physik in der ersten Hälfte des 20. Jahrhunderts — Gedanken zur Darstellung der Wissenschaftsentwicklung im 20. Jahrhundert[1]

Karl-Heinz Schlote

Wenn man das Thema dieser Konferenz betrachtet, so drängt sich die Frage auf, ob das darin angesprochene Problem des Umgangs mit der Entwicklung von Wissenschafts- und Technikgeschichte im 20. Jahrhundert wirklich ein neues Problem ist, das erst im letzten Jahrhundert entstand. Anders formuliert, was macht uns im Vergleich mit früheren Jahrhunderten den Umgang mit der Wissenschafts- und Technikentwicklung so schwierig, dass er jetzt zum Problem wird? Aus meiner Sicht sind es drei Komplexe, die hier zu berücksichtigen sind:

1. der rasante Wissenszuwachs, den wir im 20. Jahrhundert erlebt haben und den es aus rein quantitativer Sicht zu bewältigen und adäquat widerzuspiegeln gilt;
2. die fortschreitende Spezialisierung innerhalb der Wissenschaften, die sich in der Auffächerung der einzelnen Wissenschaftsdisziplinen äußert, und die zunehmende Interdisziplinarität, die sich u. a. in zahlreichen neuen Grenzdisziplinen zwischen zwei und mehr Disziplinen niederschlägt. Diese Spezialisierung führte dazu, dass sich oft schon die Vertreter innerhalb einer Wissenschaftsdisziplin nicht mehr verstehen. Wie soll dann der Wissenschaftshistoriker die Resultate einer oder mehrere Disziplinen verstehen?
3. die sachgemäße Bewertung der auf den verschiedenen Gebieten erzielten Leistungen. Der Wissenschaftshistoriker muss, um die historische Entwicklung eines Gebietes, einer Disziplin etc. darzustellen, die grundlegenden Ergebnisse auswählen und bewerten, ansonsten präsentiert er nur eine mehr oder weniger systematische Auflistung von Resultaten und Fakten, die kaum Wet hat, weil sie keine Entwicklungszusammenhänge aufzeigt und erklärt bzw. diese in einer Flut von Informationen untergehen.

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[1] Herr Professor Horst Remane zu seinem 65. Geburtstag am 29. Mai 2006 gewidmet

Die mit diesen drei Komplexen verknüpften Aufgaben standen in der ein oder anderen Form schon früher vor den Wissenschaftshistorikern und haben ihnen Probleme und Kopfzerbrechen bereitet. Es sei nur daran erinnert, dass es bereits am Ende des 19. Jahrhunderts in vielen Disziplinen zu zahlreichen Diskussionen und Bestrebungen gekommen war, um der Zersplitterung des jeweiligen Fachgebiets Einhalt zu gebieten.

Die Situation soll am konkreten Beispiel der theoretischen Physik und der Entwicklung ihres Verhältnisses zur mathematischen Physik in der ersten Hälfte des 20. Jahrhunderts in Deutschland illustriert werden.[2]

Die theoretische Physik an der Wende zum 20. Jahrhundert

Nach einer Phase des raschen Aufschwungs und der Herausbildung als eigenständige Subdisziplin befand sich die theoretische Physik am Ende des 19. Jahrhunderts in einer Phase der Konsolidierung, in der es nun galt, sich gegenüber der mathematischen Physik einerseits und der Experimentalphysik andererseits zu profilieren. An den meisten Universitäten waren zwar Extraordinariate, in ganz seltenen Ausnahmefällen sogar Ordinariate für theoretische Physik geschaffen worden, doch nicht überall gelang es, diese Position zu erhalten und außerdem war dieses Extraordinariat stets dem Ordinarius für Experimentalphysik untergeordnet. Letzterem oblag auch die Leitung des Instituts und er verfügte über den Einsatz der vorhandenen Experimentalkapazitäten. Die Mehrzahl der Berufungen für theoretische Physik erfolgte mit der mehr oder weniger explizit formulierten Aufgabenstellung, den Vertreter der Experimentalphysik in seiner Arbeit und speziell im Lehrbetrieb zu unterstützen. Im Allgemeinen bildete die außerordentliche Professur für theoretische Physik einen wichtigen Karriereschritt auf dem Weg zu einer ordentlichen Professur. Die Abgrenzung zur Experimentalphysik beinhaltete also zugleich das Ringen um Anerkennung der eigenen beruflichen Position sowohl innerhalb der Gelehrtengemeinschaft als auch im gesamtgesellschaftlichen Rahmen.

Inhaltlich konnte die theoretische Physik durchaus auf bemerkenswerte Erfolge verweisen. In den einzelnen Teilgebieten lagen theoretische

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[2] Eine ausführliche Darstellung der Herausbildung der theoretischen Physik geben C. Jungnickel und R. McCormach in ihrem zweibändigen Werk (Jungnickel/McCormach 1986). Bezüglich der Entwicklung der mathematischen Physik sei auf (Grattan-Guinness 1990) und (Garber 1999) verwiesen

Ansätze vor, die ein unterschiedliches Niveau hatten und folglich in ihrer Reichweite sehr differierten. Zeitweise standen mehrere theoretische Erklärungsmuster zur Fundierung eines Teilgebietes nebeneinander. Es sei nur an die Optik bzw. die Lehre von Elektrizität und Magnetismus (Elektrodynamik) erinnert. Gemeinsam war diesen Ansätzen, dass sie eine Basis für den systematischen Aufbau des jeweiligen Teilgebietes lieferten, eine weitgehend konsistente, mit den empirischen Daten verträgliche Erklärung der wichtigsten Erscheinungen ermöglichten und oft Hinweise für weitere experimentelle Untersuchungen gaben. Es fehlte aber lange Zeit ein spektakulärer Erfolg etwa in Form einer Theorie, die die Zusammenhänge zwischen zwei oder mehreren Disziplinen oder Subdisziplien auf einer gemeinsamen theoretischen Basis herstellte. Einen solchen Erfolg stellte dann die Maxwell'sche Theorie der Elektrodynamik dar, die ja bekanntlich eine gemeinsame Basis für die elektromagnetischen Erscheinungen, also die Elektrodynamik, und die Optik lieferte und nach jahrzehntelangen Auseinandersetzungen durch den experimentellen Nachweis der elektromagnetischen Wellen durch Heinrich Hertz (1857–1894) eine glanzvolle Bestätigung erfuhr. Die Wirkung dieses Erfolges wurde jedoch dadurch etwas geschmälert, dass durch die lange Zeit bis zur Anerkennung und Durchsetzung der Maxwell-Faraday'schen Ideen das rasche Voranschreiten der Physik bereits wieder neue Aufgaben vor der Theorie aufgetürmt hatte. Diese sollen im nächsten Punkt skizziert werden, zunächst sei aber festgestellt, dass insgesamt die theoretische Physik ihre inhaltliche Existenzberechtigung im Gefüge der Physik nachweisen konnte und in Einzelfällen eine Orientierung für weitere experimentelle Untersuchungen gegeben hatte. Es war ihr aber noch nicht gelungen, einen Ersatz zu liefern für die analytische Mechanik, die bis zum Beginn des 19. Jahrhunderts die mathematisch-theoretische Basis für die Physik bildete und die diesen Anspruch mit der Herausbildung der klassischen physikalischen Disziplinen im 19. Jahrhundert immer weniger erfüllen konnte. Dieses Manko auszugleichen, war das große Desiderat in der Physik am Ende des 19. Jahrhunderts.

Es sei noch kurz das Verhältnis der theoretischen zur mathematischen Physik skizziert. Ohne die Entwicklung im 19. Jahrhundert genauer nachzuzeichnen, sei vermerkt, dass die Entstehung der theoretischen Physik wichtige Impulse aus der mathematischen Physik erhielt und sich eine zeitlang innerhalb derselben sogar einige Elemente der theoretischen Physik entwickelten, was zeitweise zu einer Gleichsetzung der beiden Begriffe führte, wie es Hermann von Helmholtz (1821–1894) noch

1893 in der Einleitung zu seinen Vorlesungen zur theoretischen Physik konstatierte. Als durch die rasche Entwicklung der Physik mit der Herausbildung ihrer klassischen Disziplinen das Bedürfnis und der Drang nach einer theoretischen Fundierung derselben entstand, nahmen sich Physiker und Mathematiker dieser Aufgabe von unterschiedlichen Standpunkten an und kamen zu entsprechend abweichenden Ergebnissen. Vereinfacht gesagt: Die Physiker gingen von der experimentellen Basis aus und leiteten daraus einige Hypothesen zum Aufbau einer Theorie ab. Die mathematische Modellierung der Zusammenhänge war dabei von untergeordneter Bedeutung und beschränkte sich oft auf wenige Relationen. Die Mathematiker stellten einige Grundannahmen an den Anfangihrer Betrachtungen. Diese Annahmen sollten natürlich mit den vorhandenen Tatsachenmaterial (Experimenten) im Einklang stehen, wobei das Auffinden sowie die Formulierung dieser Grundprinzipien den Physikern als eine zentrale Aufgabe zugewiesen wurde. Aus diesen Prinzipien bzw. deren mathematischer Umsetzung wurde dann eine logisch exakte Theorie errichtet. Die theoretischen Physiker strebten also nach einer in erster Linie physikalisch konsistenten Theorie, für die Mathematiker musste sie im mathematischen Sinne exakt sein. Die physikalische Konsistenz wurde oft als Folge der Tatsache gesehen, dass die Grundannahmen aus der physikalischen Erfahrung abgeleitet waren. Als ein typisches Beispiel sei hier auf die Auseinandersetzung von Carl Neumann (1832–1925) und H. von Helmholtz um die Begründung der Elektrizitätslehre in den 70er Jahren des 19. Jahrhunderts verwiesen.[3] Die unterschiedliche Interessenlage von Physikern und Mathematikern hat die Herausbildung der theoretischen Physik und deren Abgrenzung zur mathematischen Physik stark beeinflusst und förderte eine Präzisierung der Aufgaben der theoretischen Physik. Sie musste mehr umfassen als eine phänomenologische Beschreibung des jeweiligen Vorgangs und zugleich mehr sein als eine quantitative Erfassung der verschiedenen Erscheinungen und die Berechnung der damit verknüpften Größen.

Die Veränderungen in der Stellung der theoretischen Physik zur Experimentalphysik und zur mathematischen Physik

In dem Jahrzehnt vor der Wende zum 20. Jahrhundert erlebte die Experimentalphysik dann eine Reihe aufsehenerregender Entdeckungen

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[3] Vgl. dazu Buchwald 1993; Darrigol 2000, Kap. 6.2, 6.3; Kaiser 1993; Schlote 2004

und schuf damit neue Herausforderungen hinsichtlich der theoretischen Fundierung der physikalischen Disziplinen: Untersuchung der Kanalstrahlen mit Entdeckung des Elektrons (1897), 1895 Röntgen-Strahlen, 1896 Radioaktivität, Bestätigung der Wien'schen Strahlungsformel für den schwarzen Strahler, Zeeman-Effekt der Aufspaltung der Spektrallinien im Magnetfeld, 1897 Erfindung der Braun'schen Röhre (Kathodenstrahlröhre), 1898 Entdeckung von radioaktiven Elementen, Radium und Polonium. Diese Erfolge der Experimentalphysik stützten im gewissen Sinne die Vormachtstellung der Experimentalphysik gegenüber der theoretischen Physik und wirkten zugleich auf die Abgrenzung zur mathematischen Physik, indem bei mehreren Berufungen für theoretische Physik an der Wende zum 20. Jahrhundert eine deutlich antimathematische Note zu verzeichnen ist. Als beispielsweise 1902 in Leipzig ein Nachfolger für Ludwig Boltzmann (1844–1906) gesucht wurde, war es das Ziel von Otto Wiener (1862–1927), dem Ordinarius für Experimentalphysik, „einen Mann zu gewinnen, dessen Schwerpunkt in der Physik und nicht in der Mathematik gelegen ist“[4]. Nach hartem Ringen hat sich Wiener gegen die Kollegen in der Fakultät durchgesetzt, was für die folgenden zwei Jahrzehnte ein Zurückbleiben des Leipziger Physikalischen Instituts in der Entwicklung zur Folge hatte.

Doch die erneute, deutliche Dominanz der Experimentalphysik und die stärkere Bezugnahme auf physikalische Kenntnisse seitens der theoretischen Physiker sowie die damit verbundene Abgrenzung der theoretischen von der mathematischen Physik dürfen nicht als ein Zurückdrängen der Mathematik bzw. eine Abkehr von der Theorie interpretiert werden. Das Gegenteil war der Fall. Was man zunächst als Dominanz der Experimentalphysik wahrnimmt, erweist sich letztlich als eine enge Verzahnung von Experimental- und theoretischer Physik. Die Fortschritte in der Physik erhöhten vielmehr den Stellenwert theoretischer Betrachtungen und auch der Mathematik. Einerseits waren viele experimentelle Untersuchungen, etwa die oben erwähnten Studien zur Strahlenphysik, ohne die Verwendung theoretischer Überlegungen zu den Strahlenvorgängen undenkbar. Andererseits bestand eine enge Verknüpfung zwischen den Fortschritten in der Theorie und dem experimentellen Material und den darin enthaltenen physikalischen Vorstellungen. Als Beispiele seien die Elektronentheorie und die Strahlungsphysik genannt. Erstere führte zur Erklärung wichtiger optischer und elektrischer Er-

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[4] UAL, PA 410, Bl 35

scheinungen, auch in der Strahlungsphysik. Von Letzterer seien die Studien zur Wärmestrahlung hervorgehoben, die in die berühmte, die ganze Physik revolutionierende Planck'sche Quantenhypothese einmündeten. Es handelte sich also insgesamt darum, dass das Verhältnis zwischen theoretischer und Experimentalphysik auf höherem Niveau neu etabliert wurde und sich dabei enger gestaltete. Eine entscheidende Ursache für diesen Prozess war die Tatsache, dass für die theoretische Erklärung der hier in den Blick genommenen sowie anderer physikalischer Erscheinungen zunehmend im atomaren Bereich angesiedelt waren und von den atomaren Eigenschaften der Teilchen als Basis ausgingen. Bei der Festlegung dieser Eigenschaften konnten sich die Physiker immer weniger von der direkten sinnlichen Wahrnehmung leiten lassen und mussten zunehmend auf abstrakte, nur in ihren Konsequenzen überprüfbare Hypothesen im atomaren Bereich Bezug nehmen. Die Überprüfung der Annahmen geschah meist durch den Vergleich von quantitativen, mit der entsprechenden Messtechnik ermittelbaren Versuchsergebnissen mit theoretisch berechneten Werten. Die hinreichend genaue Berechnung der Vergleichswerte war aber ohne eine gute mathematische Modellierung und die Anwendung mathematischer Methoden nicht zu bewältigen. Zugleich musste der logischen Struktur beim Aufbau der Theorie eine größere Aufmerksamkeit geschenkt werden, um Fehler in den Vergleichswerten durch falsche logische Folgerungen zu vermeiden. Da ein anderer Weg zur Kontrolle der Hypothesen und der daraus abgeleiteten Theorie meist nicht möglich war, konnte nur im steten Wechselspiel der drei Komponenten, Experiment, theoretisch-physikalische Hypothese und mathematische Modellierung, ein Erkenntnisfortschritt in der Physik erreicht werden. War eine Hypothese mit hinreichender Sicherheit bestätigt, so bildete sie den Ausgangspunkt für weitergehende theoretische Folgerungen, aus denen nicht selten neue Annahmen bzw. Anregungen für neue experimentelle Forschungen hervorgingen. Eine ähnlich stimulierende Wirkung konnte natürlich auch von der Widerlegung einer Hypothese ausgehen, man denke nur an die Auseinandersetzung um die Ätherhypothese, die einen Anreiz zur Schaffung der Relativitätstheorie darstellte.

Die stärkere Einbeziehung mathematischer Elemente in die theoretische Physik erhöhte einerseits die Ansprüche an die Flexibilität der mathematischen Verfahren und stimulierte andererseits die Schaffung neuer Methoden. So hat das Vordringen in den molekularen und atomaren Bereich die Verwendung von Elementen der Statistik in der theoretischenPhysik spürbar gefördert. Die mathematische Physik hat diese Aufgaben weitgehend bewältigt, sowohl durch Rückgriff auf bereits vorliegende Resultate als auch durch Generierung neuer. Man denke nur an die großen Fortschritte auf dem Gebiet der Analysis. Viele Differentialgleichungen wurden unter schwächeren Voraussetzungen an die Koeffizienten, an die Rand- bzw. Anfangswerte oder an die Randkurve gelöst, mit der Theorie der Integralgleichung entstand ein neues Teilgebiet der Mathematik, das neue Methoden zur Lösung von Differentialgleichungen bereitstellte. Die Verallgemeinerung des Integralbegriffs bis zum Lebesgue'schen Integral ermöglichte die Einbeziehung einer größeren Funktionenklasse in die jeweiligen Untersuchungen. Insgesamt wurde die mathematische Beschreibung physikalischer Sachverhalte spürbar verbessert. Die numerischen Lösungsmethoden wurden verbessert und ihr Einsatz vielfältiger. Viele Formeln und Rechnungen erhielten durch die Verwendung der Vektor- und Tensorrechnung eine einfachere und übersichtlichere Gestalt. Durch die Vereinigung der Zeit mit den räumlichen Kordinaten schuf Hermann Minkowski (1864–1908) die Basis für eine völlig veränderte Sicht auf die Physik und schlug eine Brücke zur Theorie der Mannigfaltigkeiten. In dieser Beziehung sind schließlich auch die Ansätze zu weiteren Abstraktionen in Algebra, Funktionalanalysis, Topologie usw. zu erwähnen, da sie sehr bald auf die Begriffsbildungen in der Physik zurückwirken sollten.

Mit der oben erwähnten Neugestaltung des Verhältnisses zur Experimentalphysik und zur Mathematik auf höherem Niveau hatte die theoretische Physik ihre Konsolidierung abgeschlossen und trat wieder stärker in den Vordergrund. Insbesondere fiel ihr Anfang des 20. Jahrhunderts eine integrative Rolle in der Physik zu, und zwar der Tendenz der fortschreitenden Spezialisierung und Verbreiterung der Physik entgegenzutreten. Ähnlich wie in anderen Wissenschaften sollten durch den Aufbau eines theoretischen Gerüsts aus einfachen Annahmen und Prinzipien Beziehungen zwischen den verschiedenen Teildisziplinen hergestellt und die Fülle der Entwicklungen überschaubar gemacht werden. Die Vertreter der theoretischen Physik nahmen sich der Herausforderung mit Nachdruck an. Wilhelm Wien (1864–1928) sprach beispielsweise 1915 davon, dass die theoretische Physik die Aufgabe habe, „die Gesetze aufzustellen, durch die ein möglichst ausgedehntes Gebiet physikalischer Vorgänge beherrscht wird“. „Diese Aufstellung funktioneller Zusammenhänge ist recht eigentlich die Aufgabe der theoretischen Physik“, denn erst „durch die Aufstellung quantitativer

Gesetze wird eine wirkliche physikalische Theorie begründet".[5] Bloß qualitative Theorien seien höchstens als Anregung für Versuche brauchbar, als wirkliche Leistungen der theoretischen Physik wird man sie nicht ansehen können. Sechs Jahre später beschrieb Hans Thirring (1888–1976) in seiner Antrittsvorlesung an der Universität Wien den Zweck der theoretischen Physik mit den Worten, „die Unsumme der Erfahrungstatsachen, die uns die Arbeit der Experimentalphysiker beschert hat, unter einen Hut zu bringen, von großen Gesichtspunkten ausgehend zu ordnen und zu verstehen."[6] Ähnlich äußerte sich 1932 auch Georg Joos (1894–1959) in seinem „Lehrbuch der theoretischen Physik".

Getragen von den Fortschritten ihrer Disziplin gelang es den theoretischen Physikern innerhalb von zwei Jahrzehnten den Platz ihres Faches innerhalb der Physik grundlegend neu zu bestimmen. Aus der Hilfskraft für die Experimentalphysik wurde ein ebenbürtiger Partner mit berechtigtem Führungsanspruch. „Keine Naturwissenschaft kann ohne Theorie bestehen, denn aus ihr wird erst die Anregung zu experimenteller Forschung geschöpft, durch sie werden die Ergebnisse untereinander verbunden."[7] Die „Art der Naturbeschreibung, wie sie in der theoretischen Physik vorgenommen wird," ist „die rationellste und in denkökonomischer Hinsicht die vollendetste . . . , die wir kennen."[8] Im eigenen Selbstverständnis stellte sich die theoretische Physik damit nicht nur gleichberechtigt neben die Experimentalphysik, sondern sah sich sogar in einer gewissen Leitfunktion, denn sie schuf eine gemeinsame Basis für die verschiedenen Teildisziplinen, ordnete die Fülle der Beobachtungen und Erscheinungen systematisch, stellte Zusammenhänge her, leitete daraus Folgerungen ab und regte neue Experimente an.

Die Abgrenzung zur mathematischen Physik bereitete scheinbar auch keine Probleme mehr, wobei mancher theoretische Physiker wohl in der Euphorie der erreichten Anerkennung etwas über das Ziel hinausschoss. Wenn Wien 1915 feststellt: „Die mathematische Physik besteht . . . in der Ausbildung der für die Weiterbildung der theoretischen Physik erforderlichen mathematischen Hilfsmittel."[9] so wird die mathematische Physik zu sehr in die Rolle der Hilfsfunktion gedrängt. Ähnlich

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[5] Wien 1915, S. 242, 246.

[6] Thirring 1921, S. 1023.

[7] Wien 1915, S. 241.

[8] Thirring 1921, S. 1024.

[9] Wien 1915, 242.

drastisch, aber doch klarer,weil auf eine reale Aufgabenteilung abzielend, formulierte Joos, dass es „nicht Aufgabe des theoretischen Physikers ... ist, mathematische Beweise zu liefern“. Der Physiker kann sich nicht mit mathematischen Existenzbeweisen aufhalten, wenn das Resultat physikalisch evident ist und oft stehen die strengen Forderungen der Mathematik im Widerspruch mit den physikalischen Gegebenheiten.[10] Die große Bedeutung der Mathematik für die theoretische Physik wurde hier voll anerkannt, beide haben nur unterschiedliche Aufgaben und Ziele bei der Behandlung physikalischer Fragestellungen. Ganz in diesem Sinne ist auch der Ausspruch von Thirring zu sehen: „nur ein guter Mathematiker kann ein guter theoretischer Physiker sein“.[11]

Ähnlich wie bei der scheinbaren Dominanz der Experimentalphysik um die Jahrhundertwende mündete die Abgrenzung zur mathematischen Physik ein in eine engere Wechselbeziehung von mathematischer und theoretischer Physik. Ein wichtiger Grund lag in dem schon erwähnten Vordringen der Physik in den atomaren Bereich. In diesem Prozess begannen die Physiker immer mehr mit idealen Begriffen wie Feld oder Elektron zu operieren, die wesentlich dadurch handhabbar wurden, dass sie mit anderen Größen in bestimmten Relationen, letztlich mathematischen Formel, standen. Schon Heinrich Hertz (1857–1894) hatte zur Begründung der Elektrodynamik vermerkt: „Auf die Frage »Was ist die *Maxwell*'sche Theorie?« wüsste ich also keine kürzere und bestimmtere Antwort als diese: Die *Maxwell*'sche Theorie ist das System der *Maxwell'schen Gleichungen.*[12] Mit der Relativitätstheorie, der Atomphysik und der Quantentheorie entstanden im ersten Drittel des 20. Jahrhunderts neue Gebiete der Physik, die einen noch höheren Abstraktheitsgrad aufwiesen und für ihren exakten Aufbau auf eine Reihe tiefliegender mathematischer Resultate zurückgriffen. Eine enge Zusammenarbeit von Mathematikern und Physikern, ein Ineinandergreifen ihrer Arbeitsfelder, war hierbei unabdingbar. Die theoretischen Physiker mussten in ihre Darlegungen stärker Elemente der Mathematik einbeziehen und deren Regeln beachten, die Mathematiker konnten bei der Absicherung einzelner Beweisschritte und den sich ergebenden Folgerungen durchaus neue physikalisch relevante Aussagen ableiten. Trotz der Abgrenzung der Aufgaben zwischen theoretischer und mathematis-

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[10] Joos 1934, S. 2.

[11] Thirring 1921, S. 1028.

[12] Hertz 1894, S. 23.

cher Physik boten sich vermehrt Möglichkeiten, erfolgreiche Forschung in dem jeweils anderen Gebiet zu betreiben. A. W. Stern drückt die neue Situation auf dem Internationalen Mathematiker-Kongress in Bolgna 1928 wie folgt aus: „Physics has taken on a more rigorous and decidedly intellectual character, … What was Newtonian physics and Maxwellian electrodynamics has become unified and absorbed into the general theory of continuous manifolds of four dimensions.“[13] Die Theorie vierdimensionaler Mannigfaltigkeiten war aber eindeutig ein Arbeitsgebiet der Mathematiker.

Eines der ersten Beispiele für dieses enge Zusammenwirken von mathematischen und theoretischen Physikern war sicher die Suche nach den Grundgleichungen der Allgemeinen Relativitätstheorie, bei der Albert Einstein im Wettstreit mit der Gruppe Göttinger Mathematiker um David Hilbert nur sehr knapp den Sieg errungen hatte. Bekanntlich haben Mathematiker dann auch einen großen Anteil an der Ausgestaltung und Durchbildung der Relativitätstheorie gehabt, es sei nur an die Wirkung von Hermann Weyls Buch „Raum, Zeit Materie“ (1918) erinnert. Natürlich kann man die Durchbildung der Theorie im Sinne der skizzierten Aufgabenteilung den Mathematikern zuweisen, doch ist dies nicht unproblematisch, da dieser Prozess auch mit neuen physikalischen Erkenntnissen verknüpft war, also genau das angedeutete Ineinandergreifen beider Gebiete widerspiegelte. Als ein zweites Beispiel sei noch die Herausbildung der Quantenmechanik in den 20er Jahren des vorigen Jahrhunderts genannt. Wichtige Elemente der Funktionalanalysis, speziell die Spektraltheorie der selbstadjungierten beschränkten Operatoren von John von Neumann (1903–1957), entstanden im Kontext der mathematischen Begründung der Quantenmechanik.

Die engen Beziehungen zwischen mathematischer und theoretischer Physik entwickelten sich in den nachfolgenden Jahrzehnten auf diesem hohen Niveau weiter. Die Zahl der mathematischen Teilgebiete, aus denen Erkenntnisse für die Lösung der physikalischen Fragen verwendet wurde, erhöhte sich ständig, parallel dazu vergrößerte sich auch der methodologische Einfluss der Mathematik. Die Aufgabenstellung der theoretischen Physik blieb dabei im wesentlichen erhalten, ein auf möglichst wenigen von einander unabhängigen Hypothesen ruhendes logisches Gedankensystem aufzubauen, das den ganzen Komplex der physikalischen Prozesse zu erfassen gestattet. Die Auswahl der für die

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[13] Stern 1928, S. 410.

Schaffung einer einheitlichen Basis der Physik notwendigen mathematischen Mittel erfolgt nach physikalischen Gesichtspunkten, die mathematischen Operationen und deren Ergebnisse innerhalb der Physik zu interpretieren, bildeten und bilden einen Grundbestandteil der Theorie. Der mathematischen Physik oblag es, die von den Physikern verwendeten mathematischen Methoden abzusichern, auszugestalten und gegebenenfalls zu erweitern. Dazu gehörte, sowohl durch möglichst schwache notwendige bzw. hinreichende Voraussetzung eine breite Anwendung der einzelnen Theoreme und Sätze zu ermöglichen, als auch den sich im Rahmen der physikalischen Darlegungen ergebenden Anregungen zu weiterführenden mathematischen Überlegungen nachzugehen. Es braucht wohl nicht besonders hervorgehoben zu werden, dass in diesem Kontext ein physikalisches Verständnis der behandelten Probleme seitens der Mathematiker wie auch eine gewisse Vertrautheit mit den mathematischen Grundlagen bei der Anwendung der einzelnen Theoreme seitens der Physiker sehr nützlich, ja fast unumgänglich ist. Dieses Übergreifen in das Nachbargebiet führt im Allgemeinen nicht zu einer Vermischung der Aufgaben- und Zielstellung der Physiker und Mathematiker, schließt aber Hinweise auf mögliche weiterführende Untersuchungen und in Ausnahmefällen auch Forschungen in den Nachbargebiet nicht aus. Ein solches außergewöhnliches Beispiel wären die Arbeiten von Edward Witten (geb. 1951) zur Quantenfeldtheorie. Er deckte darin wichtige Beziehungen zu differentialgeometrischen Invarianten auf und verlieh den Forschungen zur Differentialgeometrie bemerkenswerte neue Impulse. 1990 wurde er als Physiker mit der Fields-Medaille, der höchsten Auszeichnung der Mathematiker, geehrt.

Anmerkungen zur Darstellung der neueren Wissenschaftsentwicklung

Nach dem kurzen Überblick über die Veränderungen im Wechselverhältnis von theoretischer und mathematischer Physik in der ersten Hälfte des 20. Jahrhunderts sei nochmals auf die Fragestellung dieser Konferenz eingegangen. Der Blick auf die Entwicklung der theoretischen Physik hat wohl gezeigt, dass die drei eingangs genannten Probleme bei der Behandlung der Wissenschaftsentwicklung in ähnlicher Weise auch zu Beginn des vergangenen Jahrhundert präsent waren. Sie stellen sich allerdings heute in verschärfter Form, da rein quantitativ der Wissenszuwachs in den vergangenen 100 Jahren viel größer war als im 19. Jahrhundert und damit auch die Fragen der Verarbeitung und Bewertung dieses Wissens eine ganz andere Dimension erhalten. Trotzdem darf die Antwort nicht darin bestehen, dass man etwa in Vorlesungen die Entwicklung im 20. Jahrhundert nur ganz kurz behandelt oder gar ganz weglässt. Jeder ernsthafte Versuch, die Entwicklung von Wissenschaft und Technik im 20. Jahrhundert oder Teile davon zu erfassen, ist besser als sie mit Stillschweigen zu übergehen. Dabei wird der Einzelne das eine oder andere Fehlurteil fällen und manches Missverständnis wird sich in eine solche Darstellung einschleichen, das alles ist aber vernachlässigbar gegenüber dem Gewinn, den ein solcher Beitrag zur Wissenschaftsentwicklung im 20. Jahrhundert für das allgemeine Verständnis und die Anerkennung der Wissenschaften in der Gesellschaft mit sich bringt. Wenn es gelingt, eine Diskussion über die Wissenschafts- und Technikentwicklung im 20. Jahrhundert im größeren Rahmen zu initiieren, werden sich viele individuellen Fehleinschätzungen beseitigen lassen. Aber gerade dies ist wohl fast so schwierig wie die Aufgabe selbst, denn man müsste die Vertreter unterschiedlicher Richtungen, die Wissenschafts- und Technikhistoriker der einzelnen Disziplinen, die Fachverterter für diese Disziplinen, die Wissenschaftstheoretiker und die Repräsentanten der allgemeinen Geschichte, zu diesem Projekt zusammenbringen und ihnen eine klare Zielsetzung vorgeben. Letzteres ist nötig, da es den Überblick über die Wissenschafts- und Technikentwicklung des 20. Jahrhunderts nicht gibt, sondern er wird je nach Zielgruppe mehr oder weniger unterschiedlich ausfallen. Es ist das Verdienst der Organisatoren dieser Konferenz einen Anstoss zu diesem Projekt gegeben zu haben.

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Some questions for the study of history of mathematics

Roman Duda

I. The growing volume of mathematics is accompanied by the growing volume of its written history. The modern process of studying the history of mathematics has started with Jean-Etienne Montucla (1725–1799) who created a new literary genre and who may indeed be considered as the first professional historian of mathematics. In his main work1[1], his idea was that of progress, that is, his intention was to show, under the influence of encyclopaedists, that progress in mathematics has been brought by reason only but with precise criticism.

In the 18th century mathematics was a rather modest field, mathematicians were not many, each had a command of the whole — the task of writing its history seemed to be relatively simple. Now, after two hundred years, the picture is different. The volume of mathematics has grown so enormously that nobody is able to cover a large part of it, to say nothing of the whole. There are so many branches of mathematics (e.g. *Mathematical Reviews* lists over 1000 branches) that even the question has arisen: is it still reasonable to speak of one mathematics (and not of many)2[2]? There is also the Ulam's dilemma3[3]: how to recognize among nearly 200 000 produced yearly theorems in mathematics those few which are worthy to study and which will survive? And since the role of mathematics has also grown enormously, the goals of writing the history of mathematics require reexamination. This opens the way to a debate what the history of mathematics is and what it should be. The debate is vivid and going on.4[4]

1[1] J.-E. Montucla, *Histoire de mathématiques, dans laquelle on rend compte de leurs progrčs depuis l'origine jusqu'à nos jours*, 2 volumes, Paris 1958; II edition, 4 volumes, Paris 1799/-1802 (completed by J. de Lalande), reprint: Paris 1985.

2[2] In France there are traditional "les mathématiques" and modern "la mathématique" (N. Bourbaki).

3[3] S. Ulam, *Adventures of a Mathematician*, Berkeley: University of California Press, 1976. See also Ph.J. Davis, R. Hersh, *The Mathematical Experience*, 1981.

4[4] To mention only two recent titles: J.W. Dauben, Ch.J. Scriba> (eds.), *Writing the history of mathematics: its historical development*, Basel: Birkhäuser, 2002; I. Grattan-Guinness, B.S. Yadav (eds.), *History of Mathematical Sciences*, Hindustan Book Agency, 2004.

Nowadays there seem to be two main trends in writing the history of mathematics. Perhaps the best way to describe them is to recall basic questions which they tend to pursue: 'what actually happened in the past ?' or 'how did we get here ?'. Followers of the first trend may be called 'cultural historians'.[5][5] They do their best to describe everything that happened in mathematics, including influences on the part of philosophy, economy, art etc., all details of the development, its prehistory and concurrent developments, the chronology, the immediate impact. Followers of the second one may be called 'mathematical historians' (K.S. Chaudjuri) or wardens of 'heritage' (I. Grattan-Guinness). They look upon the past from the standpoint of the present state of mathematics and see their task in unfolding how some germs from the past have evolved into present notions, theorems, or theories, all the rest being treated as irrelevant, a sort of a burden. The controversy between the two may be illustrated in this way: according to cultural historians, older theories deserve due consideration in their own, while mathematical historians prefer to see how a particular modern theory arises out of older theories. Typical representative of the first tendency is M. Cantor[6][6] and of the second — N. Bourbaki.[7][7]

The division between the two trends is quite sharp. "Both kinds of activity are quite legitimate, and indeed important in their own right. [... However,] the confusion of the two kinds is not legitimate"[8][8]. And besides those two main trends there are some minor ones like ethnomathematics, women in mathematics, mathematics in a particular country, etc.

II. Let me express my personal views.

1. Although there is no commonly acceptable definition of mathematics, every mathematician easily recognizes what is mathematics and what is not. Consequently, it is still reasonable to speak of mathematics

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[5][5] K.S. Chaudjuri, *Evolution of History of Mathematics: Some Trends* in: I. Grattan-Guinness, B.S. Yadav (eds.), *History* ... , op. cit., pp. 1–12.

[6][6] M. Cantor, *Vorlesungen über Geschichte der Mathematik*, 4 volumes, 1900–1908.

[7][7] N. Bourbaki, *Éléments d'histoire des mathématiques*, deuxième edition, Paris: Hermann, 1969.

[8][8] I. I. Grattan-Guinness, "History or Heritage? A Central Question in the Historiography of Mathematics", in the book: Grattan-Guinness, B.S. Yadav (eds.), *History* ... , op. cit., pp. 13–31.

as of a one and unique field of human activity. Since, however, the field became too vast for one man to comprehend it fully, mathematics is no longer a concentrated effort of its followers. Under such circumstances there has arisen the danger of a total disorientation. It is my deep conviction that it is here that the history of mathematics can play its new and important role, and it is rather the history in its mathematical and not cultural form. To be more specific, such a history of mathematics may offer a deeper view upon the present mathematics, transcending its internal borders and showing interconnections.

2. Not diminishing the value of a cultural history of mathematics, there seems to be a growing demand for historians of a mathematical type, those having a good command in some areas of mathematics and able to tackle questions like the following ones: what trends can be distinguished in the evolution of mathematics?, what forces are lying behind its development?, why mathematics is so "unreasonably effective"[9[9]]? etc. Since questions of such a type apparently are of growing importance, there must be people ready to answer them. Some mathematicians try to do the job but, to my mind, it is also a proper job for those historians of mathematics who understand modern mathematics and are interested in a collaboration with proper mathematicians and possibly with philosophers of science.

III. To illustrate my position let me examine briefly the case of Banach's discovery.[10[10]]

1. Since the second half of XIX c. there begun to appear in mathematics collections of functions, together with some operations upon these functions, particularly in the calculus of variations, theory of differential equations, theory of integral equations, etc. It has been recognized that in order to economize efforts it would be desired and reasonable to define a new more general field comprising all mentioned ones. More

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[9[9]] P. Wigner, "The unreasonable effectiveness of mathematics in the natural sciences", *Communications in Pure and Applied Mathematics* 13 (1960), pp. 1–14.

[10[10]] The history of Functional Analysis has been described by several authors, e.g., J. Dieudonné, *History of Functional Analysis*, North-Holland, 1981; for the contribution of Banach, see, e.g., R.Duda, "On the origins of Functional Analysis and the Lvov school", *Commentationes Mathematicae, Tomus Specialis in honorem Iuliani Musielak*, 2005, pp. 5–45; – "The discovery of Banach spaces", in the book: W. WiŠsaw (ed.), *European Mathematics in the Last Centuries*, Stefan Banach International Mathematical Center & Institute of Mathematics.

specifically, one should develop a sort of function calculus, generalizing concepts originated in the classic analysis. In Italy and France there appeared some attempts to that end (*Calcolo Funzionale* in Italy, *calcul fonctionnel* in France), rather unsuccessful.

2. At the beginning of XX c. there appeared first clearly defined "spaces" of functions, like the space C of all real continuous functions on [0,1], the space L^2 of all square integrable real functions on [0,1], sequential Hilbert space l^2 of all countable real sequences $\{x_n\}$ such that the series $\sum x_n^2$ is finite, etc. And there came an unexpected discovery, known as Fischer-Riesz theorem, that the spaces L^2 and l^2 are isomorphic. This, together with Hilbert's work on spectral theory, became a strong push towards generality.

3. In the years 1920–1922 three men — Wiener, Hahn, Banach — have proposed a definition of a general function space. Wiener had put in the language of logic systems; his definition was fairly complicated, without any motivations, and without any applications. Hahn did it, following his teacher Helly, for sequential spaces and with the specific aim to solve infinite systems of linear equations. And only Banach did it in the clear-cut version: a normed and complete vector space, soon to be called a *Banach space*. Wiener recognized Banach's priority and left the field, while Hahn continued to work within his framework and received some good results. In the development, however, Banach's attitude won and it was the real beginning of Functional Analysis as an autonomous field of mathematics.

4. What I have described so far is a story as seen from the modern point of view. In the 19th century, and even in the first three decades of the 20th century, it was a marginal development, not attracting much attention. Main stream of mathematics seemed then to run a different way. And it was only after 1930 that Functional Analysis has won a common recognition and became a leading field in contemporary mathematics.

The situation is extremely interesting and intellectually provocative, thus allowing to raise up several questions. What really happened and why? What were the forces behind the development? Was it only the tendency towards generalization? How strongly was the development influenced by the axiomatic trend? Why that generalization has stopped at the level of Banach spaces? For fear of loosing the meaning? What is "meaningful" for mathematicians? What happened to Functional Analysis later on? In what directions run its evolution? What is the value of Functional Analysis today? Did it fulfill the initial hopes for a new field embracing several other fields?

Questions of this kind seem to be important for the living mathematics and thus for its future. Answers are not obvious but they may be provided by men versed both in Functional Analysis itself and its history, hopefully with some command of philosophy.

IV. Functional Analysis seems to be one example only of a more general and unquestionably more fundamental change that took place in the 20th century mathematics. If we look upon such modern fields like Theory of Sets or Topology, we see the same picture: start somewhere at the periphery and then rapid growth to a common recognition, not without resistance, however, sometimes quite strong. Resistance is a human factor, but there seems to be a certain regularity in those developments. What is really happening? What are the real forces behind the evolution of mathematics? And why mathematics is still so "unreasonably" effective?

Chemistry and Society in the 20th Century: Science, Engineering and Technology

Ivana Lorencová

1. Introduction

Twentieth century, the century of unbelievable technical and scientific progress, but also the century of many political and social turns, gives us many occasions to think about what was the driving force of the development of new technologies, why the production of some goods was increased, whereas some products weren't produced anymore. Economic and political situation of the society was often the motive power of development of the science and technologies, which on the contrary retroactively affected the society. Successes in scientific research are dependent on many factors, including the situation in society, contemporary trends of the society, level of educational institutions and support from the state.

In the context of all-European development, even the chemical industry was developing. Chemical technologies were gradually taking over new scientific theories and technical solutions and their development was dependent on the progress in chemistry, physics, medicine, biology, and in many other fields.

The quality of life in the 20th century was radically changed by the emergence of transport, better distribution of electricity, by introduction of the batch production and last but not least, by both World Wars. To understand the whole process of production, we have to know that the production consists of two types of technologies: firstly, technology of the product, which creates its characteristics and qualities, and secondly the process technology that encompasses the whole system of the production.

The introduction of new manufacturing processes desperately needed some special education of future scientific experts. That's why I mention the beginning and the rise of chemical engineering and the first educational training centres that appeared all around the world.

At the time first contacts between the scientific research and industry were arranged, the scientific companies were the first ones to engage. The state assistance and support from private sector came soon.

At the end of the 19th and the beginning of the 20th century, many specialized research institutions were founded, mostly in Germany and in the USA. Chemical companies started to organize and financially support their own research centres.

Ever-growing requirements of mankind demanded development in chemical industry. Due to chemical products, people can live longer (disinfectants, pharmaceuticals) as well as the lives of millions of people can end (chemical and nuclear weapons). Chemical products also changed the fashion and dressing style (synthetic fibers). Plastic materials are inherent part of every single industrial branch. In fact, modern society is totally dependent on chemical products. It is estimated that approximately one third of chemical products is sold within the chemical branch and specialized companies use it for production of goods with higher value (for instance automotive, oil, textile, pharmaceutical, paper and rubber industry or building industry and agriculture). Concerning the volume of products, chemical industry alone is the number one consumer.

2. The situation of the chemical industry from the late 19th century till the beginning of WWI.

Throughout the 19th century, chemistry flew both theoretically and technologically vertically upwards and therefore made the application of new discoveries possible. In Europe and in the USA, there was a big hunger after new scientific findings and also perceptible scientific euphoria showed up, mostly because of really quick advancements in physics.

The chemistry started to differentiate itself into separate branches (for example general, inorganic, organic and analytic chemistry) and also some boundary branches appeared (physical chemistry and biochemistry).

Because of the need of rationalization of the production (catalysis, thermodynamics, knowledge of chemical reactions), chemical industry gradually derived benefits from scientific researches.

Concerning scientific research and production in the early 20th century, Germany was definitely world's number one in both branches. Thanks to constant support from the state, Germany was at least at this time the country with the best developed knowledge and scientific base. Universities were deeply wedded to the industry, university labs tried to solve problems that appeared throughout the production and the dons were often advisors to these companies, which of course supported the universities, allowed their students to practice in factories and greeted graduates, who wanted to start working as scientists, with open arms.

The representatives of industry tried to convince chemists to elaborate some concrete problems and also tried to provide them with good financial and material conditions; for example Fritz Haber, Carl Bosch or Friedrich Bergius could be mentioned.

In 1911, the "Kaiser–Wilhelm–Gesselschaft" (KWG) was founded and therefore, better cooperation between universities and industrial companies was guaranteed. Just one year after, two institutes were established: Kaiser – Wilhelm – Institut für Chemie led by Emil Fischer and Kaiser – Wilhelm – Institut für physikalische Chemie und Elektrochemie led by Fritz Haber. With this unusual connection between research institutes and chemical industry, Germany started its successful effort to link those two branches.

The concept of applied research was firstly mentioned at that time, and more and more companies were founding their own testing laboratories. Industrial companies insisted on fast and efficient work of well-paid and precisely selected scientist. At the International Exhibition in Paris in 1900, Germany presented many by that time singular exhibits. Before the war, Germany was the number one producer of many chemical products, for example one fifth of pharmaceuticals came from Germany. Increasing consumption of ammonia that was widely used in agriculture and in production of chemicals, led to deeper elaboration of the method of ammonium synthesis, which was discovered by Fritz Haber (1868 – 1934) and Carl Bosch (1874 – 1940). The first industrial synthesis of ammonium took place in BASF factory in Ludwigshafen. Problem with high consumption of ammonium was solved and Germany was virtually independent of the import of natural nitrates from Chile and since then, BASF supported this research significantly. Fritz Haber, the inventor of industrial synthesis of ammonium, was awarded a Nobel Prize in 1918. He was an excellent scientist with outstanding education and he experienced various and inconsistent stages, both in his personal and his professional life.

The synthesis, which was named after him, secured Germany with supplies of nitrogen fertilizers. On the other hand it prolonged the war, because the blocked Germany was able to stay independent from import for a longer time.

British industry along with French industry was on its peak in the first half of the 19th century. British and French chemists were the pioneers of cooperation between science and final production. Thanks to the effort of George Davis (1850 – 1906), the first society that associated chemical engineers was founded (Society of Chemical industry, SCI, est. 1881). Although French and British scientists were excellent, there was a lack of cooperation with industry. That's why France had to relinquish her chemical superiority to Germany.

Though there were some top scientific institutions, which often worked in harness with departments of universities and even the level of polytechnic schools was high, the most of discoveries weren't put in practice.

Chemistry in other European states was at the beginning of its development and specialized on one certain type of product. Switzerland produced aluminum, calcium carbide, acetylene, bicarbonate, explosives, cellophane, dyes and substances that were used for perfumery and food processing industry. Italians had huge resources of sulphur in Sicily and therefore they produced superphosphates. Italy was also the first to produce blue vitriol, which was used as a herbicide.

Belgian chemical companies were mainly focused on the production of bicarbonate, for example Solvay (est. 1863) manufactured over 90% (in some of the cases in cooperation with local producers) of worldwide production of bicarbonate.

In Sweden, Alfred Nobel's company manufactured dynamite, also the production of fertilizers was very important and after establishing the AGA in 1904, Sweden was ready to become world's number one producer of technical gases.

Norwegian company Norsk Hydro (est. 1905) produced nitric acid and nitrates. The situation in czarist Russia was much more complicated. Although Russia had unbelievable amounts of mineral resources, it wasn't able to use it properly and only collaborated with Germany and some other countries. Russian scientists were on a relatively high level, nevertheless, their discoveries were used improperly and misapplied.

In the USA, chemical industry had good conditions to develop and gain momentum. Cooperation with universities played an important role in the development of American industry. Lewis Norton (1855 – 1893) established the "Course X", lectures on chemical engineering on MIT (Massachusetts Institute of Technology, founded in Boston in 1861 and moved to Cambridge US in 1916). Top scientists from all around the world were trying to investigate various technical problems there. They were, among others, very well financially supported and therefore more motivated. Lots of scientists studied in Europe, mostly in Germany or Switzerland and then went to the USA to continue in their careers. Many prominent businessmen of that time invested in scientific research, for example industrialist and owner of steelworks and railways Andrew Carnegie (1835 – 1919) founded the Carnegie Institution in 1902. Brothers Andrew W. Mellon and Richard B. Mellon established the Mellon Institute of Industrial Research in 1913.

Another type of organization was represented by a society, which was founded in 1909 by Arthur D. Little (1863 – 1935). This society was established in order to do researches ordered by their clients, more plainly it was the first research centre, which was established to make money. Little and his colleagues William H. Walker (1869 – 1934) and Warren K. Lewis (1882 – 1975) were the first to stake out chemical engineering as an independent branch. Having its own research institute was for a company a keystone of success.

Eastman Kodak (1893), B. F. Goodrich (1895), General Electric (1900), DuPont (1902), Standard Oil or Colgate were among the first companies which had their own research centres.

Plastic materials were firstly used to substitute expensive materials (ivory etc.), but soon they came to be used in many other branches. Belgian Leo H. Baekeland (1863 – 1944) was the first to successfully produce synthetic plastic – the bakelite (in 1909, NYC). He was using a special autoclave.

The petrochemical industry has its roots in the middle of the 19^{th} century. John D. Rockefeller (1839 – 1937) established the Standard Oil in 1868 and in 1913 this company began with thermal cracking of oil. During the next years, many refining plants were built and developed with the aim of getting a wide spectrum of oil products. The USA was independent of import in the sphere of pure chemicals, but this situation was soon to be changed.

Pfizer (est. 1849), one of the oldest pharmaceutical companies, produced a variety of pharmaceuticals, from disinfectants to citric acid, which became very popular in those days, because it was used in beverage production.

Although Japan entered the world of chemistry later, it was able to get on the top very soon. Before the WWI, Japan was the number one producer of camphor, which was used for making celluloid, and was also the superior producer of iodine.

Many fertilizer-producing companies (Japan Nitrogenous Fertilizers, Nichitsu, Sumimoto Fertilizer Factory) were also important for Japanese industry and research, which assimilated the knowledge of western countries and took over the German know-how of organizing scientific education.

3. The situation of chemical industry in the Czech Lands from the middle of the 19th century till 1914

The chemical industry in our area came to existence in the middle of the 19th century. By then, only small-scale production of basic chemical substances appeared. Among others sulphuric acid, hydrochloric acid, nitric acid, bicarbonate, alum, blue vitriol, potash, dyes, saltpeter, and sulphur were produced here. In this period, also the first Czech scientific schools were established, mostly focused on inorganic and analytic chemistry.

At the turn of the 20th century, Czech chemistry became internationally known and Czech chemists often worked abroad after graduation, mostly in Germany, Switzerland and France.

When judging the situation in our country, we have to consider that a German minority lived by the Czech border. Many of the factories belonged to German industrialists and the know-how and experience were often brought by foreign experts. Production of our national industry was based mostly on foreign patents and licences. The best known were Starck factories, Kinzelberger's company, chemical factories in Petrovice and Hrušov and United Chemical and Metallurgical Production (Spolek pro chemickou a hutní výrobu, nowadays Spolchemie) in Ústí nad Labem. In this period, the later company played an important role in all-European scale. The main items of its production were sulphuric acid, bicarbonate and hydrochloric acid. Thanks to the effort of Max Schaffner (1830 - 1906), the first research centre of the company was established. It was the first research institute in monarchy and due to its discoveries the Society was able to keep pace with worldwide research and progress. Soon it became the member of many international cartels of bicarbonate, sulphuric acid and superphosphate producers and also had a share in international cartel of alizarin convention.

At the turn of the century, electricity was introduced into chemical factories and enabled the progress of electrochemistry.

The beginning of production of fertilizers is closely connected with Adolf Schram (1848 - 1927), who founded a factory (est. 1904, nowadays known as Lovochemie) that produced sulphuric acid and superphosphates.

In step with the worldwide trend, the consumption of grease skyrocketed and their production was in the hands of Johann Schicht (1855 - 1907), who was, besides Tomáš Baťa (1876 – 1932) or Emil Škoda (1839 - 1900), one of the most important industrialists in our country. In 1911, the first European grease-hardening plant was built and Georg Schicht (nowadays Setuza) company was the greatest of its kind in Europe.

The petrochemical industry firstly appeared at the end of the 19^{th} century and the refineries were built during the years 1887 – 1901, when plants in Ostrava (Bohumínská rafinérie, 1898), Pardubice (Fantovy závody, 1889), Kralupy nad Vltavou (Lederer, 1900) and Kolín (Kolínská rafinérie petroleje, 1901) were founded. The discovery of radium and polonium increased the demand of uranium oxide from Jáchymov, where the production of radium chloride was introduced in 1908.

4. The First World War

The First World War affected the lives of millions of people in many countries and almost all the technical branches had to focus their researches and production on war. In fact, war accelerated the progress of chemistry and WWI is sometimes called the “chemical war”, because of the first use of chemical weapons and war gases.

Fast progress of armament industry revealed the weaknesses of technologies and contributed to a closer connection between research and production. The first state-owned organizations were founded, whose objective was to support and coordinate the cooperation of research institutions and industry. In this respect, Germany was the most developed. Every single branch that had something to do with war or armament was largely supported by the state. The situation in Great Britain was similar, armament industry and scientific research were properly organized and in 1916, even the Department of Scientific and Industrial Research (DSIR) was founded. France had its Commission supérieure des inventions (CSI), which was responsible to the Ministry of Defense. In the USA, the National Research Council (NRC) was established.

During the WWI, governments got to know that the army must be necessarily supported by industry, which must, on the other hand, be supported by scientific research. Since then, many research institutions were financially sponsored by private sector and chemistry became a military branch. The most remarkable impact of chemistry on war was the use of war gases, firstly used by the German troops (chlorine) in the battle of Ypres in 1915. In the battle of Verdun, Germans used chlorine and later, in 1916, yperite.

5. Chemical industry in Czech Lands during the First World War

The Czech chemical industry experienced some remarkable changes. The work of factories was narrowed because many employees were enlisted as soldiers, external relations were interrupted and there was a lack of raw materials. In contrast to Germany, Austro-Hungarian government did not adjust the scope of the chemical industry and even didn't have a crisis plan of importing important base materials. At that time, the most important chemical company in the Czech Lands, United Chemical and Metallurgic Production, switched its production to military technologies.

6. Interwar period

The return to peace in 1918 wasn't easy, because the conditions in the whole world were diametrically different. Germany was defeated, Austria-Hungary split and some few new states came into existence. War decimated countries had to deal with millions of casualties and face up to the economic collapse.

In 1920, the League of Nations was founded in order to keep the world in peace, to demilitarize Germany and to potentially stave off any other conflict. According to the Treaty of Peace of Versailles, Allies were free to use German patents, trademarks and technologies. The only state that profited from the war was the USA. All the European states were damaged badly and the US companies seized an opportunity and started to trade with them. The end of the war meant the stoppage of production of some chemical products, mostly militarily focused products that were useless in the time of peace.

Germany lost its pre-war position and was forced to stop its oversea trades and let it to the Allies, mostly Americans. American industry and research switched its focus back to pre-war problems and profited from the fact, that many German scientists and other experts went to the USA to continue in their researches and therefore helped the USA in rebuilding and improving its position.

Many cartels were founded at that time and a lot of smaller companies incorporated themselves into one huge corporation, which enabled them to “stay alive”. Europe had two gigantic companies of this kind, British ICI (Imperial Chemical Industries, established in 1926) and German IG Farben (in 1925, AGFA, Casella, BASF, Bayer, Hoechst, Hüls and Kalle merged together). While German, British and American companies tried to associate themselves into bigger corporations, French companies stayed independent.

The USA founds the Department of Chemical Engineering in 1920 as a part of MIT (Massachusetts Institute of Technology). The most important American companies in the interwar period were for example DuPont, Allied Chemical & Dyes, Union Carbide & Carbon (UCC), American Cyanamid Company (ACC), Dow Chemical, Hercules Powder, Eastman Kodak, Rohm & Haas, US Rubber, B. F. Goodrich, Goodyear Tire & Rubber, Firestone, Charles Pfizer, Merck, Eli Lilly and others.

The appearance of new chemical products came hand in hand with the progress in technology and was often a reaction to the needs of new industrial branches. Typical example of this close connection is the cooperation between automotive and chemical industry.

Due to the expansion of automotive industry, there was a growth in demand for rubber. Natural resources were not sufficient and therefore, research institutes had to deal with the synthetic preparing of rubber. The quality of petrol had to be increased too. The main objective was to develop anti-knock fuel additive, which would increase the efficiency of the engine. Thomas Midgley (1889 – 1944), industrial scientist, who worked for General Motors, invented tetraethyllead, which improved the efficiency of combustion.

Some other considerable improvements came with the invention of catalytic cracking of oil, which was patented by Standard Oil. French engineer Eugène Houdry (1892 – 1962) who cooperated with Socony Vacuum and Sun Oil was another important scientist. He invented silicon-aluminum catalyzer, which was used for the production of high-octane Nu – Blue Sunoco petrol. Thanks to this Frenchman’s invention, Allied forces were a bit stronger, because the RAF (Royal Air Force) imported 100-octane US petrol instead of 87-octane petrol which they used before the war.

Germany coped with own after-war situation relatively successfully. In 1925, two German scientists Franz Fischer (1877 – 1947) and Hans Tropsch (1889 – 1935) discovered new way how to make petrol from coal. First synthetic petrol appeared in 1926 in the factories of IG Farben, which invested into this research. However, synthetic petrol wasn't able to compete with petrol made from at that time cheap oil. In the interwar period, most of the vitamins and hormones were discovered and described, but their industrial production was the question of the after-war period, because special technical equipment and analytic methods were needed.

The growth of population and civilization advance entailed the problem of the production of food. Another, more efficient fertilizers were discovered and scientists tried to improve herbicides, fungicides and insecticides. The most important discovery in the sphere of insecticides was the DDT, which was described by Paul Müller (1899 – 1965) from the J. R. Geigy's company. Germany also launched its research in the field of macromolecular chemistry. First macromolecules, formed by chaining smaller molecules, were prepared by Herrmann Staudinger (1881 – 1965) who worked for the BASF. Staudinger's work was the beginning of polymer chemistry. Chemists tried to connect more and more monomer units into longer chains and polymer chemistry was in the greatest progress in that time. DuPont founded Experimental Station for polymer research, which was led by Wallace Carothers (1896 – 1937). Their first success was neoprene, synthetic rubber, which was patented and its production started in 1931. The next goal of DuPont was to find synthetic fiber. This fiber, called nylon, was patented in 1935 and implemented in 1939 in New York. Nylon was the first completely synthetic fiber in the history.

8. World crisis

The economic depression that began in 1929 in the USA afflicted the whole world and caused cut-down of investments into industrial production. Companies wanted to cut the costs to minimum and as expected, the research laboratories were affected by this policy too.

Germany was the most affected country in Europe. Germans tried to find the sources of energy, food and materials that would be applicable both in the time of piece and in war. Nazis expected that if another war appeared, Germany would be completely isolated from other sources.

The research of synthetic fuels was reinforced and largely supported. Herrmann Göring, who was responsible for the economy in Hitler's Germany, subordinated whole national industry to his own company, Reichswerke Herrmann Göring. More than that, the power and range of his "empire" was magnified by confiscations of Jewish property. Göring's company had collusions with for example IG Farben, the most generous sponsor of Hitler's election campaign.

The expectations of IG Farben were fulfilled during the WWII, when IG was the only supplier and producer of explosives and synthetic petrol in Germany. The Nazi ideology didn't wish well towards scientific research and many outstanding scientists, doctors and technicians of Jewish origin had to leave the country.

9. Interwar period in the Czech Lands

The Czech universities were still isolated from the most of the industrial production. Many new scientific schools were founded by people who spent some time of foreign universities, mostly in Germany or in Great Britain. There was a lot of chemical industry in Czechoslovakia, but the export possibilities were narrowed by the existence of a really strong competition with Germany. Nevertheless, during the twenties and thirties of the 20th century, Czechoslovakia was one of the economically strong states in Europe. The first-republic industry had a wide range of products and some of them were able to compete with the products of foreign states (for instance alkaline hydroxides, adducts of chlorine, active carbon or citric acid). Czech chemical industry mostly used some foreign patents or worked under the license of a foreign company, the influence of the Czech scientists on industrial research was minimal in the thirties (many foreign scientists, mostly from Germany, Hungary and Austria worked in Czech laboratories). The Czech research workers were focused mainly on fertilizers, sugar industry, alcohol industry and agricultural industry and most of them were university teachers.

In 1920, the University of Chemical and Technical Engineering (VŠCHTI) was founded, and concerning industry, United Chemical and Metallurgical Production was still dominant.

10. Second World War

The needs of WWII started the implementation of discoveries from the interwar period, and the results of research were more important than ever before. Huge amounts of money were invested in military research and some projects had virtually unlimited access to money (for example Project Manhattan).

Not only weapons, but also pharmaceuticals recorded a considerable development (mainly in preparations that were used against infectious diseases). In 1939, Australian Howard Florey (1898 – 1968) along with German biochemist Ernst Chain (1906 – 1979) isolated the *Penicillium notatum* mould, which was described by Scottish microbiologist Alexander Fleming ten years before. The US Government wanted to fasten the production of penicillin and entrusted 21 chemical companies with the production of this pharmaceutical. The first company that introduced penicillin was Merck in 1942 and two years after, Pfizer started to produce penicillin in large amounts and became the world's number one producer. This miraculous pharmaceutical was used for treatment of allied forces and world stepped into the era of modern medicine.

11. Czech chemical industry during the Second World War

The Czech chemical industry suffered because of the German occupation, because it was used unevenly, according to the needs of the German occupants. Jewish property was confiscated and redistributed to the supporters of the regime. Czech universities were closed on 17th November 1939 and buildings were given over to German institutions. Some of the students were forced to work in German factories, few research workers were allowed to continue in their work in German research institutions, but the most of the students and teachers were simply fired.

12. Postwar chemical industry till 1973

After the Second World War, the chemical industry totally changed. The refinement of oil and the development of polymers are the main objectives of the chemical research. Oil and industry was developing really fast, because it was obvious that resources of coal are exhaustible.

Polymer products came to be produced in large amounts and they literally flooded the market.

The situation was different in socialist countries, because they started to use the oil and natural gas a bit later than the western countries. Although the chemical industry was dependent upon the licenses and patents of western countries, it was very hard to obtain it, especially during the Cold War. The industrial production was often subordinated to political interests and therefore some of the products became useless and unnecessary.

New economical crisis appeared at the beginning of seventies, when OPEC (Organization of the Petroleum Exporting Countries) suddenly started to increase the prices of oil.

13. Czech chemical industry in the postwar period

The Czech industry after the WWII was remarkably changed. It was subordinated to the international agreements within the RVHP (Council of Mutual Economical Support). Scientific instruments from abroad were rare and when they occasionally appeared, it was a donation from UNRRA (United Nations Relief and Rehabilitation Administration). In 1952, Czechoslovak Academy of Sciences was established.

The Czech chemical industry was one of the most energy-consuming branches. At the beginning of its postwar development, the Czech chemical industry was mainly focused on so-called “heavy chemistry”.

14. Chemical products from the seventies till the end of the millennium

In seventies, industrial companies started to care about the energy savings and ecology. In Europe, the USA and in Japan, the issue of research and development became the part of economic planning that cannot be thought apart from.

The first oil shock in 1973 only confirmed that the world inheres in a deep, long-lasting crisis. Especially the overproduction of plastics and artificial fibers was the problem, some of the companies were producing reserves, because they expected that the prices would increase. It was necessary to reduce the production of oil products and reorient priorities.

Today's chemistry needs absolutely precise products and therefore the technologies must be precise too. Of course this preciseness is compensated with high financial requirements.

15. Czech chemical industry from seventies till the end of 20th century

Chemical industry lost its connections from communist era and soon was separated from its Slovakian partners. All the big industrial groupments and business infrastructures of large companies fell apart. Czech chemical industry can base on the experience of scientists from the Academy of Sciences, universities and companies research centers.

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The Development of Research Organisations in the World and in the Czech Lands

Jaroslav Folta

> Motto: *The Research in the modern industry is a Tower-shaped Skyscraper, which has its safe basis in the rock of pure science. The beams are formed by the utilization of Science or technological Research and the brickwork is filled in practical knowledge and experience of Industrial Research.*
>
> Maurice Holland*

1. The first signs

Since antiquity, there have been attempts to concentrate groups of scholars aimed at the development of learned activities: *Plato's Academy, Aristotelian Lykeion, Alexandrian Museion* of the epoch of Hellenism, *The Assembly of Scholars* and *The Astronomical Bureau* of the Tchang Dynasty of China, *Houses of Wisdom* of Baghdad in the 8th and 9th C., as well as praiseworthy activities of the *medieval Irish monasteries* and the Alcuin's Learned Society of the short period of Caroline Renaisance of the 8th C. in conservation and development of knowledge and culture. With development of trade and artisans' activities and rise of towns, secular schools for fundamental education of merchants and craftsmen appeared and the universities for higher clerks as well. In renaissance Italy, however, the life of artists, artisans, technicians, scholars, but also of musicians, actors, poets, and writers was concentrated also in *»bottegas«***.

The free *Republics of Science* revived the idea of Academies (Platonic Academy, Academy de Lincei) in the last decennium of the 16th C. Giambattista della Porta, Marin Mersenne or hundert years later in the Czech Lands baron Joseph Petrasch with his *Societas Incognitorum* (1746), or Josef Stepling, Director of the Philosophical studies at the

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* member of the Board of the Advisors Committee of the US National Research Council, in his paper on the 1st International Congress for Science Management of Labour which took place in Prague, on initiative of Czechoslovak and American Engineers in the year 1924.

** bottega = workshop of handycraft.

Prague university at the same time, belong to the scholars–prophets of the new organisations of learned activities. Twenty years later Ignaz Born edited the *Prague gelehrte Nachrichten* (1771–1772).

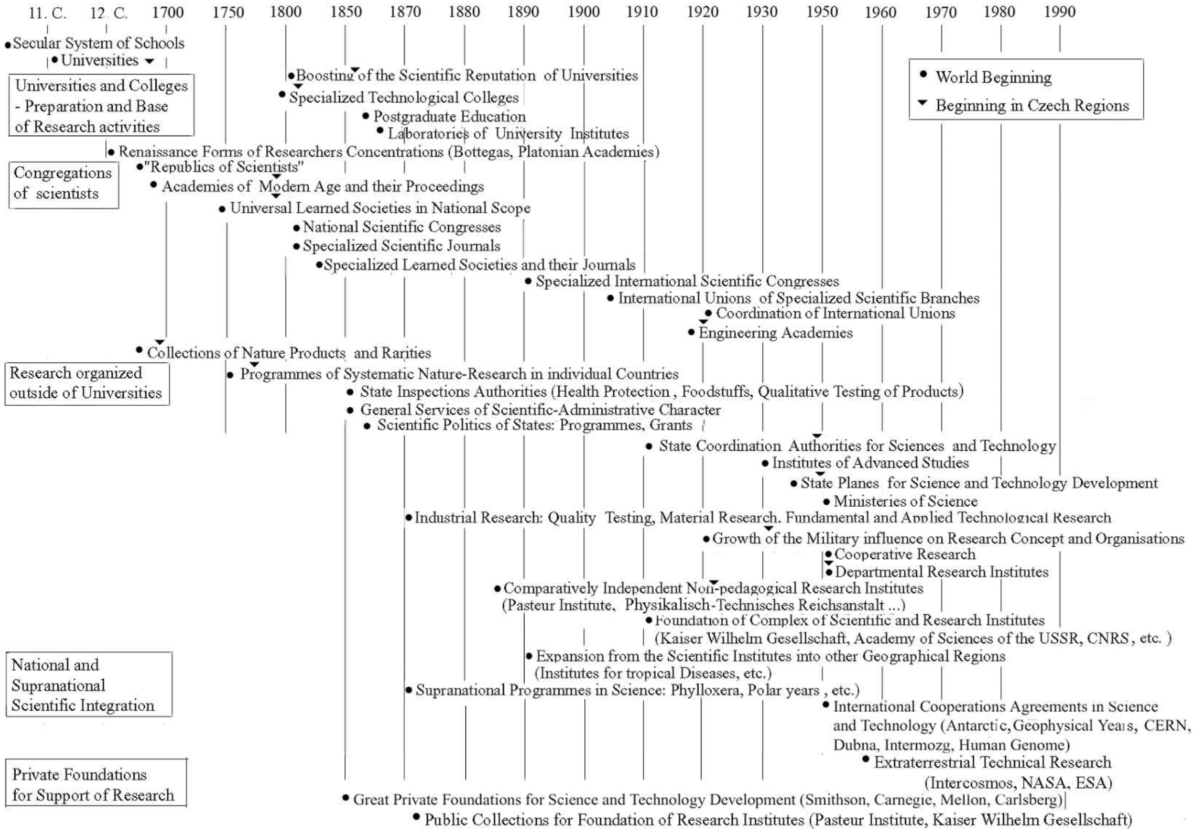
On the other hand, there were also interests of sovereigns whose protection contributed to founding similar associations or centres of research. Example of Medici and creation of Academy is well known. In the last third of the 16th C., scientific interests of local rulers and their support led to a quite new form of research centres. These were mostly astronomical observatories in which famous scholars of the time worked. Wilhelm IV of Hessen founded observatory in Kassel, Frederik II of Denmark gave opportunity to Tycho Brahe to work on the island Hven, Rudolf II of Hapsburg with his scientific adviser Tadeus Hájek of Hájek (known also as Hagecius or Nemicus) created conditions for the whole Brahe's team — Kepler, Bürgi, Raymondus Ursus and other — to work in Prague.

Towards seventies of the 17th C., famous Academies of Sciences in London, Paris and Berlin were founded; in 1724 — after negotiations of Peter I with Leibniz — the fourth academy, namely the Academy of St. Petersburg came in life. The Transactions of these Academies were the first regular and up to now surviving scientific periodicals.

In Prague, modern society of scientists started with a periodical "Abhandlungen einer Privatgesellschaft in Böhmen zur Aufnahme der Mathematik, vaterländische Geschichte und Naturgeschichte" (1775). The "Private Learned Society" arouse from scholars who regularly visited the Gerle's great specialised bookshop or the salon of count Kinský and created the first scientific corporation of the Hapsburg Monarchy, which has continued its activities after many reorganisations and under new names (*e.g.* Royal Bohemian Learned Society, which was one of the sources of the Czechoslovak Academy of Science and of its successor) up to the present. Mentioned Ignaz Born, important member of the Society, founded in Slovak Skelné Teplice (1786) International Society of Mining Sciences.

At the same time, noble Collections of Rarities were transformed to professional museums, where also groups of researchers formulated their programmes regarding systematic research of nature of their countries, as initiated by attempts to explore the raw-materials needed for the starting industrialisation. British Museum was opened 1759. The oldest museum in the Czech Lands was founded in Opava (1814), soon after followed by Brno (1818) and Prague (1818).

Tab. 1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● World Beginning
▼ Beginning in Czech Regions
Universities and Colleges - Preparation and Base of Research activities
● Secular System of Schools
● Universities ▼
● Boosting of the Scientific Reputation of Universities
● Specialized Technological Colleges
● Postgraduate Education
● Laboratories of University Institutes
Congregations of scientists
● Renaissance Forms of Researchers Concentrations (Bottegas, Platonian Academies)
● "Republics of Scientists"
● Academies of Modern Age and their Proceedings
● Universal Learned Societies in National Scope
● National Scientific Congresses
● Specialized Scientific Journals
● Specialized Learned Societies and their Journals
● Specialized International Scientific Congresses
● International Unions of Specialized Scientific Branches
● Coordination of International Unions
● Engineering Academies
Research organized outside of Universities
● Collections of Nature Products and Rarities
● Programmes of Systematic Nature-Research in individual Countries
● State Inspections Authorities (Health Protection , Foodstuffs, Qualitative Testing of Products)
● General Services of Scientific-Administrative Character
● Scientific Politics of States: Programmes, Grants
● State Coordination Authorities for Sciences and Technology
● Institutes of Advanced Studies
● State Planes for Science and Technology Development
● Ministeries of Science
● Industrial Research: Quality Testing, Material Research, Fundamental and Applied Technological Research
● Growth of the Military influence on Research Concept and Organisations
● Cooperative Research
● Departmental Research Institutes
● Comparatively Independent Non-pedagogical Research Institutes (Pasteur Institute, Physikalisch-Technisches Reichsanstalt ...)
● Foundation of Complex of Scientific and Research Institutes (Kaiser Wilhelm Gesellschaft, Academy of Sciences of the USSR, CNRS, etc.)
National and Supranational Scientific Integration
● Expansion from the Scientific Institutes into other Geographical Regions (Institutes for tropical Diseases, etc.)
● Supranational Programmes in Science: Phylloxera, Polar years , etc.)
● International Cooperations Agreements in Science and Technology (Antarctic, Geophysical Years, CERN, Dubna, Intermozg, Human Genome)
● Extraterrestrial Technical Research (Intercosmos, NASA, ESA)
Private Foundations for Support of Research
● Great Private Foundations for Science and Technology Development (Smithson, Carnegie, Mellon, Carlsberg)
● Public Collections for Foundation of Research Institutes (Pasteur Institute, Kaiser Wilhelm Gesellschaft)

Military needs forced to introduce the military technical education (esp. regarding fortification and artillery). First school of that type was founded in the Venetian Arsenal (1506). Mining and metallurgical technology, however, needed already prepared workers too. They were in the 15th C. educated in the first European centre of that time, located also in Venice. In the 16th C., the Czech Lands and Saxony (their border areas of The Ore Mountains) were centres of silver mining and this is why also special schools were founded in Jáchymov (Joachimsvalley), as well as in Freiberg. At the same time, mining education was developed in Banská Štiavnica (Slovakia); (these schools had some significance later as a pattern, during the French school reforms, at the beginning of the French Revolution).

With spreading the trade also other levels of society needed better public techniques, such as nets of roads, bridges and river constructions, with ambivalent purposes — both civilian and military. Similar request came from agriculture, which had a task of providing sufficient amount of nourishment for constantly growing number of inhabitants. The ascent of industrialisation demanded specialised technical professions. This is why specialised technical schools were created by states, at first with only a few students and one tutor. In the Hapsburg Empire, the process started in 1717 when — after ten years of negotiations — The Technical Chair on the Prague University was founded. The latter became a nucleus of the quite civil Polytechnic Institute of Bohemian Kingdom (1806) in Prague, resulting from F. J. Gerstner's efforts, which started in 1795.

2. Research Institutions in the Industrial Revolution

Great changes started to take place when the French *Ecole Polytechnique* was established in 1794, and the *Conservatoire National des Arts et Métiers* the same year. The Prague Polytechnic Institute was the first secular technical college in Europe, which was followed a few years later by Karlsruhe, Vienna, *etc.* The French Revolution, by words of Monge, wished to overcome the progress in industrialization on the British Isles by using the technical education. With the time of Napoleon, however, the education received rather military character.

Reforms penetrated also into the universities. Humboldt in particular made a decisive step in Berlin (1810) and showed the way how the students should be prepared to begin the research work.

Similar features could been seen at the University of Königsberg (Jacobi) around the middle of the 19^{th} C. Liebig's chemical laboratories in Giesen (1830s) were used not only for demonstrations, but also for the research of teachers accompanied by their students.

The firs decades of the 19^{th} C. brought the first national congresses of scientists and physicians and the first specialised scientific journals. Such attempts for editing the first learned periodical appeared also in the Czech Lands. The *Krok* journal, founded by J. S. Presl (1821) and edited by J. E. Purkyně, was a very ambitious, though only a modest start which finished in 1840. Palacký's *Musejník* (Journal of Czech Museum) started in 1827, and Pukyně's *Živa* (1852) survived with some interruptions up to now. Only after the fall of the Bach's regime in the 1860s, the specialised scientific journals were founded, hand in hand with the first specialized Czech scientific associations of mathematicians and physicists, physicians, chemists etc. Tradition of the Czech scientific journals like *Časopis lékařů českých, Listy chemické, Časopis pro pěstování matematiky* (journals of physicians, chemists, mathematicians), edition of which was only exceptionally interrupted during the WWII and continues up to now, has had a great cultural importance, also for creating and establishing the specialized Czech terminology.

The industrial expansion, accumulation of inhabitants into large cities (agglomerations) contributed, however, to some negatives phenomena too; namely the increase of maladies and their easy spreading — epidemics. Much of it was caused by ignorance of the efficiency of infection, of hygienic conditions, poisonous effects of some colours used in food-industry, lack of hygienic economy of supplies of water and food. State authorities had to establish the food- and health-testing institutions and also laboratories with specialized research. Pasteur, Koch, Ehrlich, Weismann, and Mechnikoff were prepared for such an opportunity. This was the start of the research connected with occurrence and impacts of "protozoa", TB, and other contagious diseases of civilisation. Thanks to this attention, during years 1876–1908 various means were found which were able to improve the environment of that time. The Prussian Empire Health Institute was founded already in 1875.

Growing cities which were separated from the country and growing number of their inhabitants needed new scientific approaches also in agriculture, in order to provide the food provisions. Research in climatology had its origin in Prague Klementinum, where Josef Stepling started regular thermometric and klimatic observation in the midst of 18th C., which continued up to now. Later, Alexander Humboldt at the beginning of the 19th C. organized the net of meteorological, hydrological, and also geophysical observatories. It was assumed that the long-time observations would support the basis for introducing suitable crop plants. Also, the first agricultural testing institutes were established at that time. State services were developing increasingly in industry, geology (searching for deposits), health care, but also in metrology and normalisation. This warranted the compatibility of technical equipment made in large series first of all on the territory of one country and allowed spreading the international trade worldwide later.

Progress in industry, its technical equipment, instruments, carried out in Germany to distribute new inventions and knowledge to other producers and to common use. In 1872 representatives of Prussian specialists with support by the Court and millitary circles proposed to create the central exhibition of those products accompanied with a pattern-workshop of exact mechanics. Negotiations were long but ideas crystalized. Development of electrotechnical industry which documented the Paris electrotechnic exhibition in 1882 led at least to founding the *Physikalisch-technical Reichsanstalt*.

Some of the countries — the United States serves as a clear example — had a very low university level of education, even in the last third of the 19th C. The proper tax policy and the private sources, however, helped to subsidize the education, research, as well as some great cultural projects. When the first financial source appeared – coming from the James Smithson's heritage(1830) – the U.S. Congress was puzzled almost two decennia whether to accept it or not, together with the Smithson's conditions. After it had been accepted, the Smithsonian Foundation was used (1846) to establish the *Smithsonian Institution*, which contributed to increasing and broadening of education, science and culture. At the end of the 19th C., the support of the *Carnegie Foundation* into the science appeared, followed by famous foundations of industrial magnates — Rockefeller and Mellon — in the 20th C. In Europe, J. C. Jacobsen devoted the income of the Carlsberg Brewery in Copenhagen to important foundation *Carlsbergfondet* for supporting science and the Carlsberg Laboratory; the latter and the *Nobel Foundation* in Sweden as well as the enterpreneur Emil Solway of Bruxelles are well known. These patterns were followed by several other donators, mostly not too rich. In the Czech region, Josef Hlávka was the greatest maecenas, whose financial support was decisive for creating the national Czech Academy of Science and Arts (1891). In small countries even little sponsorships should not be underestimated; especially in times of the economic crises, when the governmental subsides were shortened, the little foundations helped to cover expenses on publishing some research results.

Concentration of chemical, electrotechnical industries, the heavy and machine industry in the 1870s and efforts for keeping and improving quality of the production in international competition, necessitated establishment of the appropriate basic research, testing stations and laboratories of large enterprises. The top specialists from universities came sometimes to the industrial research and took the head positions in the whole industry later. The career of Prof. Abbe and Schott in Zeiss factories in Jena, Prof. Carl Duisberg in IG Farben were not the only cases.

During the 1870s, several problems arose on an "international scale" which could not be handled by individuals and required a broader co-operation. One of the first and successfully solved problems was protection against spreading of Phylloxera — a very dangerous disease of vine-grapes which could destroy all European vineyards. Another problem arose from the finding that the climate of the Earth is under the influence of the meteorological situations in polar areas. This was the reason of great investigations of regions around the Earth's poles and of organizing the "polar years" at the turn of the 20th century. These efforts continued and were followed after the WWII by broad international treaties which penetrated into a great number of research areas (International Geophysical Year, Year of Calm Sun, Geophysical Decade, COSPAR, Intercosmos, Antarctica–Expeditions). There were many other similar projects like CERN, Dubna, Intermozg, Human Genome, *etc.*

It was realized in Europe towards the last third of the 19th C. that the Universities and Colleges were not able to cover the needs formulated by the "R & D authorities" of that period. The laboratories were completely devoted to students' education and not in disposal for long-term experiments separated from the practical training of students. Donors of the kind as in The United States were missing in Europe. This is why some greater institutional projects were implemented by collecting the financial means. Thus the money for building the Pasteur Institute in Paris was amassed after the famous success of defeat of Phylloxera, hydrophobia and solving the fermentation process by Louis Pasteur. The Institution was built (1888) through national collection and was directed only towards research and was independent and relieved of pedagogical duties.

Some of the applied research institutions were not suitable to be directed by a production enterprise, owing to the decisive role they should play in creating universal and obligatory technical standards. They were better to be established as independent governmental institutions. The interests of the main entrepreneurs in fast implementation of such institutions, however, helped to form them. The already mentioned Physical-Technological Institute built in Berlin is an example of such institution, the implementation of which was in the interest of the owner of the important electrotechnical Werner Siemens concern. This is why Siemens – donating land and money – forced the Prussian Government to build the Institute and to take care for its further running. The Institute became a pattern for financing of institutions in Germany on one side and for other research institutes of experimental physics as well as of other scientific branches — also in other countries — on the other side. That achievement inspired first Emil Fischer in Germany to organize the *"Verein Chemisches Reichsanstalt"* project which collected means in the whole country for building the Chemical Institute. Only when the idea came to the hands of the Prussian Ministry of Education and was further supported by the Emperor Wilhelm II, the *Kaiser Wilhelm Gesellschaft* (KWG) was founded (1910); with its help, the whole complex of institutes of oriented basic research was then formed. This pattern has been followed *e.g.* by CNRS in France and by the Academy of Science in the USSR. Institutes of the KWG survived the WWII and — as transformed into the *Max Planck Institutes* (MPI) — they form an important part of oriented basic research units up to now.

The last decade of the 19th C. brought in a great extent also the first specialized international congresses, which led soon to creation of international unions of various scientific branches, having their national groups in individual countries. National groups were formed from leading scientists who were able to support the development of scientific activities in the specialized fields. Efforts for world collaboration and coordination of international unions emerged especially after the WWII, and such tendencies have been preserved up now, as indicated by the ICSU (International Council of Scientific Unions and lately International Council of Science).

The WWI showed that hitherto liberal development of industry and trade led to situation when any strategic products and raw materials (chemistry, optics *etc.*) were achievable only in the factories of the enemy. This is why the government coordinated councils consisting of the best scientists were called to find a way to overcome the deficiencies and to spare funding duplicate research. The achievements of such councils, however, were seen only after the War. Delayed organization of research could not fulfil the set tasks in time.

Between both WW, since 1930s in particular, the military research projects in some countries had been pushed forward and they influenced gradually the civil research too. But not all countries were prepared on the escalation of international tension. Only during the WWII the research expanded considerably in a great number of world countries. The tendency continued also after the War; let us recollect the laboratories in Los Alamos, the research of computing devices, all cosmic research in different countries, the substantial part of Silicon Valley, similar centres in the United Kingdom, »Academicheskij gorodok«, and other innominate secret soviet research towns as well. The best specialists worked in such institutions.

Only at the beginning of the 20th C., the technical education received equal rights with the university one. After the WWI, the independent technical academies were created and the Czechoslovak Masaryk Academy of Labour belonged to the first of them. The latter corporation was the first on the Czechoslovak territory which intended to create also research laboratories and institutes, though only on a very limited scale.

In 1930, quite a new institute for distinguished senior researchers and their scientific projects — Institute of Advanced Studies — was established in Princeton. Its pattern has been followed step by step also in some West European countries since 1950s.

It is like the following thesis was there confirmed: "The higher social-economic structure is developed, the greater demands on education and favourable milieu for research activities arise". This thesis has been already proved by the development and broadening of school- and university education since the middle of the 18th C.

In some countries with planned economy (since 1930s) the plans of development of science and technology have been prepared. Czechoslovakia with its first “Two Year Plans of Economic Reconstruction” (starting in 1946) belongs among them too. Efforts for keeping the constant proportional increase every year, however, would mean an exponential growth, which cannot be the real case. Centralized control of industry led also to concentration of main research activities into specialized research institutes which had to investigate problems of individual industrial or economic branches and which were ruled by the governmental departments. Activities of these institutions were linked up to the basic research institutes of the Academy of Science. In Czechoslovakia, the Academy of Science was formed from the whole series of existing scientific centres at the turn of 1953 and was then expanded step by step, also with personnel, for a long time.

Since the middle of the 20th C., specialized ministries of research and development have been established in some countries.

In the middle of the 20th C., new research institutions appeared — especially in the USA — investigating various scientific problems on the basis of contracts with private customers. System of support of scientific activities with help of grants both from private and public sources was developed namely in the USA in the second half of the 20th C. The system entered also the new transformed states in the last decade of the 20th C., after the political blocks had broken up. Contrary to the USA, however, the financial support came here from the government only. The research projects in the new transformed countries were proposed mostly by the individual researchers. To receive the support, however, a positive decision of independent specialists was required, where also economical point of view played a role.

In the overall development of research institutions we can see an interesting point. In spite of forming new types of research institutions, which were evoked by different reasons, the old forms only slightly fell behind, even in conditions when the subsidy means for their activities were lacking. The new institutions went through just with the public support and with hope in success in solving both general and particular problems, which were considered to be important at that time. Sometimes, however, especially in conditions of crises, it is too late to form necessary institutions, laboratories or research projects. Always that country has its advantage which has prepared necessary institutions and specialists who are able to respond immediately to arising problems; also a special department is needed, which is able to present contemporary problems of the society to a qualified research in time.

3. Some remarks on research development in the Czech Lands

We have already mentioned such moments from the history of research and development in the Czech Lands which entered the world history, but it is necessary to touch other moments of the development too. Those are important for the local Czech history, but show also how, and with what delay, the main world features materialized in the national history.

The first University east of Rhine and north of the Alps was founded in Prague by the Emperor Charles IV on April 7th, 1348. The University was founded in the country which already had a great network of elementary schools and even High Capitulary School, the level of which was well known and valued beyond the Czech border and which the Czech King Wenceslas II wanted to promote to the University a half century earlier. The Prague University was organized, at least in some features, in a similar pattern as the well-known universities of Bologna and Paris. At the end of the 14th C., professor of astronomy Jan Ondřejův (Andree) called Šindel (*i.e.* shingle) began his activities there. His astronomical tables were used and appreciated even by Tycho Brahe 200 years later. Šindel collaborated theoretically on the construction of the Prague Astronomical Clock with Mikuláš, horologist of the north Bohemian town of Kadaň (1410).

Great progress in the Czech Lands in mining and metallurgy of silver was made in the 14th C. and again in the 16th C. In 1556, Georgius Agricola published in Basle his *De re metallica libri duodecim*, where he with a great care described and in wood-cut form presented mining equipment with which he became acquainted during his stay in Bohemian north-west region of Jáchymov (Joachimsthal), on the Czech-Saxony border. For example, the reversible water wheel had productivity twenty times higher when compared with the hand hoist winch, and allowed water pumping from a depth of 500 m.

Geodetic and mining levelling required relatively similar exact measuring instruments. Mining needed them for exact tracing and mapping of mining activity under the earth surface, and for exact marking of boundaries for motion of workers. As for the agriculture, Jakub Krčín of Jelčany and Štěpánek Netolický started building a system of mutually connected fish ponds in south, as well as in east Bohemia. The first system was supplied with water of the river Lužnice by a 45 km long "Golden Drain" (1508–1518). For this purpose the exact levelling was needed.

No wonder that in the Czech Lands and especially in Prague worked a whole heap of precise artisans, such as Schissler, Roll, Markgraff, Stolle, Bürgi, and Habermel, who were engaged in manufacturing of observation and measuring instruments. Among them, Erasmus Habermel († 1606) in particular was the famous one. His instruments are scattered in museums as well as in private collections all over the world and are considered to be the most valued articles nowadays.

Religious arguments and protestant character of the Prague University contributed to its isolation and decline of its scientific niveau. Exodus of a great part of nobility, of intellectuals, but also of simple peasants, changed the face of the Czech Kingdom. Economic progress covering the whole Western Europe, from the North Italy over the French seaside up to the Netherlands and British Isles, was accompanied by a "second serfhood" in the Czech Lands. Only the reign of Maria Teresia and Joseph II descried that the Hapsburg monarchy faces economic backwardness and loss of the dominating position in Europe at the same time. The economic and social growth was to be achieved through education, mercantilism and easing the ideological pressure imposed by church and its authorities. Therefore also the Charles University went through reforms, which prepared the way to its further progress in the last decades of the 18th C.

Industrial Revolution changed the whole political, national, and even cultural situation in the Czech Lands. Since the beginning of the 19th C., the Czech language has become step by step not only the language which was taught at the elementary schools, but also the language of science. Along that time, world-known domestic scientists of the Czech or German origin appeared. First of them could be, for example, the famous mathematician and logician Bernard Bolzano, whose discoveries were appreciated only a few decades after his death. Bolzano had to fight with the intolerance of the church hierarchy of that time. Jan Evangelista Purkyně was a physiologist of world importance, who recognized the necessity of an academy of sciences not only as a representative, but first of all as an active research corporation provided with experimental research centres. His ideas were published in a scientific journal Živa as early as 1861. It was also Purkyně, who struggled in 1818–1819 for the birth of the first Czech science popularizing journal Krok. The main reason of such journal was to spread the science, its terminology and its up-to-date results, in the Czech language; especially at the time, when the University was even closed to this language. The third scientist to be mentioned could be Ernst Mach, professor of the experimental physics at the German University in Prague, who lived in last decades of the 19th C. Being an excellent experimentalist, he educated a heap of both German and Czech students into excellent physicists at the German part of the Prague University (divided in 1882). His skills are known from his experimental measurements of extreme velocities (velocity of sound, Mach Number).

4. Research basis of the Czechoslovak Republic

Emancipation of the Czech science in the second half of the 19th C. and formation of the independent Czechoslovak state in 1918 created convenient conditions for the development of scientific corporations, but also a suitable milieu for research activities and their results, which were acceptable in the world of science and technology. Let us pay attention first to the development of scientific corporations and their territorial dislocations.

Tab. 2. Structure of Scientific and Research Organisation in Czechoslovakia 1918 – 1939

Years	1925	1930	1935	1938
Number of Institutes:	79	148	120	1230
Location:				
% in Prague	45,6	50,07	50	In Prague together with Brno about 70 %
% in Brno	28	18,2	19,2	
% in Bratislava	3,8	5,4	5,8	
% in other regions	22,6	26,33	25	
Institutional location:				
Educational Branch	57 %	38 %	38,3 %	730 Universities and Colleges
State and Public	21,6 %	31,8 %	22,5 %	211 Museums,Archives
Librairies				
This % of out of school Institutions	50 %	51 %	27,5 %	122 Research Institutes 134 Professional Societies 21 Professional Journals 12 Lab. & Research Stations
Staff:				
20 and more		8,1 %	14,1 %	
10–19		17,6 %	24,1%	
less than 10		74,3 %	61,8 %	

Date of foundation:	before 1918	1919–1920	1920–1930	1930–1935
	42	22	30	3
therefrom state/school-institutions		8/14	11/8	

The Table 2* points out some important facts: Research was concentrated all the time in Prague (50 %) and together with the Moravian metropolis of Brno it formed the most important part (70 %) of the whole research basis of Czechoslovak Republic. Research units of the Universities and Technical Institutes predominated (from 38 to 50 %). Laboratories and testing stations in factories show increasing tendency. The former agricultural state research was privatized during the economic crises of the 1930s. While 42 of the followed research institutes were founded before 1918, then within the first two years after formation of Czechoslovakia 22 new institutions were established (8 at the universities and 14 founded by the state, from which 11 were agricultural and the other geological and hydrological institutes). In a relative peaceful decade of 1920–1930, 30 new research establishments were open, among them only 8 were formed by the state and 11 by universities. The rest (11) was oriented towards the industrial- or food testing and research. As for the number of staff, only 1/12 to 1/6 of the followed institutions had more than 20 employees and about 2/3 of them had less then 10. Among the great research bodies we could see research institutes of the Iron-Works Vítkovice (58)**, the Mining Company Vítkovice (49)**, Iron-Works Třinec (47)**, Iron-Works Poldi Kladno (47)** but also Hydrological Institute (62)**, State Health-Service Institute (196)**, State Agricultural Institutes (72)**, Research Institute of Sugar Industry (26)**, Testing institute in Brno (28)**, Leather Research Institute (22)**, Institute for Utilizing Coal (21)**, Institute for Improving Trade (21)** *etc.*

The necessity of a better organisation of technical research was incited especially by Stanislav Špaček (he became later the Technical Attaché of The Czechoslovak Embassy in The United States), who initiated — immediately after the formation of Czechoslovakia (1918) — establishment of an engineering association, which later received the name Masaryk Academy of Labour. At its start, the institution received a great financial support, amounting to one million crowns, from the Czechoslovak President T. G. Masaryk.

We should mention a whole series of results — which could not be achieved without supporting the developing research laboratories — such

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[*] Table is composed using registers prepared by the Masaryk Academy of Labour in the years 1925, 1930, 1935, and completed by another unpublished register from 1938 preserved in the Archive of the Czech Academy of Science.

[**] Number of employees

as discovery of polarography (1924, J.Heyrovský), original system of TV (1935–1937, J. Šafránek) or construction of a ferro-concrete bridge-bow of 150 m span, one of the greatest in the world at that time (1939–1940, Podolsko).

5. Situation in the Czechoslovak "R&D" after the WWII

Even after the WWII, Czechoslovakia did not belong among the outsiders in research and development. Scientists and researchers — whose number was already very limited due to the economic crisis since the middle of the 1930s — were decimated or forced to leave their research work during the Nazi occupation. On the other hand, in the time of the WWII some of the scientists had to work in large factories, which were important for the war (so called »total Einsatz« according to the Nazi terminology). They used their situation and illegally carried out applied research and prepared new products for the postwar industry. In spite of stringent Nazi supervision, the following products were developed: the Czech kind of nylon in Baťa's laboratories in Zlín, mykoin (Czech penicillin) in Fragner's pharmaceutical plant in Prague-Hostivař, motorcycle JAWA 250 in Janeček's weapon factory, and the car Aero Minor. A similar situation was in Prague research institute of Škoda enterprise, in Aero Letňany and several other, which provided a very good position for the Czechoslovak industry after the end of WWII.

Destroyed factories, war-oriented industry and whole economy and poor supplies for the citizens led to a decision on a two-year plan of economic reconstruction (1946–1948), which was succesfuly fulfiled. In postwar Europe, however, Czechoslovakia came under the influence of the Soviet Union (1948) and the planned economy and its central control was totally introduced. Industry, agriculture and trade were nationalised and their central control went through many changes. It touched the base of research and development too. After the War, decisive steps were made for creating a base of fundamental research (to be financially fully covered by the government) and for governmental support of research work[*]. Centre of scientific research (Ústředí vědeckého výzkumu) was

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[*] As early as 1945, a group of professors of the Prague University and Technical Institute gathered on a private basis, which was later, on the 2nd April 1946, institutionalised as The State Research Council — a commission of The State Planning

established by The State Commission for Planning (Statní plánovací komise) and six Central Research Institutes were founded there in 1950: Mathematical, Physical, Polarographic, Geological, Biological and Astronomical. It was the first step towards organising the Czechoslovak Academy of Science in 1952.

Interests of scientists were coincident with the ruling so called "scientific ideology", which considered science as a substantial part of the "planned and directively controlled society". Centralisation of industry needed also a net of institutes of applied research. These had a small tradition from the interwar period (Škoda, Poldi, Baťa, Vítkovice, Spolek pro chemickou a hutní výrobu, *etc.*) and through newly organised integrated enterprises large institutes were founded*.

Number of students at universities of all kinds was five times larger in comparison with the situation between both WWs. Statistics show that there were about 150 thousands of employees working in different branches of science and research. Scientific institutes were formed, which — together with other former research centres — created the Czechoslovak Academy of Sciences (1952) and the whole network of research establishments, controlled by the central offices, ministries and central commissions. On the other hand, in spite of the full economic support of science, the ideological concept of controlled and planned society impeded not only the free development of science, but introduced also some economic barriers which were unfriendly to further development of science (restrictions of scientific contacts with western countries, of import of scientific journals and literature, embargo on special materials and instrumental equipment, *etc.*).

Science and technology in conditions of divided world — of the technologically and economically very isolated national economy — was forced to prepare programmes for the Czechoslovak industry and agriculture, which could overcome barriers imposed by the political development. In spite of difficult conditions, there are series of results showing a good quality of the Czech and Slovak specialists whose achievements

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Bureau. The council formulated "The overview of the tasks of research in the Two Year Plan", which was the first attempt to coordinate the research activities in the Czechoslovak Republic.

* For example, Research Institute of Communication Engineering (Výzkumný ústav sdělovací techniky) was founded in 1952; in 1980s, it had 1500 employees in Prague and 300 in its branch in Košice. Results of their activities were used in production plants of TESLA Concern *etc.*

are comparable with those obtained internationally. In the 1970s and 1980s, however, stagnation in the research and development was evident.

Not all the registers of research institutes which were made in the last decades are compatible with each other in all aspects. Therefore, we used for analysing research organisations only the register from 1972. The latter shows the rise in number of institutes

Tab.3. Structure of Research Organization in Czechoslovakia in 1972

	1972	%	Founded before 1945 (in % of the whole)
Number of Research Organisations in Czechoslovakia	296	100	39,3
Therefrom:			
• Departmental Research organized by ministries or enterprises	168	56,7	13
• Basic Research:			
Natural Sciences and Technology (without Universities)	90	30,4	3,3
Humanities (without Universities)	38	12,9	23

(From total number of organisation were) founded in years:

Before 1945	34	11,0 %			
1945–1950	35	11,9 %		Departmental (ministerial) research	21,2 %
1951–1956	121	41,2 %	includes	Science/Technology	15 %
1957–1961	27	9,2 %		Humanities	5 %
1962–1967	50	17 %			
1968–1972	27	9,2 %			

Tab. 4. Territorial Location of R&D Institutes in 1972

							Therefrom			
	Total	%	Depart.	%	Basic	%	Sci/Tech	%	Hum.	%
Czech Regions	198	66,7	128	74,8	71	56,3	52	58,5	19	51,3
(Prague)	100	33,9	46	27	55	43,6	40	45	15	40,5
(Brno)	26	8,7	16	9,3	10	8	7	7,9	3	8,1
(outside metropolis)	72	24,1	66	38,5	6	4,7	5	5,6	1	2,7
Slovakia	98	33,3	43	25,2	55	43,6	37	41,5	18	48,7
(Bratislava)	63	21,5	19	11,2	45	35,7	28	31,5	17	46
(outside metropolis)	35	11,8	24	14	10	8	9	10	1	2,7

Research organisations in 1972 according to the number of their staff:

	Total	%	Depart.	%	Basic	%
less than 30 persons	22	7,5	2	0,7	20	6,8
30–100	79	26,6	23	7,8	56	18,8
101–500	166	56	118	40,1	48	15,9
501–1000	24	8,2	20	6,8	4	1,4
more than 1000	5	1,7	5	1,7	–	–

during the period 1951–1956, especially in industrial research, but also in basic research — either in natural sciences or in the technological fields.

Tab. 5. Changes in directors in R&D institutes between 1966 and 1972 (data incomplete)

	Total	Departmental	Basic
Number of Institutes	256	168	128
(Comparable subset)	(216)	112)	(104)
Change of directors	124	72	52
Without change	92	40	52

Tab. 6. Number of staff and total funding of R&D (Czech regions) 1965–1993:

Years		1965	1970	1975	1980	1981	1982	1983	1984	1985
Total Number										
of staff in R&D	Czechosl.	128,2	147	160	181,4	180,7	183,2	185	188,5	193
in thousands	Czech Lands	–	–	120,3	130,9	129,3	130,3	130,8	132,8	135
Therefrom:										
•graduates	Czechosl.	29,2	37,9	45,7	54,9	54,9	56,9	59	60,9	63,3
	Czech Lands	–	–	33,9	36,7	38,2	39,3	40,5	41,4	42,7
•with sci. degree	Czechosl.	4,8	6,8	8,2	10	10,6	10,9	11,3	11,7	12
	Czech Lands			6,1	7,3	7,5	7,7	8	8,3	8,5
Total funding										
in thousands mill	Czechosl.	0,7	1,1	1,6	18,3*	18,2	18,7	19,4	19,9	21,3
of used currency	Czech Lands									14,9

Years		1986	1987	1988	1989	1990	1991	1992	1993
Total Number									
of staff in R&D	Czechosl.	196,2	199,1	205,4	198,5	155,4	113,9		
in thousands	Czech Lands	136,8	137,9	140,4	137,9	105,9	76,5	57,2	40,2
Therefrom:									
•graduates	Czechosl.	65,2	67,2	69,3	68,5	46,2	35,6		
	Czech Lands	43,8	45,2	46,4	46,3	31,2	23,4	18,8	13,3
•with sci. degree	12,2	12,7	13,2	13,4	11,5	14,7			
	Czech Lands	8,6	8,9	9,2	9,4	7,9	6,3	5,9	5
Total funding									
in thousands mill	Czechosl.	22,9	24,7	25,9	24,7	17,3			
of used currency	Czech Lands	15,9	16,3	17,8	16,7	12,4	15,2	14,5	12,3

* since 1980 another statistical methodology

In comparison with the interwar structure, territorial transformation of localisation of scientific and research institutes is obvious (institutes of universities are not included). First of all, it looks as if it was planned that one third of the research institutes should be located in Slovakia, therefrom 2/3 in Bratislava. Prague, which had about 50 % of the state's research capacity in the inter-war period all the time, had half capacity of only the Czech regions in 1972. This was mostly covered by institutes of basic research operating with a small staff. While Prague together with Brno covered 70 % of research capacity of the whole Czechoslovakia in 1918–1939, then the same held for the Czech Lands in 1972. Research was transferred out of the metropolis, though the Prague region played still an important role. Number of staff in research institutions rose substantially. This concerns especially research controlled by ministries, where almost 50 % of institutes had around 500 employees. Scientific and research base was hurt to a large extent by political interventions after "Prague Spring" in 1968. Even incomplete data following from the comparison of two registers show that there were great changes on the leading positions (posts of directors), as a consequence of the reaction to the soviet intervention in 1968. We only have data for 216 research organisation of 296 in total and in 124 of them the director was replaced.

In the post-war period, modern new buildings were built for many institutes. This concerns not only the institutes of basic research of the Academy of Sciences (Biological Institutes, Institute of Physics, Institute of Nuclear Research, Institute of Biochemistry, Institute of Mathematical Machines, Institute of Theoretical and Applied Mechanics, Institute of Macromolecular Chemistry *etc.*). Research centre was built sometimes in cooperation of the Academy with University (*e.g.* The joint research centre of the Academy of Sciences and The University of South Bohemia in České Budějovice). Also, every industrial branch had its own research institute; there were more than 60 such institutions in Prague itself even in 1990. It is not easy to give account of the results which were produced by such extensive research base (it is still the task of contemporary historians of science). Therefore only a few examples are given here:

- construction of the SAPO computer (1953) and further development of computing technology (of COMECON) (in period 1968–1989 series called in Czech JSEP (united series of electronic computers)
- production of semiconductors and integrate circuits (1955, 1965)
- development of own series of the artificial satellites MAGION (since 1978) and other basic equipment for cosmic research
- development of macromolecular materials resulting in production of contact eye lenses from hydrophilic-gel (1956-57)
- production of nuclear reactors for nuclear power plants (since 1956) and further development of nuclear engineering
- development of open-end spinning machines (1963-1965)

- in aircrafts industry, focusing on special training planes with engines developed and produced in Czechoslovakia (the first type L-29 Delfín 1959, *etc.*)
- in weapon industry development of new generation of very effective passive aircraft locators (types: Kopáč, Ramona, Tamara, Věra *etc.*, since 1964)

Such results were fully comparable with other achievements of scientific and technological research in the world and in some features brought even new views and elements.

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The Question of the Mysterious Tycho Brahe's Death Still Alive: Book Review[1]

Igor Janovský

The book by Joshua and Anne-Lee Gilder[2], considered often to be a bestseller, could be described as a historical and biographical book with a criminal plot — Tycho Brahe's death. Brahe's death has been repeatedly discussed and explained on the basis of testimonies of three Brahe's contemporaries — Kepler, Brahe's friend Jessenius and a doctor Wittich. It is known that on 13th October 1601, at a banquet by Petr Vok from Rosenberg, Tycho Brahe — apparently without any previous symptoms — was taken seriously ill, was unable to urinate and died on 24th October 1601.

The Gilders returned to the problem on the basis of results of relatively recent analyses of Brahe's beard and hair samples. In 1901, three centuries after Brahe's death, the crypt in the Tyn Church in Prague was opened, Brahe's remains were identified and hair and beard samples were taken. In the 1990s, some of them were transferred to Scandinavian countries and analyzed in Denmark and in Sweden, in 1993 and in 1996, respectively. In both cases mercury was detected in samples.

It is known that the acute mercury poisoning leads to damages of renal tubules which results in uremia and this is basis of the Gilders' story. It is well known that Brahe worked with mercury for many years (he prepared medications containing mercury, used mercury in a time-measuring equipment and also for gilding his instruments), moreover, his body was possibly embalmed with ointment containing mercury. Despite that, the authors have no doubts that Brahe was murdered. They admit that it is of course impossible to achieve absolute certainty as to who Brahe's murderer was four hundred years after the act, but through a process of elimination and examination of those three forensic standbys

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[1] Joshua Gilder and Anne-Lee Gilder: *Heavenly Intrigue. Johannes Kepler, Tycho Brahe, and the Murder Behind One of History's Greatest Scientific Discoveries.* (Doubleday, New York, 2004, pp. XVI + 304, ISBN 0-385-50844-1). The book review has also been published in Czech [1].

[2] Joshua Gilder worked as a journal editor and Ronald Reagan's speechwriter. Anne-Lee Gilder worked as a news reporter/producer for German TV.

— opportunity, means and motive, they believe that the circumstantial evidence points directly to Kepler. According to the authors, the main Kepler's motive was his apparent desire and almost an obsession of getting hold of the Brahe's results of thirty-years observations of celestial bodies, which he needed for verifying and completing his theories and model of solar system. Regarding the biographical data, the authors describe Kepler as a rather sickly and reclusive person with a rather doubtful character. They document it by many quotations from his private autobiographical notes, denominated as *Self-analysis.*[3] To what extent, however, these Kepler's ideas from his youth and student years reflect the reality remains questionable. According to the authors, Kepler is an opposite to the noble, strong and extrovert Brahe; *apart from their genius and love of astronomy, the two could hardly have been more different* and their eighteen-months long collaboration at the dawn of the 17th century is classified as *one of the most emotionally fraught and contentious collaborations in scientific histories.*

What are the results of analyses actually about and how are they interpreted in the book? A 4-cm long beard sample was used for the analysis performed in the Institute of Forensic Chemistry of the University of Copenhagen [2]. The sample was dissolved in nitric acid and by atomic absorption spectrometry the average concentration of 6.25 microgram of mercury per gram of beard was determined; for comparison, a value of 0.5 microgram per gram was determined as today's "normal" concentration. Kaempe and coworkers assume that if Brahe ingested mercury 11–12 days before his death, it would be concentrated in beard near to the roots, and concentration in the first half-centimeter of the sample would be then eight times higher than it was found (i. e. 50 microgram per gram, which is hundred times the "normal" value). This value, however, was not determined experimentally. Nevertheless, the Gilders' in the book say (p. 207): *The level of mercury, however, was practically out of the charts, some hundred times the quantity found in Kaempe's "control" – the hair of a modern-day Dane used as a standard of comparison. To Kaempe, the quantity found clearly suggested a lethal dose of mercury.*

Today's "normal" concentration of mercury in hair which Danish scientists state seems to be rather low for a country with a high consumption of sea fish; significantly higher levels are stated nowadays, due

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[3] Probably according to the *Selbstcharakteristik* contained in Johannes Kepler's *Selbstzeugnisse* (F. Hammer, Stuttgart 1971).

to the sea contamination mainly by organic mercury compounds [3]. In Brahe's time, there were no ecological problems; nevertheless, since Brahe worked with mercury for many years, the concentration of mercury in his beard need not necessarily be negligible. Mercury could be spread then all along the beard. An analysis, which could have excluded such possibility, apparently was not performed.

External contamination could also create problems with determinations of various substances in hair [4-6]. Small ions of trace metal elements easily get into the internal hair structure and bind to many sulfhydryl groups of keratin proteins; moreover, old hair has increased permeability.

Having disregarded the above uncertainties, how important is the stated concentration of mercury and what risk it means, based on the current knowledge? For instance, with the mercury concentration in hair of about 50 micrograms per gram, there is a five percent risk of a neurological damage [7]. Therefore, even such concentration does not necessarily prove an acute poisoning.

The hair sample was also analyzed by J. Pallon in Sweden at The University of Lund [8,9]. His method makes it possible to determine spatial distributions of elements in material[4]. According to his report, *a very high local concentration of mercury* was determined close to the hair root and it was found that mercury is present inside the hair sample. Since mercury is carried into the hair by blood and its metabolism is very fast, tracing the mercury concentration from the hair root towards the tip means actually studying a time dependence. Based on that, Pallon came to a conclusion that Brahe ingested mercury one day before his death and the mercury-exposure had a duration of less than one hour. Besides mercury, there were also domains with local concentrations of iron and calcium. What a pity that only section of hair corresponding to three days before Brahe's death was analyzed and not a longer one, which might have perhaps shown a potential occurrence of mercury corresponding to the ingestion of mercury 11–12 days before the death, which Kaempe assumed.

In the Pallon's report, there are no data on absolute mercury concentration and it says then relatively little about possible poisoning. As for the speed of the hair growth (on top of the head), 1 cm per month is stated usually, however, there have been also values of 0.6–3.6 cm per

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[4] PIXE method (Particle Induced X-ray Emission).

month reported [4] and it is possible that the speed is affected also by the state of health. And what did the Gilders do with the results of the Pallon's study? They say that Brahe was poisoned by mercury twice: first time 11 days before his death, when he got ill, and the second dose, which was lethal, he was given 13 hours before his death. The Gilders give the latter time without any tolerance[5], because it obviously suits their scenario and one of the book chapters is even called *Thirteen hours*. According to the Gilders, Brahe was given the second dose of mercury on the eve of his death, before he went to bed, on the day when he felt somewhat relieved from his illness and bequeathed his longterm observation data to his heirs. The Gilders in their fantasy go too far explaining the occurrence of iron and calcium in hair in such a way, that the poisoner used a semi-product from the laboratory preparation of Brahe's "elixir", containing very poisonous corrosive sublimate (mercuric chloride) and iron. And in order to disguise its strong corrosive effects, the poisoner put it in the milk, which contains calcium. It is well known, however, that both elements are natural components of organism and their occurrence in hair can reflect their release in the body due to a damage to organism or to some organ; there are also phenomena called "biologically unavailable calcium", in which case calcium precipitates in hair tissue, instead of remaining in the blood [10].

It is worth mentioning that mercury was also found in the hair of Isaac Newton, allegedly in concentration of approx. 200 micrograms per gram, which is significantly higher than in the Brahe's case; since Newton as an alchemist also worked with mercury, this probably didn't surprise anybody and his peculiar behaviour in a certain period of his life was ascribed to it [11].

And how do the experts who performed chemical analyses explain Brahe's poisoning by mercury? Kaempe, Director Emeritus of The Institute of Forensic Chemistry, assumes that Brahe was murdered and most likely by Kepler's wife Barbara, whom he calls "a serial killer" (he accuses her of murdering her previous husband and two of her kids and perhaps even of an attempt to poison Kepler) [12,13]. Claus Thykier, Director Emeritus of The Ole Rømer Museum in Taastrup in Denmark, who collaborated with Kaempe, assumes that Brahe suffered from malady common for men of his age and poisoned himself accidentally by his own "universal medicament", whose one component contained mercury

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[5] Apparently according to the Pallon's diagram given the book.

(*Medicamenta tria*), in other words that Brahe committed suicide by misadventure [14, 15]. Pallon admits that it is possible that Brahe poisoned himself by taking the medicament or by mistake, or that he was poisoned by somebody else [9].

Fact, that there are also other ways how to explain Brahe's death, shows very well in his review Professor of physics and astronomy Marcelo Gleiser[6], who — only as an "exercise in bias" — gives also reasons for possibility of Brahe's committing suicide [16]. Gleiser mentions Brahe's depression due to his younger brother's death, distress by disputations with Ursus who falsely accused him of plagiarism, serious financial difficulties, and finally understanding the fact that his geocentric concept of the world is false and that Kopernik is right. On the other hand, the Gilders in their bias exclude any other possibilities except for murder.

It is clear that Kepler needed Brahe's observation data and the relationship between him and Brahe was full of problems. But how do the following facts compare with his accusation of murder? Only a few weeks before Brahe's death, it was agreed at a joint audience with the Emperor Rudolf II. that Kepler would work on the Brahe's data (*Rudolphine Tables*); allegedly on his deathbed, Brahe begged to complete the Rudolphine Tables as soon as possible, adding that he hoped Kepler would demonstrate their theory in terms of the Tychonic system and not the Copernican [17]. Not too long after Brahe's death, Kepler wrote his known *Elegy on Tycho Brahe's death*.

Some passages in the book are word for word repeated (quotations from *Self-Analysis* on pp. 23 and 244 and description of Brahe's *Elixir* in Chapter 24 and in Appendix). The following statement could evoke also certain doubts in readers: *While it's something of a mystery why so many of Kepler's incriminating letters have been lost to history (and are known only from the often shocked replies of his correspondents), it would not be hard to imagine Mästlin's desire to destroy such correspondence* (p. 189).

The book contains a fairly extensive bibliography, portraits, historical illustrations of models of planetary systems, and of astronomical observation equipment. Obviously, it was supposed to evoke sensation. It is written in a very suggestive way, the book is gripping, so it is more or less on reader himself how critical attitude he takes up. Although the authors collected a lot of valuable material, to accuse of a murder

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[6] Marcelo Gleiser (Dartmouth College, Hanover, New Hampshire) currently works on a book dealing with Kepler's life and work.

a man, *nota bene* a famous scholar, who is almost four centuries dead and cannot protect himself, has to be held highly unethical.

The Gilders' book was published under the title *Der Fall Kepler — Mord im Namen der Wissenschaft* also in Germany (List-Verlag, 2005) and it provoked a very strong criticism from the Board of Kepler Society, as expressed by Professor Manfred Fischer [18, 19]. Also, Professor Volker Bialas, a long standing Director of the Kepler Commission of the Bavarian Academy of Sciences, expressed his disapproving attitude to the book [20].

To a reader, who is interested in lives and works of Brahe and Kepler, without being burdened by various speculations, some other and fairly new books can be recommended [17, 21–24]. He will then be able to judge himself the "justification" of the Gilders' statement given at the very beginning of their book (p.1): *if it hadn't been for Tycho Brahe, Kepler would be a mere footnote in today's science books.*

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The Hwang Woo-Suk Scandal Hasn't Ended

Song Sang-yong

In Korea, the recent scandal of Hwang Woo-Suk in stem cell research is compared with the Lysenko Affair of the Soviet Union in the 1930s. The Hwang scandal, however, is one of the biggest in history considering its scope and impact. "The Hwang affair is not simply a case of 'scientific fraud.' It is a unique mixture of scientific, ethical, ideological and politico-economic elements. Its impact has not been limited to the scientific community in Korea, but has extended to the whole Korean nation and even to the international arena." (Kim H.-S. 2006b)

After the fall of Hwang Woo-Suk in 2006, more than ten academic meetings were held to discuss the meaning and impact of the Hwang scandal. They were organised by the Korean Bioethics Association and the Korea Association of Science and Technology Studies as well as by the NGOs including the National Council of Professors for Democratisation and the Centre for Democracy in Science and Technology. Outside of Korea some international conferences dealt with various problems of the Hwang scandal in broader context. There were plenary sessions on the Korean situation at the 3rd International Conference on Clinical Bioethics, Okayama and the 8th World Congress of Bioethics, Beijing. There was a session on "What Does the Korean Stem Cell Scandal Imply to STS?" at the EASST (European Association for the Study of Science and Technology) 2006 in Lausanne. Four sessions were organised in the 2006 Annual Meeting of 4S (Society for Social Studies of Science) in Vancouver by Kim Sang-Hyun, a Korean sociologist of science at Harvard.

There have been much reflections on the adverse aspects of science and technology in the West. Thus it might be said that scientism is being overcome to considerable extent. However, the situation in Asia is quite different from that of the West. East Asia has a deep-rooted tradition of scientism, which lasted for more than a century. In the 19th century East Asia was under the challenge of Western imperialism. East Asian countries had to make desperate attempts to survive. It was believed that the only way to survival was catching up the Western science and technology. Japan became the first country, which succeeded in modernisation. Similar aspirations for science and technology were both in China and Korea, though there was more resistance by traditionalists. It was hard for China to attain modernisation even after the revolution in 1911. Korea lost the last chance and became a victim of Japanese imperialism in 1910. In Korea there was belief that independence could be achieved through science and technology. Nationwide science movement in the 1930s is a good example. After the liberation in 1945, "nation building through science and technology" has been the national motto of Korea. (Song 2006a)

Korea emerged as an economic giant from a poverty-stricken country in the 1960s. During the period national income per capita rose from $200 to nearly $20,000. The amazing success in industrialisation was possible at the expense of environment, tradition and ethics. Science and technology was the handmaiden of economy. It was only since the end of last century that the Korean government began to consider science and technology as culture also. Nevertheless, scientism continues to be paramount in Korea. Both the government and oppositions are growth-oriented and they are supported by major mass media.

The government has been extraordinarily interested in developing biotechnology. In 1983, it made the Genetic Engineering Promotion Act (changed to Biotechnology Promotion Act in 1995) for the first time in the world. "Though not a great success in terms of immediate impact, the Act provided an institutional framework for Korea's future biotechnology R&D activities. But more importantly, the Act was crucial in framing biotechnology as a vehicle for the nation's economic development." (Kim S.-H. 2006) By the time Kim Young-Sam came into office in 1992 as the first civilian president since 1961, national R&D expenditure in biotechnology had already shown a nearly twelve-fold increase from 1983. In 1994, the government launched an ambitious 14-year national strategic R&D programme called "Biotech 2000" and proclaimed that year the "Year of the Take-Off of Biotechnology". Under the programme, the government and industry would invest $18 billion by 2007, aiming to catch up the biotechnological capabilities of the G-7 nations.

The birth of Dolly in 1997 aroused great concern among Koreans. Hwang Woo-Suk, a veterinarian appeared suddenly at the centre of reproductive technology in which Korea was at high level. (Kim G.-B. 2006) Korea was fifth country in the world where mammalian cloning was done. President Kim Dae Jung was so glad to see the achievements of Hwang Woo-Suk. It was he who named the cloned cow 'Chini'.

Then Hwang moved from animal cloning to human embryonic cloning by making a team with Mun Shin-Yong, Professor of Obsterics and Gynecology at Seoul National University and Noh Sung-Il, Chair of the MizMedi Hospital. The Roh Moo-Hyun government started in 2003, when Hwang Woo-Suk attracted increasing attention. Roh Moo-Hyun had Park Ky-Young as Advisor on Information and Science Policy, who was an enthusiastic supporter of Hwang. Roh was tremendously impressed when he visited Hwang's lab. Thus Hwang was brought to the focal point of biotechnology which was chosen as the the next generation growth engine.

If animal could be cloned, it was probable that human cloning would be realised eventually. Many people talked about the necessity of a National Commission on Bioethics. As "cowboy cloners" (Rose 2004) did sensitive researches with embryo, the pressure to regulate them was mounting. In 2000, the Ministry of Science and Technology (MOST) created the Bioethics Advisory Commission (KBAC) to make policy recommendations on human cloning and stem cell research. While China and Japan were making guidelines in stem cell research, Korea went for legislation. (Lee & Yamazaki 2003; Wang 2003) The primary task for KBAC was to draft the Bioethics Law. KBAC consisted of 20 members: 10 scientists (biotechnology and medicine) and 10 non-scientists (philosophy, social sciences, NGOs and religion). It existed for only one year.

KBAC could complete the framework of the "Basic Law on Bioethics" after meeting 13 times for 7 months. The recommendations of KBAC to MOST were 1) to prohibit both reproductive and therapeutic cloning, and 2) to allow temporarily stem cell research on the surplus frozen embryos created through *in vitro fertilisation* (IVF). It was an unexpected result of the dramatic compromise between scientists and non-scientists. Neither conservatives nor liberals were satisfied with the compromise. The recommendations should have been respected as promised at the beginning, but MOST obviously did not like them. As a result MOST failed to submit its own version of the bioethics law to the National Assembly. After one year the Ministry of Health and Welfare (MHW) took over the bioethics issues, which MOST had been responsible for. Unlike MOST, MHW took a position similar to the recommendations by KBAC.

The preparation of the bill on the government side dragged on more than three years. According to Jung Kwang-Jin, it was a conflict among three competing frames: biotechnology frame (MOST), biomedicine frame (MHW) and bioethics frame (religious groups and feminists). (Jung K.-J. 2006) At the end of 2003, the adjusted bill passed the National Assembly. The final bill was very much like a biotechnology frame. It meant the victory of growth-oriented MOST. There must have been considerable pressure from scientists and industry. The degraded bill caused a furious reaction from civil movement groups. The important points in the "Bioethics and Biosafety Act" were twofold. First, human embryonic cloning was permitted in case it is approved by the Stem Cell Research Committee. Second and more serious was that the bill could be interpreted to allow research where genetic mix between humans and animals takes place. (Cf. Han et al. 2003; Pak U. J. 2005, Ch. 8) The "Bioethics and Biosafety Act" was to be enacted from 2005 after one year deferment. It is believed that the Act was made meticulously to protect Hwang Woo-Suk. If the Korean government had taken the recommendations of the Bioethics Advisory Commission, the Hwang scandal could not have happened.

In 2004, Hwang surprised the world by establishing a stem cell line from a cloned blastocyst. Another breakthrough of the next year in making the patient-specific embryonic stem cells made him rise to international stardom. It was also the fruit of the deliberate operation of the Korean government to make him a national hero. But for the massive support of major media in Korea, it would have been impossible for him to be a god-like figure among the people. After the 2004 paper of Hwang et al. was published in *Science*, a wide boulevard was waiting for him. He was made a 'Supreme Scientist' with special guards provided by the government. No Nobel Prize winner has ever had such honours as Hwang enjoyed. The Korean Air gave him two first class tickets for ten years. In October 2005, Hwang was at the peak of his career when he opened the World Stem Cell Hub with President Roh Moo-Hyun and Ian Wilmut. Then, he fell abruptly.

In Korea the main concern in bioethics was with human cloning; then the concern moved to embryonic cloning. Numerous papers on cloning appeared in philosophy journals: most of them against human cloning, but there were some favourable to it. The Korean National Commission for UNESCO organised a consensus conference on cloning, which reached a conclusion not only against reproductive cloning but also against embryonic cloning. The Korean media, however, failed to turn the discussions to public debate; they were simply all out for Hwang

Woo-Suk. There have been no debates on cloning in the true sense of the word. In the case of Korea, the socio-political context was much more important than philosophy or religion in the problem of stem cell research. One - third of South Koreans are Christians. However, the idea that life belongs to the realm of God does not matter very much to them. In other words, religious affiliation has little to do with bioethics in Korea. (Cf. Song 1999)

Contrary to the common belief outside of Korea, it is not true that there was no ethical backlash to Hwang's research. Catholic Church, NGOs and bioethicists were outspoken critics of Hwang from the outset. Right after the 2004 paper came out, the Korean Bioethics Association (KBA) formed the "Ad Hoc Committee on the Research Ethics of Therapeutic Embryonic Cloning". KBA sent a letter to the editor of *Science* concerning the problem of the Ethics Committee. (Song 2004) The letter was published with Hwang's response more than half a year later. At the General Meeting in May 2004, KBA adopted a statement challenging Hwang to have an open discussion on the ethical problems of his research: IRB, authorship and acquisition of eggs. (Koo 2005) The problem of authorship was raised by Lee Pil Ryul, Professor at Korea National Open University and the Centre for Democracy in Science and Technology, an NGO and the egg problem by Lee Pil Ryul and David Cyranoski, *Nature*'s correspondent in Tokyo, respectively. (Lee P. R. 2006; Cyranoski 2006b) The request was ignored by Hwang, though he admitted that he had some ethical problems on other occasions. The indifference in ethics on the part of the government and media also helped Hwang's arrogance. The resistance of bioethicists was not only reported inadequately in the Korean media, but also was underrated abroad. "South Korea's handful of bioethicists had no leverage." (Editorial, Nature 2005) Only two articles by a Korean historian of medicine in Japan and two social scientists in Europe gave due credit to them. (Shin 2005; A. Bogner & W. Menz 2006)

Gerald Schatten's sudden break with Hwang Woo-Suk was a turning point for the decline of Hwang. It brought out the charges of oocyte donation irregularities by *Nature* anew. It was not until the "PD Notebook" of MBC (Munhwa Broadcasting Corporation) television raised questions about the research that Hwang confessed his wrong-doing in obtaining the eggs. All the ethical suspicions regarding his paper turned out to be true. The verification efforts of young scientists through BRIC (Biological Research Information Centre) and the prompt investigation by Seoul National University further concluded that Hwang's two papers were nothing but fakes. It was shocking news even to the critics of Hwang. Both papers of Hwang published in *Science* were retracted. Hwang was fired from Seoul National University after a long deliberation. The Korean Society for Molecular and Cell Biology expelled him and the Ministry of Health and Welfare removed his license to conduct embryonic stem cell research. The Ministry of Science and Technology stripped him of the title "Supreme Scientist." Intensive investigations by prosecutors followed and the trial is going on. Investigations by the National Assembly agreed by major parties have not yet been carried out. Hwang resigned the membership of the Korean Academy of Science and Technology (KAST) in 2006, but still holds some important honorary posts. There is no doubt that the Korean society is too magnanimous to him. The case is yet to be concluded in the midst of continuing resistance of the fanatic supporters of Hwang.

The Korean government should bear the main responsibility for the Hwang scandal. Its growth — first policy of developing biotechnology blocked any kind of regulations or criticisms. All Asian countries are keenly interested in developing biotechnology. Only Korea, however, dashed ahead recklessly and the result was a debacle. President Roh Moo-Hyun with his entourage was out in front to give huge support to Hwang, and all the leaders of political circle except Democratic Labour Party praised Hwang as a hope for the nation. Distortion and exaggeration in the reports of the irresponsible media aggravated the situation. Even the National Human Rights Commission of Korea, which had opposed the dispatch of Korean troops to Iraq, remained silent concerning the misconduct of Hwang. The situation in Korea until November 2005 was something like the United States right after the September 11.

Crude nationalism is also to be blamed. Korea had good reasons to be nationalistic in the past. It is now the 11th economic power in the world. Yet the majority of Koreans are still nationalists or patriots. Hwang exploited the nationalist feeling of people shrewdly. He kept paraphrasing Pasteur's famous words: "There is no national border in science, but a scientist has a fatherland." When he came back home after reading his paper, he said proudly: "I have put our national flag in the heart of the United States." Some politicians and journalists joined him in instigating patriotism.

It is held that the Hwang scandal was a confrontation between the

‘Alliance of Science and Technology’ (Chang 2005, Kim J. Y. 2006)) and the ‘Solidarity of Ethics.’ The former consisted of scientists, government, business and media which were united with vested interests and ideologies. The latter was composed of NGOs, religious groups and bioethicists. A formal alliance never existed, but the de facto alliance was extremely powerful. An alliance with such a scale is unprecedented in Korean history. There were formal solidarities for several campaigns in different forms, but they were heterogeneous, loose and hence weak. Only the Catholic Church and some conservative Protestants among religious groups were critical of Hwang. Feminist and environmental NGOs did not cooperate actively with the Centre for Democracy in Science and Technology, which alone fought against the ‘Alliance’ consistently. The defeat of the ‘Solidarity’ by the ‘Alliance’ was too natural, since these two were incomparable.

After Hwang was dishonoured, the main issue now becomes research ethics. The government hurriedly made a guideline for research ethics. Of course research integrity is important, but due to the over-emphasis on it, other ethical problems of stem cell research are blurred. There are also campaigns for making a ‘Code of Conduct for Scientists and Engineers’ (Song 2006c) and for strengthening bioethics education. However, it is to be regretted that neither the government nor media is interested in them.

One of the early issues of the Hwang’s research was eggs. Many Westerners find it difficult to understand the indifference of the Koreans to the problem of eggs. How could Hwang get over two thousand eggs so easily? They tend to consider that it is due to cultural difference, but it is not that simple. Korea was tremendously influenced by Confucianism, which is profoundly ethical. Confucianism was the guiding principle of the last dynasty in Korea for 500 years. The negligence of ethics is quite a new phenomenon resulting from the civil war and industrialisation. According to the Confucian ethics, all parts of the body are important, since they are from the parents. In the 1950s the Korean government launched a successful campaign for birth control. Thus abortion became a common practice in Korea, though it was against criminal law. It seems that the negligence of life has something to do with the ‘paradise for abortion.’ It was disgusting to see thousands of Korean women including three members of the National Assembly volunteer to donate eggs to Hwang. Hwang’s misconduct in acquiring eggs is no less serious than his fraud in research. It is vital for the Koreans to restore the respect for life. Extensive discussions on this problem are badly needed.

Korea is suffering from its failure in liquidating the past properly. The Japanese colonial rule, the Korean War, two military dictatorships, the Kwangju massacre have never been concluded. They still cause not a few problems. This is why the Hwang scandal should be finished neatly. If the Koreans fail to do so, there is no guarantee that there will not be a second Hwang. According to two Austrian political scientists, the imprudent fraud of Hwang is a result of political irresponsibility. "Korea should provide the system of science with clear structure of political-administrative responsibility, transparent decision processes and the room and chance for scientific criticism." (Gottweis & Triendl 2006) President Roh has never made sincere apology for the national tragedy. Minister of Science and Technology left the office with the praise of the president. The former Pesidential Advisor was reinstated as a member of the Presidential Committee on Policy and Planning. No progress is visible in amending the Bioethics and Biosafety Act. There is no sign of reshuffling the Bioethics Review Committee. The Korean government lost a chance to turn the scandal into an opportunity.

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