A2004:004

American Science – the Envy of the World?

An Overview of the Science System and Policies in the United States

Kerstin Eliasson

itps
SWEDISH INSTITUTE FOR GROWTH POLICY STUDIES

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Kerstin Eliasson
Science Counselor
Swedish Institute for Growth Policy Studies, ITPS
Embassy of Sweden, Washington, DC

SWEDISH INSTITUTE FOR GROWTH POLICY STUDIES

ITPS, Swedish Institute for Growth Policy Studies
Studentplan 3, SE-831 40 Östersund, Sweden
Telephone + 46 (0)63 16 66 00
Telefax + 46 (0)63 16 66 01
E-mail info@itps.se
www.itps.se
ISSN 1652-0483
Elanders Gotab, Stockholm 2004

For further information, please contact Magnus Karlsson
Telephone + 1 202 467 2654
E-mail magnus.karlsson@itps.se

Foreword

The United States is often used as a benchmark in the Swedish research policy debate. The scope and quality of American research, the ability to commercialize research results and the entrepreneurial spirit are some reasons for this.

Against this background the Swedish government commissioned the Institute for Growth Policy Studies (ITPS) to undertake a study on the science system and policies in the United States. The ITPS Office at the Swedish Embassy in Washington D.C. was assigned to conduct the study. The results of the project will serve as an input to the next Bill on Research that will be presented to the Swedish Parliament 2004–2005. The results are presented in this report and three others*.

The purpose of this report is to give an overview of the science system and policies in the United States. It includes the historical development of the science system, the major funding sources of research and development (R&D), the major performers and a discussion on issues and priorities in American science policy.

Stockholm, March 2004

Sture Öberg,
Director-General

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- “From Doctoral Student to Professor – The Academic Career Path in the United States”, by Eva Karlsson.
- “The Structure and Financing of Medical Research in the United States – An Overview”, by Eva Ohlin.
- “Commercialization of Research Results in the United States – An Overview of Federal and Academic Technology Transfer”, by Magnus Karlsson.

Content

1 Introduction

1.1 The Assignment

The United States is often used as a benchmark in the Swedish research policy debate. The scope and quality of American research and science, the ability to transform research results for the benefit of the economy and society, the entrepreneurial spirit and the great number of foreigners contributing to the scientific and technological enterprise in the US, are some reasons for this. The question is whether other countries can learn from the US in order to increase their own competitiveness or whether totally different solutions have to be found to achieve the objectives of high quality research and economic growth.

In recent years, there has been a debate in Sweden about the funding for medical research. Studies have shown that during the last decade funding for other scientific areas have grown more than funding for medical research. Here too, and not surprisingly, the US has been used as a benchmark. Some proponents of increased funding for medical research have argued that the United States spends more than fifty times as much per inhabitant on medical research as does Sweden.

One of the most important science policy issues in Sweden is the recruitment of people to science and engineering careers. This is a particularly pertinent issue in view of the demographic developments. It is estimated that 30 percent of teachers and researchers in academia will retire in the next ten years. Whether this will create serious problems in higher education and research largely depends on the competitiveness of colleges and universities vis-à-vis the rest of the labor market. It is important for Sweden to learn from other countries how they deal with the recruitment, training and retainment of scientific personnel.

Another issue is how to secure the future quality of research by supporting and nurturing creative research environments so that Sweden can stay competitive in an international perspective. In a relatively small country, priorities are particularly important, as it is impossible to be at the scientific frontier in every possible area. How funding agencies can help universities and colleges to create internationally competitive research environments is an issue of highest priority to the Swedish government. The concept of centers of excellence has gained ground also in Sweden. Closely related to this question is the issue of concentration vs. dispersion of research resources.

Against this background the Swedish government commissioned the Institute for Growth Policy Studies (ITPS), a newly created government agency in Sweden, to undertake a study on the research system and research policies in the United States with a focus on medical research. The ITPS branch at the Swedish Embassy in Washington D.C. was assigned to conduct the study. The results of the project will serve as an input to the next Bill on Research that will be presented to the Swedish Parliament 2004–2005.

The purpose of this report is to give an overview of the research system and research policies in the United States. It will include an overview of the historical development of the science system, the major funding sources of research and development (R&D) and the major performers. The National Institutes of Health (NIH) and the National Science Foundation (NSF) will be presented in some detail whereas other major federal actors will be left out. The reason is that the first two are of particular interest in a Swedish perspective and that priorities had to be made in order to avoid too a cumbersome report.

Trends in funding will be presented and the most important science policy issues will be presented. The report attempts to apply a comparative perspective; one chapter deals with U.S. science in an international perspective and the other presents similarities and differences between the American and Swedish science systems and policies. In spite of the differences in size, history, culture and traditions there are in fact similarities in the way the research system is organized, the way universities work, how science and research is applied for the benefit of society, how innovation and commercialization takes place – comparisons which may be interesting and useful in science policy making.

This report will also include a chapter on competitive research environments, which was part of the assignment from the Ministry. An important research policy issue in Sweden is how universities and colleges can develop strategic efforts and prioritize and how the research councils can contribute to creating competitive research environments at the universities and colleges. The section will attempt to describe what is considered a strong and creative research environment in the United States, what the characteristics of such environments are, what conditions are prevalent, and what measures are taken by different actors to foster excellence.

Three separate studies will cover the career system in American research, the structure and financing of medical research, and the commercialization of research results with a focus on federal and academic R&D. Some of the findings from these studies have been incorporated into this report.

The separate studies deal with the following issues:

- The Career System in American Research. This study covers the higher education system, and describes the American academic career paths in a broad perspective. It includes a presentation of institutions, degrees, funding, students, doctoral studies, U.S post-docs, faculty and tenure, and gives examples of measures to promote recruitment to scientific careers. It also draws attention to the most important research policy issues in higher education.
- The Structure and Financing of Medical Research. The structure of medical research in the US in a research policy perspective is in focus in this study. The financing and performance of research, the distribution of funds by the National Institutes of Health, NIH, the degree of competition for funds in the funding processes, the different costs to be covered by the funding and grants, earmarks, and, finally, the relationship between higher

education and research are treated and analyzed. Research at the universities and the role that different kinds of funding are playing in university research are included. The crucial role of the National Institutes of Health (NIH) in the funding of medical research in the United States makes it necessary to devote particular attention to the NIH in this study.

- Commercialization of Research Results. This study covers federal and academic technology transfer in the United States in a broad sense. It includes university-industry relationships, licensing and patent activities, business incubators, funding of technology transfer, intellectual property policy, entrepreneurship and education, small business policy and other government initiatives and programs, and issues in technology transfer in the United States.

1.2 Summary

The United States is often used as a benchmark in the Swedish research policy debate. The scope and quality of American research and science, the ability to transform research results for the benefit of the economy and society, the entrepreneurial spirit and the great number of foreigners contributing to the scientific and technological enterprise in the U.S., are some reasons for this.

Against this background the Swedish government commissioned the Institute for Growth Policy Studies (ITPS), a newly created government agency in Sweden, to undertake a study on the research system and research policies in the United States with a particular focus on medical research. The ITPS Office at the Swedish Embassy in Washington D.C. was assigned to conduct the study. The results of the project will serve as an input to the next Bill on Research that will be presented to the Swedish Parliament 2004–2005.

American Science in an International Perspective

- The United States started to take a leading position in world's scientific enterprise after the 1950s. Americans became the major recipients of the Nobel awards. The proportion of American laureates in the natural sciences since 1950 is more than 70 percent.
- The U.S. spent 292 billion dollars on R&D in 2002, representing 44 percent of the OECD total. In relation to the GDP, this was 2.8 percent for the U.S. compared to an OECD average of 2.3 percent.
- R&D financed by industry grew dramatically in the OECD area during the 1990s, by 50 percent in ten years. Government spending on R&D grew by 8.3 percent.
- The number of researchers relative to total employment in the OECD area is 6.5 per thousand. Japan has the highest number followed by the United States.

- Public-private partnerships are common in the U.S. They are important in the development of innovation systems. Innovative clusters started to develop in the U.S.
- The United States was one of the first countries to support small and medium-sized enterprises through the SBIR program. American universities have been pioneers when it comes to commercialization of R&D. Landmark legislation was the Bayh-Dole Act, which allowed universities to keep ownership of intellectual property developed in federally funded research programs.
- The U.S. is competitive in the export of high-technology products, the number of patents and of scientific publications and citations. More than half of the approx. 150,000 patents granted in the U.S. in 1999 were issued to American inventors. The U.S. also leads foreign inventors abroad. The U.S. accounted for 36 percent of the patent families developed by OECD, but when population is taken into account Sweden ranks higher with 107 compared to 52 for the U.S. The economic benefits in the U.S. from intellectual property amounted to a 23 billion dollar surplus in 1999.
- Even if the publication of scientific articles did not grow as much in the U.S. as for example in Europe, the U.S. accounted for approx. one third of the total 530,000 articles published in 1999. 55 percent of U.S. articles were in the life sciences. Universities were the primary institutional source of publications in 1999, accounting for more than 70 percent.
- Even if competitiveness in American science and economic returns on those investments remain high, there are some indicators which lead Americans to worry about the future. The concern is focused on federal investments in R&D, the future requirements of the labor force, the educational achievements of pupils and students, the shortage of skilled teachers in mathematics and science and under-representation by women and minorities in science and technology.

The Development of the American Science System

- At the end of the 19th century there were approximately 250 colleges all over the U.S. They became centers of American science and research at an early age. The colleges were initially focusing on practical and commercial education. Some of them turned into universities at this time. They were very dependent on private funding.
- The federal engagement in R&D took off during and after World War II. In five years the share of government funding of total R&D rose from less than 20 to 75 percent. The federal government became the major sponsor of academic research after the war. By 1960, federal investments in academic R&D had reached 60 percent of total academic funding.
- After the war, a number of government laboratories, mainly in the defense sector, were created, most of them for nuclear research.

- The needs of the military drove the federal R&D investments. By the mid 1960s, defense-related research accounted for 50 percent of federal R&D spending. DOD accounted for 44 percent of total federal expenditures for academic research in 1958. This share diminished in the next decades and reached 9 percent in 1980.
- During President Reagan, defense R&D increased and reached 75 percent of total federal R&D expenditures. Defense R&D in the 2003 federal budget amounts to 54 percent. In the late 1980s and early 1990s, the U.S. was preoccupied with competition from Japan and technology transfer became the key objective of federal investments.
- The other characteristic of U.S. federal investments in R&D is the very substantial spending on health R&D. The federal engagement stemmed from the needs of the military. The origin of the NIH was a military laboratory. This was transformed into a Hygienic Laboratory on Staten Island in New York and this, in turn, was transformed into the NIH in the 1930s.
- In twenty years, the budget of the NIH increased from a few million dollars to more than a billion in the mid 1960s. During this time a number of NIH institutes were created. Resources continued to increase in the 1970s after President Nixon declared “war on cancer”.
- In five years, the resources for the NIH doubled, reaching 27 billion dollars in 2003.
- The driving forces for federal investments in R&D have been to achieve a societal mission. Science for science´ sake was never the main goal. The only agency which has the promotion of fundamental science as its main mission is the NSF, which was established in 1950. In 1954, Congress decided that other federal agencies could support basic science as well.
- The NIH is the most important agency for basic biological and biomedical research. It funds 54 percent of total federal support for all basic research compared to 13 percent for the NSF. However, the NSF is vital for the support of non-life-sciences basic research.

The Present Science System

- The American science system is a large and complex structure with a loose coordination of efforts. Many are involved in decision-making; the administration, Congress, government agencies, industry, states, foundations, universities and colleges, government laboratories, academies and special interest organizations.
- The OSTP within the White house gives science and technology policy advice on a number of issues, including the budget, and coordinates efforts of federal agencies and other actors. The head of the OSTP is the President’s science advisor.

- The NSTC has a strategic function in setting the research agenda and in coordinating the federal policies and interagency programs in science and technology. It includes the President and Vice-president and heads of government departments and independent agencies. The Director of the OSTP directs the work of the NSTC on behalf of the President. The work takes place in committees and subcommittees.
- PCAST gives the President advice in science and technology policy and includes members from business and industry, academia and NGOs. The PCAST is co-chaired by the Director of the OSTP and a leader from the private sector.
- The OMB coordinates and prepares the whole budget of the President, and is therefore a powerful actor also in R&D matters. However, there is no formal R&D budget. There are separate R&D budgets in every department and agency. The AAAS summarizes and analyzes the annual proposals of the Administration.
- The U.S. is not a parliamentary democracy. Congress is more powerful than parliaments in many other countries. Congress decides on most items and sub-items in the budget for departments and agencies. Its work on R&D issues takes place in many committees and subcommittees, including authorization and appropriations committees.
- Congress has several support functions at its disposal. Among them is the GAO which audits and evaluates federal programs and activities. The CBO gives Congress current budget information and produces annual reports on economic and budget trends.
- Hearings with representatives of the Administration, outside experts and individual citizens are common.
- Many departments and federal agencies are involved in the funding of R&D. Some agencies have R&D as their main objective, such as the NIH and the NSF. Most support R&D as part of their mission. Five agencies, the DOD, NIH, NASA, DOE and NSF account for 93 percent of the federal R&D investments.
- The national academies play an important role in science advice. They get most of their funding from federal agencies. They undertake studies for federal agencies and Congress but they also initiate projects at their own initiative. The activities cover every scientific area as well as policy and innovation issues.
- Non-governmental organizations also play a role, and there are several thousands of them, mostly located in Washington, D.C. The AAAS has 140,000 members and its mission is to advance science and innovation throughout the world. Three programs are important from a science policy perspective: the analyses of R&D data, the S&T Policy Fellowship Program and the Center for Science, Technology and Congress.

Trends in Funding

- Total R&D investments in the U.S. in the mid 1960s made up approx. 2.7 percent of GNP. In 2002, it amounted to 2.8 percent of the GDP. Industry has increased its share and accounted for 66 percent, the federal government for 28 percent.
- R&D is a significant but declining part of the federal budget. In the mid 1960s, R&D made up almost 12 percent of the federal budget compared to 5 percent in 2003. This is largely due to huge increases of entitlement programs as a percentage of the U.S. federal budget during this time.
- Spending on defense R&D has exceeded all other R&D spending for most of the past four decades, but its share has varied considerably over the years. Space was the dominant mission in the 1960s; energy R&D has fluctuated in importance; but health R&D has shown practically uninterrupted growth and represents today the largest single share of the non-defense R&D portfolio (approx. 50 percent).
- Basic research has increased dramatically during the last decades, from 7 billion dollars in 1976 to 26 billion dollars in 2003, largely due to increases in the budget for the NIH. More than 50 percent of all federally financed basic research comes from the NIH. All performers of R&D have increased their performance of basic research since the 1970s. About half of all federally funded basic research is carried out by academia.
- Federal departments and agencies finance different performers. The NIH mostly supports academic institutions and so does the NSF, NASA is a heavy supporter of industrial research and the DOE mainly supports FFRDCs.
- The federal investments in R&D reached 117.3 billion dollars in 2003. This was an increase of 14.2 billion dollars or 13.8 percent and is the largest dollar increase in history. Most government funding agencies were awarded increases but particularly the areas of defense, health, general science and homeland security. Defense R&D increased by 8.8 billion dollars or 17.6 percent reaching 58.6 billion dollars. The NIH received an increase of 15.5 percent, reaching 26.2 billion dollars. The increase for the NSF reached 3.9 billion dollars or 11.4 percent.
- Of the total federal R&D budget, investments in research accounted for 45 percent and development 55 percent. NIH is funding 47 percent of all federal support of research and is the largest single sponsor of basic and applied research.
- The new Department of Homeland Security became a major player in federal R&D funding in 2003. It received approx. 670 million dollars in 2003, up from 266 million dollars in 2002.

- In health, the NIH budget nearly doubled between 1998 and 2003, a 3.5 billion dollars increase between 2002 and 2003 to 26.2 billion dollars for R&D, including substantial increases for bioterrorism research and bioterrorism research facilities. Another priority was general science programs, up 6.4 percent to 7.0 billion dollars, led by an 11.4 percent for NSF's R&D programs. Space R&D was also a big winner with a 9.2 percent increase to 10.1 billion dollars because of large increases in the space science program and a continuing shift from aeronautics R&D to space-related technology development.
- But funding for non-defense R&D, excluding NIH, has stagnated in recent years after steady growth in the 1980s. The 2003 increases for non-NIH agencies, while large, barely bring these agencies back to the funding levels of the early 1990s.
- R&D earmarks totaled 1.4 billion dollars, equaling 1.2 percent of total federal R&D. Four agencies received nearly 75 percent of all R&D earmarks; the USDA, NASA, DOE, and DOD.

The National Institutes of Health

- The National Institutes of Health is the single largest funding agency of medical research in the world. The mission of the NIH is to uncover new knowledge that will lead to better health for everyone. NIH works toward that mission by conducting research in its own laboratories (intramural research), by supporting the research of non-federal scientists in universities, medical schools, hospitals, and research institutions and abroad (extramural research). It also assists in the training of investigators and in fostering communication of medical information. Like many other federal agencies, the NIH is engaged in technology transfer activities.
- The budget for the NIH in 2003 amounts to 27 billion dollars. NIH accounts for nearly a quarter of federal outlays for R&D and half of the civilian R&D budget. The NIH is the second largest contributor to federal R&D after DOD and the largest supporter of basic research, applied research, and R&D at colleges and universities.
- Of the total federal R&D obligations in 2000, NIH sponsored 30.1 percent of intramural research, 16.7 percent of industrial research, 63 percent of R&D at universities and colleges, 3.6 percent of R&D at nonprofit organizations and 9.9 percent of all other organizations. The NIH plays a major role within biological sciences where it supported 87.5 percent of total R&D. NIH funded 76.1 percent of the federal R&D obligations within the medical sciences. NIH support is also vital for psychology and chemistry research.

- NIH is a decentralized organization with 27 institutes and centers, employing about 17,700 full-time employees. More than 4,000 of them hold professional or research doctorate degrees. The institutes within the NIH are quite diverse in their mission and scope of activity and size, but they are similar in the way they are organized and the way they support researchers.
- The Center for Scientific Review (CSR) of the NIH is handling the peer review process at the other NIH institutes. In 2002, NIH gave out awards worth 19.074 billion dollars and the total number awards were almost 50,000. The average cost of research grants in 2002 was about 384,000 dollars. Included are awards for salaries. The average cost per year has increased notably since 1997 when the average cost was 275,000 dollars.
- About 20 percent of the NIH extramural funds go to training. Training positions funded by the NIH reached 16,700 in 2002.
- The main part of the extramural funding is distributed to investigator-initiated applications from individual scientists. Some project grants are given to multi-disciplinary projects conducted by several researchers with different focus on the research problem and is called program project grants. Multi-disciplinary projects and collaborating researchers are also supported by research center grants. These grants are awarded to research institutions.
- One supporter of research centers is the National Center for Research Resources (NCRR). The grants also support the development of research resources to integrate basic research with applied research and to promote research in clinical applications.
- Applications for extramural funding are sent to the NIH and CSR. CSR distributes them to the different institutes. About 52,000 – 55,000 applications are reviewed annually. The final decision whether an application is to be funded or not is made by the institutes.
- The research proposal is reviewed according to the following criteria: the importance of the question, the innovation employed in approaching the problem, the adequacy of the proposed methodology, the qualifications and experience of the investigator, and the scientific environment in which the work will be done.
- About one third of all reviewed proposals are granted. It is very rare that a first-time applicant is awarded funding. The success rate has declined due to a greater number of applications and reapplications.

- A debate on the organization and efficiency of the NIH has been going on for many years. Many reports have been published on this issue. The NAS recently undertook a study which was initiated by Congress. It recommended that the clinical effort be strengthened and trans-NIH strategic planning and funding enhanced. High-risk, high-potential payoff research should be supported through a special program, and innovation and risk-taking in intramural research should be promoted.
- The other initiative comes from the new director of the NIH. A "road-map" for medical research in the 21st century has been charted. The proposals can be grouped into three themes; new pathways to discovery, research teams for the future and re-engineering the clinical research enterprise. The need to understand complex biological systems and knowledge about the interconnected networks of molecules of cells and tissues, as well as better "toolboxes" for biomedical researchers, such as technologies and databases, and an increased focus on translational research, are some features of the road-map.
- Also, research teams of the future will have to combine skills and disciplines in both the physical and biological sciences. Innovative and high-risk research will be promoted. In clinical research new partnerships should be developed and clinical trials should be conducted jointly by several academic centers. New ways have to be found to organize the way clinical research information is recorded, new standards for clinical research protocols, modern information technology and new strategies to re-energize the clinical research workforce. All in all, approximately 2.1 billion dollars will be spent over six years, starting in 2004.

The National Science Foundation

- The original mission of the NSF, which is still valid today, is to promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes. This generic mission allows the NSF to get involved in very broad or specific issues connected with the federal government. The NSF is the only government agency which has the support of basic research as its mission. The four strategic goals are: people, ideas, tools and organizational excellence.
- The NSB is the foundation's policymaking board. Its 24 part-time members are appointed by the President and confirmed by the Senate. It reports to the Office of Science and Technology (OSTP) of the President.
- The total budget for the NSF in 2003 amounted to approximately 5.3 billion dollars out of which 3.9 for R&D. This is an increase of more than 11 percent compared to 2002. There has been action in Congress and elsewhere to follow the NIH example to double the budget for the NSF in five years.

- The NSF represents approx. four percent of the total federal funding for R&D but accounts for approximately 13 percent of all federal support for basic research and 40 percent of non-life-science basic research at U.S. academic institutions. Therefore, the NSF plays a strategic role in American science and research.
- The NSF is authorized to engage in a number of activities. It initiates and supports scientific and engineering research through grants and contracts as well as education programs. The NSF supports both basic and applied research and facilities but is not engaged in development. It awards graduate and postdoctoral fellowships, and undergraduate training, either directly or indirectly through research grants.
- Part of NSF's mission is to support activities designed to increase the participation of women and minorities and others under-represented in science and technology. The NSF also serves as a clearing-house for science and engineering data, national and international, and for the collection, interpretation, and analysis of data on scientific and technical resources to be used also in policy formulation by other Federal agencies.
- The criteria according to which a proposed activity is assessed are the intellectual merit of the proposed activity and its broader impacts. The second criterion is harder to take into account than the first. It was instituted in 1997 and is being inculcated into the NSF rubric gradually.
- External experts play an important role through their advice and recommendations for funding. NSF program officers, however, have to address factors dealing with portfolio balance when making a recommendation on proposals. The final decision for awards or declines is taken by senior NSF staff.
- The NSF makes about 10,000 new awards each year, and over 96 percent are selected through its competitive merit review process. In 2002, the NSF took action on approximately 35,000 competitive, merit review research and education proposals. The overall funding rate was 30 percent which is rather similar to previous years.
- The NSF has a strategy to broaden the participation from groups currently underrepresented in the science and engineering enterprise, i.e. minorities and women. In 2002, about five percent of awards were given to minority principal investigators. However, the funding rate for them is 29 percent, slightly less than the overall rate of 30 percent. Female principal investigators were awarded 19 percent of total awards, which is a funding rate of 30 percent. Funding rates of new and prior principal investigators were 22 percent and 35 percent, respectively.

- Most awards, 76 percent, go to academic institutions. The top-ten funded institutions receive about 15 percent of NSF awards while over 25 percent goes to institutions which are not in the top-100 funded schools. However, there are outreach programs, such as EPSCoR, trying to address the issue of balance between institutions in different regions.
- The average annualized award amount for research grants in 2001 was about 115,500 dollars. The median award was about 86,000 dollars. It generally does not include salaries. NSF has had an explicit strategy to increase the award size in order to attract high-quality proposals.
- There are a number of cross-Foundation programs that are designed to integrate NSF's strategic vision and to implement the NSF core strategies. They include programs to attract and retain more Americans into the science and engineering workforce, programs that focus on the diversification of that workforce. Some focus on integrating research and education, cooperation between academia and industry, partnerships between local governments and industry, major research instrumentation and development with industry, nanotechnology, environmental research, science and technology centers, engineering research centers, science of learning centers, and small business and innovation research. The Office of Integrative Activities, an office of the Director, has management responsibility for some of these activities.

Government Laboratories

- Government laboratories or federal laboratories have typically been established to serve a mission of a particular government agency. They include government-owned but contractor-operators (GOCO) labs and Federally Funded R&D Centers (FFRDCs). In 2002, government laboratories received about 25 of a total of 81 billion dollars of total federal investments in R&D (31 percent), which can be compared to approximately 10 billion dollars for the academic sector. The biggest recipients are those under the DOD, followed by the DOE and the DHHS.
- The FFRDC’s have evolved from the research facilities which were established to meet the needs of World War II. The basic criteria for their operation were set in 1967. An FFRDC receives its major financial support (70 percent or more) from federal sources. 36 FFRDC were registered under 8 departments and agencies in 2003 and they are organized in three categories: university and college-, non-profit organization-, or industry-administered.
- In 2002, it was estimated that FFRDC´s performed federally funded R&D for about 7 billion dollars. R&D centers administered by universities and colleges accounted for the majority of this sum (63 percent).
- Less than 10 percent of the federal labs accounted for more than 75 percent of scientific publications, patents, licenses and other research awards.

Universities and Colleges

- There are 4,200 universities and colleges in the United States. Most of the research is carried out at the 263 doctoral/research universities and at the specialized institutions, such as medical schools and centres. Universities play an important role in American research. They perform about 13 percent of total R&D in the United States. Their role in the financing of R&D is much smaller. In 2002, they accounted for about 3.4 percent of the total investments in R&D.
- Total expenditures by universities and colleges for R&D in 2002 were 37 billion dollars. The federal government was the largest source of funding with 23 billion dollars, which is 62 percent of total academic expenditure. Of total academic R&D expenditure, approximately 75 percent is devoted to basic research. Universities and colleges perform close to half of all federally funded basic research.
- Medical sciences account for the largest share by far of the total R&D expenditures by universities and colleges. In 2001, 10 billion dollars (30 percent of the total amount) was invested in medical sciences while bio- and biomedical engineering received a smaller amount of 211 million dollars.
- Universities and colleges have increased their share of academic R&D investments to approx. 20 percent. Industry accounts for 6 to 7 percent of academic R&D.
- Three federal agencies are responsible for most federal obligations for academic R&D. These are the NIH with 60 percent, the NSF with 15 percent and the DOD with 9 percent.
- Federal support for R&D in the United States is very concentrated to a few research universities. 82 percent of federal funding goes to 100 universities. About ten universities receive somewhat more than 20 percent, 20 universities get 34 percent and 50 get approximately 70 percent of total federal support for academic R&D. Most universities and colleges receive very little money from the federal government.
- California, Maryland, Virginia, Texas and Massachusetts together receive half of all federal R&D resources.
- Part of the federal funding for academic R&D goes to directed, noncompetitive appropriations, also called earmarks or pork-barrel projects. In 2003, Congress directed more than 2 billion dollars for pork-barrel projects, including R&D projects, up from 1,837 in 2002. Congressional earmarks to academic institutions are not subject to peer review and are therefore questioned by many academicians and officials at government agencies.
- State and local governments provided about 7 percent of academic R&D funding in 2000. Since the 1980s, state and local funding of academic R&D has fluctuated between 7 and 8 percent. States, however, have a crucial role in the financing of public higher education.

- Funding to universities and colleges by industry in 2001 accounted for about seven percent of total academic R&D expenditures. The funds provided for academic R&D by the industrial sector grew faster than funding from any other sources during the past three decades but industry is still not a major contributor to academic research.
- Cooperation between universities and industry has always been strong in the United States, particularly in engineering research. Even closer ties with industry have been created through the technology licensing activities of academic institutions, which were enhanced through the Bayh-Dole Act in 1980 and consecutive legislation. About 200 universities and colleges are engaged in technology transfer projects. All in all, it is estimated that this legislation has contributed to 2200 new enterprises, 260 000 employment opportunities and 49 billion dollars to the U.S. economy.
- The economic returns of patents and licensing activities of universities and colleges are relatively minor. Most technology transfer offices at universities do not break even and it normally takes about seven years before they do so. Approximately 70 percent of university discoveries need further R&D before patents can be filed.
- Voluntary support accounted for about 8 percent of higher education expenditures during 2002 which is approximately 24 billion dollars. Voluntary support grew considerably in the late 1990s when the stock markets were high but declined slightly for the first time in 2002.
- Higher education institutions in the U.S. play an economically important role as they employ almost 3 million people, which is approx. 2 percent of the American labor force.

Business and Industry

- R&D performed by private industry in the U.S. reached 211 billion dollars in FY 2002. About 21 billion dollars or 10 percent of that amount was funded by the federal government and the rest was self-financed by the industry. Industry R&D has steadily grown in importance since the 1950s and its share of the total U.S. R&D enterprise has increased from 44 percent in 1953, to 55 percent in 1990, and to 72 percent in 2002.
- During the last two years, there has been less growth in R&D investments by industry, with 2002 showing barely more spending than 2001 in current dollars and slightly less in constant dollars. The level of investment varies considerably between industrial sectors, with pharmaceuticals and biotechnology firms at the high end, and telecommunications, computer makers and chemical industries at the low end.
- Two additional general trends can be observed regarding company R&D during the last two decades: the increase of service-sector R&D and the increase of small company R&D. In the beginning of the 1980s, non-manufacturing industries accounted for less than five percent of the total industry R&D – by the year 2000, it had reached almost 40 percent.

- Company-funded R&D in pharmaceuticals and medicines grew rapidly in real terms, from 4.7 to 10.4 billion dollars between 1985 and 1995, but then declined to 9.3 billion dollars by 1998.

Issues and Priorities in American Science Policy

- Seven science policy issues are brought up: national security and the openness of the science system, the balance between resources for different scientific areas, workforce development issues, research on stem cells, resources for higher education, commercialization of higher education and PhD training, post-docs and tenure.

Concluding Remarks – Similarities and Differences between the American and Swedish Science Systems and Policies

- In spite of the very different sizes of Sweden and the United States there are similarities in their relationship to science and research, to the structure of the science systems and to policies. But evidently, there are also big differences.
- Among the similarities, it should first of all be mentioned that both the United States and Sweden belong to those countries which have the highest spending on R&D in relation to the Gross Domestic Product (GDP). The use of information technology is also more widespread in both countries than in many others. The development of biotechnology and biotechnological companies has been remarkable in both countries, partly due to outstanding medical research at the universities. Strong clusters in information technology and biotechnology have developed in both countries. Quality of research is also high. The number of scientific publications and citations of scientific articles are very high in both countries.
- Another similarity is that universities receive substantial funding from the governments in both Sweden and the U.S. In the United States, universities are the greatest receivers of money for basic research; about half of federal funding for basic research is awarded to universities. In Sweden, universities and colleges receive 61 percent of their total R&D funding from the government in direct grants or via research councils and mission-oriented agencies.
- The differences between the U.S. and Sweden are greater than the similarities. The first one is the rationale for investments in research and development by the governments. Science for science´ sake was never the major motive for R&D investments in the U.S., whereas this was the main reason for supporting research for a long period of time in Sweden. This partly changed in Sweden, however, in the beginning of the 1970s.

- Another notable difference is the heavy focus on biomedical research in the United States, even if this is a rather recent trend. The rationale for supporting medical research in the U.S. and Sweden and the organization of that support are also somewhat different. In both cases, the investments in medical research are there to help curing diseases and in this sense the research is mission-oriented. There is however a stronger focus on disease-orientation at the NIH than at its counterpart in Sweden, the Research Council for Medicine.
- Another difference, which does not only apply to medical research but is very pronounced in this area, is the influence that lobbying organizations have in the U.S. on political decisions in Congress.
- The way that the research agencies in Sweden and in the U.S. work is also somewhat different. The NSF has a broader mandate as the ultimate objective for the activities of the NSF is to achieve other societal goals. The NSF's strategic goals include not only discovery (basic research) but also people and tools. The Swedish Research Council (VR) also supports Ph.D. training through its grants and as well as instrumentation, but stresses the support for basic research through peer review more than the NSF. The NSF supports both basic and applied research and is more engaged in developing the science and engineering workforce than the VR. The NSF has to deal with the science, engineering and math education of all Americans. This means dealing with more than 2000 colleges and universities in fifty states during the course of a year. The process of awarding grants and contracts at the NSF is called "merit review process" where both the intellectual merit of the proposed activity and its broader impact is taken into account.
- Another, more specific difference between government agencies in the United States and Sweden is the support to small and medium-sized enterprises, SME. In the U.S., federal agencies with external R&D obligations above 100 million dollars must set aside 2.5 percent for Small Business Innovation Research (SBIR) projects. In 1999, ten government agencies participated in the program.
- In United States, research laboratories, mainly under the DOE, play a more important role in the R&D system. In the U.S. they accounted for approximately 30 percent of federal investments in R&D in 2002. Sweden, on the contrary, has few research laboratories or institutes outside of higher education. In some R&D research areas of mutual interest to government and industry, approximately 30 industrial research institutes were established, which are co-financed by government and industry. These are now being merged into fewer institutes.

- There are great differences between the United States and Sweden when it comes to the higher education sector. The U.S. higher education system is decentralized and diverse. The U.S. has no equivalent to a centralized national ministry of education, like the Swedish Ministry for Education and Science.
- Many universities and colleges in the United States are private and many of them are very well known. In Sweden only a few higher education institutions are private. There is no tuition at Swedish institutions whereas in the U.S. tuition and fees can be substantial.
- The tradition in the United States for alumni to support institutions of higher learning with substantial donations is unique and the Swedish higher education institutions have recently started to intensify activities in this area. Tax regulations encourage donations in the United States whereas a private person in Sweden cannot deduct gifts to charitable causes in the income declaration. There are also differences in the rules and regulations, which govern universities and colleges and in the way that they are managed.
- The legislation regarding commercialization of research is different. In the U.S., the Bayh-Dole Act in 1980 and consecutive legislation made it possible for universities to keep the right to inventions made with the support of federal funds In Sweden, university professors have full ownership of intellectual property rights from their research (called "the teacher exception"). In both countries, university researchers are within certain limits allowed to do consulting.
- American universities are more dependent on their own institutional funds, which often derive from private sources. In 2000, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, an estimated 20 percent. Swedish universities and colleges are more dependent on direct grants from the government or money from government agencies. Direct funding from industry is similar in both countries; in the U.S. industry accounted for approximately 8 percent of academic R&D funding in the year 2000; in Sweden the percentage was about 7 percent of the total R&D performed in 2001.

2 American Science in an International Perspective

”American science is the envy of the world”. This is how many American reports about science and science policy begin. This is also what most people in the American scientific and science policy community state when interviewed. Americans are proud of their science and do think that it is the best in the world.

The number of Nobel prizes awarded to US scientists every year is one proof of that. But it was not until after the 1950s that the United States started to take a leading position in the world's scientific enterprise. And it was from then on that Americans started to become the major recipients of the Nobel awards. The proportion of American laureates in the natural sciences since 1950 is more than 70 percent.

No other country in the world is spending as much on research and development (R&D) as the United States. The U.S. spent 292 billion dollars on R&D in 2002 which represented 2.8 percent of its Gross Domestic Product (GDP). In 2001, R&D expenditure in the United States accounted for approximately 44 percent of the OECD total, close to the combined total of the European Union (28 percent) and Japan (17 percent). A few countries, among them Sweden, are spending more on R&D in relation to their GDP than the United States but most countries lag behind the U.S., the average for all OECD countries being 2.3 percent. The United States has the advantage vis-à-vis the European Union of being one single nation with few barriers to internal mobility. That also makes it easier to avoid duplication of efforts.

At the same time, there are multiple sources of funding in the United States. The U.S. government has many agencies from which certain scientists and engineers can get funding. It is not uncommon for top scientists to have received support from multiple agencies during their research careers. This multiplicity of support helps strengthen scientists in the United States and strengthens the research and engineering enterprise.

R&D spending has increased in OECD countries as a whole during the last decade (OECD 2002). In real terms, total OECD-wide R&D investments grew from 416 to 552 billion dollars between 1994 and 2000 and the R&D intensity grew from 2.0 percent to 2.2 percent of GDP. The existing gaps between high-investment countries and low-investment countries have increased. Those countries, which had the highest percentage increases, were those that already had high levels of R&D, such as Finland and Sweden.

It was the industrial sector that accounted for almost all the growth in R&D expenditures during the 1990s in the OECD area. It grew by more than 50 percent in real terms between 1990 and 2000 compared with 8.3 percent for the government sector. The business sector is the major source of financing of domestic R&D and accounted for more than 63 percent of funding in OECD countries in 2001. The governments´ share of total R&D declined from 39.6 percent to 28.9 percent. Industry has increased its funding in public sector organizations. Industry's share of university funding grew from 3 percent in 1981 to 6.1 percent in 2000. In the United States it grew from 4.4 to 7.7 percent.

It was particularly during the second part of the 1990s that the American economy was the strongest compared to other countries. No country could compete with the United States in terms of economic growth, productivity, investments, entrepreneurship, and budget discipline. The question that puzzled many economists was how low inflation could be combined with low unemployment. The explanations given were, among others, the development of high-tech sectors, integration of information technology into many parts of society, the development of clusters close to universities and colleges, large investments in R&D by business and industry, strong entrepreneurship, and an adequate supply of venture capital.

According to the Global Entrepreneurship Monitor (where researchers in about 20 countries compare entrepreneurship) one out of ten Americans are involved in creating a new enterprise compared with one out of fifty in Sweden. In the U.S., one out of 25 employees works in a newly created company compared with one out of 50 in Sweden. It is particularly the 25–44 year-olds who start new companies. A country that has a greater proportion of this age group in their population has an advantage over other countries.

The number of people who come to the United States as undergraduate or graduate students and faculty is an indicator of the attractiveness of American higher education and research. Many students stay in the U.S. after completion of their degrees. This is an asset for the American science system and for American companies. Certain areas, such as engineering, are dominated by foreign faculty and the U.S. is thus very dependent on foreigners for teaching and research in those areas. For other countries, like the European and Asian, it may mean an undesirable brain drain and economic loss, also because tax-payers´ money has often been used to finance the students´ education back home. If migration of scientists should be beneficial both for the receiving and the sending country it is important that there is a true circulation of talent. Some European countries, such as Ireland, are now taking special measures to make their scientists return by offering good salaries and excellent working conditions.

Another related indicator is the proportion of researchers in the labor force. According to the OECD, the stock of researchers expanded in almost all OECD countries in the 1990s, with a total of 6.5 per thousand in the labor force in 2000 compared to 5.6 in 1990. Japan has the highest number of researchers relative to total employment, followed by the United States and the EU. Approximately 38 percent of all OECD researchers reside in the U.S., 29 percent in the EU and 19 percent in

Japan. Approximately 2.1 million researchers (about 64 percent of the total) were employed by the business sector in the OECD area. The United States and Sweden belong to those countries where business researchers in industry exceed 6 per thousand employees; in the larger European economies, they are only 3 or 4 per thousand employees (OECD 2003). OECD is stressing that many countries are placing growing emphasis on “the productivity-enhancing role of human capital and higher education systems, which are central to the creation, dissemination and utilization of S&T (science and technology) knowledge” (OECD 2002).

A competitive advantage of the United States is the long established tradition of cooperation between the public and private sector. The military-industrial complex is possibly the most notable example of public-private partnerships. The mobility of people between academia, industry and government seems to be greater in the United States than in most other countries. This may lead to a greater understanding for the conditions under which each sector is working and contribute to the development of partnerships.

Partnerships and networks are becoming increasingly important in fostering the development of effective innovation systems. Innovative clusters started to develop first in the United States, in the San Francisco Bay Area, in Boston, and in North Carolina. In such clusters, public-private partnerships have been essential for their success. One of the conclusions in the three-year study made by the Council on Competitiveness (COC) on clusters in the United States is that it is vital that the public and private sectors work together in fostering innovation at the local and regional level (COC 2002).

The United States was also one of the first countries that started to support research in small and medium-sized enterprises (SME) through their Small Business Innovation Research (SBIR) program. A percentage of the funds allotted to federal agencies have to be set aside for research in SMEs. SBIR is a highly competitive program that encourages small business to explore their technological potential and provides the incentive to profit from its commercialization. Since its enactment in 1982, the SBIR has helped thousands of small businesses to compete for federal research and development awards. The projects have covered defense, environment, and health care, among other areas.

American universities have been pioneers when it comes to commercialization of research results. Landmark legislation was the Bayh-Dole Act and consecutive legislation in Congress – reforms that created a uniform patent policy which allowed universities, non-profit organizations and small businesses to keep ownership of intellectual property developed in federally funded research programs. Universities were encouraged to cooperate with commercial actors to use the results of research. Academicians receiving federal funds are obliged to report their research results with potential commercial use to the university administration. Universities are expected to file patents on innovations they choose to own and to give licensing preference to small businesses.

Other indicators of competitiveness in science and innovation are the export of high-technology products, the number of patents, scientific publications and citations. According to the NSF, the United States was the leading producer of high-technology products by the end of the century, providing more than one-third of the world's output. The U.S. world export share in high-technology products, which amounted to 20 percent in 1998, was nearly twice its world share for all manufacturing exports. However, other countries have been catching up with the U.S. except in communications equipment. The United States has also been successful in creating knowledge-intensive services in communication, financial, business, education and health services. These industrial sectors have shown even faster growth than the high-technology manufacturing sector (NSF 2002a). However, there is a tendency for the knowledge-intensive services in communication to move off-shore to India.

The number of patents granted in the United States has also grown fast during the 1990s. More than half of the 153,000 patents granted in the United States in 1999 were issued to American inventors. U.S. inventors also lead foreign inventors abroad. The economic benefits to the United States from intellectual property, including licensing fees from patents, amounted to a 23 billion dollar surplus in 1999 (NSF 2002a).

The OECD has developed patent families to eliminate the home advantage bias of patents. In 1998 there were more than 40,000 patent families in the OECD area, and increase by 32 percent from 1991. The United States accounted for 36 percent, the European Union for 33 percent and Japan for 25 percent. When population is taken into account the United States had 52 patent families per million population and Sweden 107 (OECD 2003).

When it comes to the publication of scientific articles, the number grew by 14 percent world-wide from 1986 to 1999. In Western Europe it grew by more than 30 percent. Even if US publications did not grow as fast as those in many other countries and regions, the US accounted for about one-third of the total 530,000 scientific articles published in 1999. In view of the heavy emphasis on biomedical research in the United States, it is not surprising that 55 percent of published articles belonged to the life sciences (clinical medicine, biomedical research and biology). Universities were the primary institutional sources of publications (74 percent) in 1999 (NSF 2002a). This is a sign of the focus on basic research at the American universities where faculty positions, tenure considerations and salaries are still based on the publication value.

According to the OECD, the number of scientific publications relative to the population is the highest in Switzerland and the Nordic countries (OECD 2003).

The increasing international cooperation in science and engineering is reflected in the proportion of internationally coauthored scientific articles. In 1988, among scientific articles with an American author, one article in ten had at least one non-U.S. author compared with one in five by 1999. Rates for international co-authorship were highest for physics, the earth and space sciences and mathematics (NSF 2002a).

International citations to scientific and technical articles are yet another way of measuring a country's strength and competitiveness in research. American literature is still the most widely cited even if its share fell from 52 percent in 1990 to 45 percent in 1999. This decline reflects the fall in its world share of scientific literature. Over the past decade, however, the U.S. share of cited scientific research has been 35 percent greater than the US share of scientific publications. The perceived influence of American science remains high on a relative basis (NSF 2002a).

The above examples illustrate the American competitiveness in research and innovative practices. They show that the United States is doing better than most other countries. Still, there are people and organizations in the United States who are concerned about the future American competitiveness in science, innovation and economy. In its benchmarking exercises, the Council on Competitiveness points to the following worrying signs (COC 2002). These concern the economy, the research base, education and the skills of the work force. The Council points to the rising gap between the rich and the poor in the United States, too low a savings rate, increasing foreign capital investments in the US economy, and a trade deficit. Furthermore, the share of national resources committed to R&D was lower in 1999 than in 1985, real increases have all come from industry, which in turn is dependent on public science to fuel innovation. Finally, the support for engineering and the physical sciences is lagging, particularly in view of the large increases for biomedical research.

In terms of the science and engineering talent pool, the Council points to the fact that the jobs requiring technical skills are projected to grow by 51 percent and that the undergraduate degrees in science and engineering were flat or declining, that a large share of PhDs in science and engineering are earned by foreign students, and that women and minorities are underrepresented in the science and engineering workforce. According to the Council, the educational achievements by US pupils and students are not adequate to meet the needs of the future labor market, there is a shortage of skilled teachers in math and science, and there is an under-representation in higher education by racial and ethnic minorities. All these factors and the growing international competition in science and technology make the United States vulnerable.

3 Brief Overview of the Development of the American Science System

This overview is mainly based on information from a Norwegian publication "FoU-politikk i USA – Systemer, trender og utfordringer" (Li 2001).

When the American colonies declared their independence from Great Britain in 1776 there were nine colleges in America. All of them were located on the East Coast and eight of them had been founded by a congregation and were private. One hundred years later there were 250 colleges all over the United States. The American institutions were, in contrast to their European counterparts, not exclusively for the upper-class elite. The notion of equality of opportunity was central. The colleges, therefore, had a firm support among the general public. This fact may also explain why more Americans still have a college-degree than people in Europe. The colleges became centers of American science and research at an early stage. The European universities, however, were the role models and it was in Europe that the scientific frontier was. American research was strengthened by the many European researchers who immigrated to the United States in the nineteenth and twentieth century.

In the book there is a reference to Alexis de Tocqueville and his observation that Americans seemed to be more engaged in applied than in theoretical research. This is a tradition that has been kept in the US, as will be argued throughout this report. Another characteristic of the United States at the time is the great number of inventors who also became independent entrepreneurs. An interesting comparative example in Sweden was Alfred Nobel. These inventors often created radical inventions rather than incremental ones to improve existing technologies. At the time the United States was dominated by agriculture. Many inventions were aimed at improving the working conditions and tools of farmers. The American military contracted other inventors and this was the origin of the military-industrial complex.

Around the turn of the century, the United States had changed from being an importer of technology to being an exporter. It had become the world's leading industrial nation. American companies started to establish their own R&D laboratories. Germany was a model in its investments in chemistry and physics. The first R&D laboratory was established in 1901 and by 1917 as many as 372 companies had laboratories of their own. Many of the laboratories were to be found in chemical companies. In contrast to the earlier independent inventors and entrepreneurs, the industrial laboratories were focusing on incremental inventions.

But industry was also involved in the institutions of higher learning in many ways. Several industrialists, such as Johns Hopkins, Cornelius Vanderbilt, Leland Stanford, Andrew Carnegie and John D. Rockefeller donated large sums of money to build new universities, to create foundations and to support charitable causes. This was the beginning of a business of its own, namely fund-raising at universities and colleges, private and public; an activity which is generally known as development. Former students, i.e. alumni, give large contributions every year to institutions of higher learning.

The early colleges had been focusing on practical and commercial education. At the end of the nineteenth century, many of them extended their curricula and knowledge base so that they could become universities. To do so they had to provide graduate studies. Again they were inspired by the German education and research system, adopting the right of students to studies of their choice (Lernfreiheit) and the right of the faculty to research whatever they wanted (Lehrfreiheit).

Universities and colleges were very dependent on private funding at the time as the States and the federal government did not provide much resources for higher education. Industry was the dominant partner for universities. This cooperation was not without conflict as industry had views on the management of universities and the direction of research. It was not until after World War II that the federal government took over the role as the greatest contributor to university research. Before 1940, the federal government accounted for no more than 12 to 20 percent of total R&D investment in the United States and as much as 40 percent of that went to agricultural research.

The reason for this was that agriculture was the dominant branch of business. In 1862, the Department of Agriculture was established and the same year the Congress adopted the Homestead Act, which made it possible to develop large stretches of land in the Mid-West. To spur the States to invest in education and research the Congress also adopted the Land-Grant College Act. The States were given free land in exchange for creating colleges for the benefit of agriculture and the mechanical arts. This was the origin of the present higher education system in the United States. Private universities also became involved as some states chose to use them to provide education in agriculture and mechanics. One of those was Cornell University in the State of New York. Cornell operates three colleges and one school on behalf of New York State.

The agricultural sector was one out of two sectors in which the federation before World War II was involved, in that it supported higher education and research. The other was the military. The war contributed to a greater involvement by the federal government in research. The States were supposed to finance higher education. During the decades following the war, the federal government was involved in higher education in certain specific cases, such as higher education for war veterans and financial support for education in mathematics, natural sciences and languages, after the Soviet Union had launched the Sputnik satellite. But these cases were exceptions to the then established division of labor between the federal government and the States.

The reason for the Federal Government to increase its investments in research, also in basic research, was World War II. The developments after the war, the period of the Cold War, further strengthened the involvement of the Federal Government in research. The needs of the Military were behind the investments. The share of government funding of total R&D rose from less than 20 to 75 percent in five years. Also, an increasing proportion of the federal funding went to universities and companies as contract research whereas before the war the resources were mainly given to federally owned institutions. By 1960, federal investments in research in academia had reached 60 percent of total academic funding.

Even if funding for some civilian research areas have increased in recent years, notably for medical research, the proportion devoted to military research has been continuously strong in the federal budget during the latter half of the twentieth century. Military spending started during World War II with the development of the atom bomb (the Manhattan Project) and continued through the Cold War in the government laboratories. The Atomic Energy Commission took over the laboratories from the Manhattan Project and expanded its laboratory complex in its first years. Between 1946 and 1952 nine national laboratories were established where basic and applied research in physics and engineering in the nuclear area was carried out. The Atomic Energy Commission was also the biggest funding source of physics at American universities at the time.

The launch by the Soviet Union of the Sputnik led to the creation of the National Aeronautics and Space Administration (NASA) in 1958. It also resulted in the reestablishment of a Science Advisor to the President and to the creation of The Defense Advanced Research Projects Agency (DARPA). This agency was established to support interdisciplinary research across the three military branches.

From 1950 to 1960, military expenditures rose from 12.9 to 39.2 billion dollars. During the 1960s and 1970s, however, it was felt that American research was too dominated by defense research and that there were other pressing societal needs, such as poverty, poor health and a deteriorating environment which should benefit from investments in research. By the mid 1960s, the proportion of defense-related research had decreased to 50 percent of total Federal R&D spending. The decreased spending on defense R&D also meant that the role of the Department of Defense (DOD) in academic research diminished. In 1958, the DOD accounted for 44 percent of total federal expenditures for research in academia. In 1965, this share was down to 21 and in 1980 to 9 percent.

When Ronald Reagan was elected President in 1980, defense expenditure increased dramatically, particularly for the Strategic Defense Initiative, SDI. Defense R&D also increased and made up 75 percent of total federal R&D expenditure. However, the fall of the Berlin wall changed the picture completely. During the late 1980s and early 1990s, the United States was preoccupied with the economic competition from Japan. Technology transfer became the key objective. All federal agencies were supposed to engage in activities that benefited the American economy. This was also the time when some universities started to engage more intensively in tech transfer and commercialization of research results.

Present U.S. military spending is up again to an estimated 18 percent of the federal budget. Defense R&D in the federal budget 2003 amounts to 54 percent. The terrorist attacks on September 11, 2001 have changed priorities dramatically. In the President's proposal for 2004 there are increases in defense R&D, in homeland security R&D and in the budget for the National Institutes of Health (NIH) for biodefense.

As is clear from the above, defense R&D has been very strong in the United States since World War II, even if it has fluctuated quite a bit. The other unique characteristic of the American system is the heavy spending on health-related research which has mainly taken place in the last couple of years. The budget for the NIH for 2003 amounts to 27 billion dollars and constitutes half of all civilian research.

The federal engagement in medical research originated through the needs of the military during the eighteenth and nineteenth century. The origin of the NIH was a laboratory at the Marine Hospital Service. The mission of this institution was broadened when the great number of immigrants came to the United States. A Hygienic Laboratory was founded on Staten Island in New York and was moved to Washington, D.C. in the early 1890s. This laboratory tested the quality of air and water in the Capital and was also supposed to carry out research on infectious and contagious diseases and matters pertaining to the public health.

In the 1930s, the Hygienic Laboratory was transformed into the National Institute of Health. Congress gave this institution the assignment of awarding stipends for promising medical researchers at academic institutions. The institute was supposed to function as a medical research council, not only providing funds for its own laboratories. In 1937, the National Cancer Institute was formed. From the beginning it was supposed to be separate from the NIH but through the National Health Act in the mid 1940s it was made part of the NIH. The National Institute of Health became the National Institutes of Health. Other institutes were also created. In twenty years, the budget of the NIH increased from a few million dollars to more than 1 billion in the mid 1960s. The so-called extramural support, i.e. support to academic institutions outside the NIH, had grown to 1 billion in the mid 1970s. The expansion largely took place during the Presidency at the NIH of James A. Shannon from 1955 to 1968. This was largely achieved through a powerful cooperation between Shannon, some public activists, and members of Congress.

When President Nixon declared a "war on cancer" in 1971 substantial increases were awarded the NCI. There were discussions and debates in Congress whether to separate the NCI from the NIH. Objections were raised in the scientific community to this proposal, as there was a fear that funding for the NIH would suffer, were it to be realized. A compromise was reached in that the NCI got a more independent position within the framework of the NIH. The Director of the NCI is the only of the NIH institutes directors who is appointed by the President. The Director of the NIH is also appointed by the President and confirmed by the Senate.

The great investments in defense R&D and biomedical research were and still are made mainly to achieve a specific mission, i.e. for national security and for public health reasons. However, a substantial amount of basic research is financed as part of those missions. What then has been the development of basic research in the United States?

Up until the Second World War, investments in American science had largely been motivated by the needs of certain sectors; agriculture, the military and the needs of industry. Support for basic science was not prevalent and American science and research was not as prominent as it was in Europe. The war changed this situation when many scientists fled from Germany and other European countries to the United States. After the war there was a debate in the U.S. about the control of science and research. In 1941, Dr. Vannevar Bush had become director of the newly established Office of Scientific Research and Development (OSRD) under President Roosevelt. OSRD was responsible for coordinating the federal investments in research. Vannevar Bush became an advisor to President Roosevelt in science matters. Bush strongly believed in the freedom of science and that this freedom had to be secured both from the politicians and the military. In his famous report of 1945, Science the Endless Frontier, he presented his proposal for a National Research Foundation. The main ingredients were the establishment of a research council for basic research in all areas, including military and medical research, and the idea to leave decisions about the direction of research to the scientists. Bush also believed that there was no great need for extensive coordination of the federal research effort.

After many years of discussion the National Science Foundation was established in 1950. Bush's ideas were largely adopted. But the defense-related research had become so large at the time and separate institutions to fund defense R&D had been created that defense-related research and development was left out of the NSF. In 1954, the Congress decided that other federal agencies could finance basic research as well. In fact, the most important funding source of basic research in the U.S. is the NIH. In 2002, the NIH was funding 54 percent of total federal support for basic research compared to 13 percent for the NSF. Even so, the NSF is the only federal agency, which has the support of basic research as its main mission. This support covers all research areas except the humanities.

The argument can thus be made that support for science and research in the United States has not been guided by an objective to support science for science's sake but has mainly been driven by other motives or missions. This of course does not mean that basic research in the US is different from that in other countries. But had the main motive been to support basic research, the investments could possibly have been greater in basic research and lesser in applied research. The mission-oriented perspective also affects the balance between different kinds of basic research, i.e. between disciplines. Another balance might have been struck if the NSF had been the main supporter of basic research in biomedicine.

The science system in any country evolves over time. This is also true of the United States as is clear from the historical overview. When organizations have been in existence for a long time it is hard to change them. It is often heard in the United States that structural reforms of the science system such as those, which are frequently made in other countries, could never occur in the US. The size and complexity of the U.S. make such changes unlikely. However, when major threats occur, as they did during the Second World War and when the Soviet Union launched the Sputnik, major changes did take place. This is also true today after the terrorist attacks on September 11, 2001. The major reform, which is also affecting the US science system, is the creation of the Department of Homeland Security.

4 The Present Science System

4.1 Introduction

In this section an overview over the American research system will be presented in terms of main actors in funding and performance. The focus will be on decision-making, science advice, and priorities. Obviously, it is not possible to be all-inclusive. The special features of the American system will be in focus as well as facts, which are of particular interest from a Swedish perspective. Two funding agencies will be presented more in detail. These are the NIH and the NSF.

The two most important functions of governments in the area of science and research are to provide funds and to secure that the system works. One obvious question in relation to funding is how much is enough? There is no clear answer to the question, as there is no limit to the needs of research for funding. It can even be argued that the more a government provides the greater the need gets. Also, there are virtually no research areas where it could be argued that the job is done at a certain point and that no more money is needed.

Science and research have to compete with other societal areas for support and decisions about the amount of funding for science are dependent on other needs in society. An equally difficult issue is how to make priorities in research, i.e. where should the money go? Here also, other factors than the perceived need of the research area itself come into play. Every society wants to use science to promote the well-being of its citizens in terms of safety, health, environment and energy, education, defense, and so on. Priorities will be made with these missions in mind.

To create an effective science system may be an easier task. However, there are many seemingly logical ways in which than can be done. Take for example coordination of a government's investments in research. In some countries, there are ministries for science, in others research is combined with education, and in still others science is combined with technology and innovation, and so on. These organizational structures also vary over time.

4.2 The Structure of Funding

The American science system is a large and complex structure with a loose coordination of efforts. Many are involved in decision-making, not only the President and the Administration, Congress, and government agencies, but also business and industry, States, foundations, universities and colleges, government laboratories, etc. The sheer size and the federalist structure of the country make its system pluralistic and different from those in many other countries. Also, the American constitution plays a role in that the power and decision-making is split between the President, the Congress and the Supreme Court. The American political system is not a parliamentary democracy. The role of Congress in science policy is different from the role of many European parliaments. The system is also different in that business and industry play an important role in the formulation of policies as representatives sit on boards of advisory committees, panels, etc. Other organizations and associations, such as professional societies, industrial interest groups and think tanks are influencing science policies, when lobbying to promote their own interests, particularly in Congress. Money from private sources is often needed to support such interest organizations.

4.2.1 The Role of the Administration in Research Policy

The executive power in the United States rests with the President. Within the Administration there are a number of administrative offices and advisory functions for the formulation of science policies. The most important are

- The Office of Science and Technology Policy (OSTP). The head of the office is also the President's science advisor. The mission of the OSTP is to give science and technology policy advice on a number of issues, on the budget for science, to coordinate efforts of federal agencies and other actors, and to promote international cooperation in research. The position as science advisor was first established at the Office of Scientific Research and Development during the war. Since that time, the position has been abolished a few times or its importance has varied in accordance with the stress that the American presidents have placed on science. In times of national crises, the position has normally been reestablished. The power of the OSTP varies a lot with the personality of the science advisor and the access that the science advisor has to the President. The science advisor has always been male and usually a physicist. The current incumbent is Dr. John Marburger III.
- The National Science and Technology Council (NSTC). The Council has a strategic function in setting the research agenda and in coordinating the federal policies and interagency programs in science and technology. Its members include the President and Vice-president and heads of government departments and independent agencies. The NSTC seldom meets, if ever. The work takes place in committees and subcommittees. The Director of the OSTP directs the work of the NSTC on behalf of the President. The federal agencies provide staffing to the NSTC Secretariat, which is co-located with the OSTP.
- The President's Council of Advisors in Science and Technology (PCAST). Its members are appointed by the President from business and industry, academia and non-governmental organizations. They are assigned to give the President independent expert advice. The Director of the OSTP co-chairs the PCAST with a leader from the private sector, and the OSTP functions as its secretariat.
- The Office of Management and Budget (OMB). It coordinates and prepares the President's budget proposal to Congress. In this capacity, it is a very powerful institution in determining the actual size of the research budget. Each year, the Directors of the OSTP and OMB jointly issue a memo to the federal research agencies outlining the Administration's top priorities in R&D, which should be considered as the agencies develop

budget proposals. It should be stressed, however, that there is no formal research budget. There are separate R&D budgets in every department and agency. The actual size of the R&D budget becomes clear only ex-post. Every year, the American Association for the Advancement of Science (AAAS) publishes a report analyzing R&D in the proposed federal budget in order to make available to the scientific and engineering communities and to policymakers timely and objective information about the Administration's plans for the coming fiscal year. The AAAS also follows the actions by Congress on those proposals.

The most important prerogative of the President and his Administration is to formulate the budget proposal on the basis of the proposals from the department and agencies. The process is cumbersome and lengthy. The time from inception to final decision by the Congress and the President is about 18 months. As will be clear in the following, Congress has much more power in the decision-making of the budget than parliaments usually have in many European countries.

4.2.2 The Congress

In the Congress, science and research issues are dealt with both in the House of Representatives and the Senate. The modest level of coordination in R&D in the executive branch is not matched by Congress. In each chamber, there are several committees and subcommittees which deal with different science issues. It is in the committees that the real work takes place, particularly in the subcommittees. As the budget has to be dealt with in both chambers and they often have different views on the different budget items – the Senate being more independent from the Administration than the House – an important mediating role is played by conference committees which are joint committees of both chambers. The process is all the more complicated as there are both authorization committees and appropriations committees. The former give the departments and agencies authorization to continue or start programs whereas the latter authorize the money for the departments and agencies. Science issues are dealt with in nine committees in the Senate but there are three which are really important; the Committee of Commerce, Science and Transportation, the Committee on Health, Education, Labor and Pensions (biomedical research) and the Appropriations Committee. In the House there are also nine relevant committees, but the business is more concentrated to one committee, the Science Committee. As was pointed out earlier, there are subcommittees in addition. The House Appropriations Committee is a major player.

Congress actually decides on most items and sub-items in the budget for departments and agencies, i.e. how much money can be spent on different programs. It is also common that members of Congress propose funding for specific research activities in their local districts, so called earmarks.

In order to deal with the budget in this detail, it is necessary for members of Congress to have very skilled staff at their disposal. Congressional staff plays an important role in the decision-making processes in Congress. But there are also other support functions for members of Congress, such as the Congressional Research Service (CRS), which is part of the Library of Congress. The Congress also has a

General Accounting Office, which audits and evaluates federal programs and activities. Finally, the Congressional Budget Office (CBO) gives Congress current budget information and produces annual reports on economic and budget trends.

Information is also gathered through the many hearings in Congress. This happens particularly when new bills are introduced and in the follow-up on the implementation of Acts of Congress by the federal administration. It is common that representatives of the Administration are called to hearings as well as outside experts, for example representatives of the National Academies and the AAAS. Individual citizens can also be called to a hearing. This has been the case in the debates about stem cell research.

Much more could be said about the way Congress works and the budget process. Suffice it to stress that the budget process is extremely complex both for the Administration and Congress and that, in a comparative perspective, Congress plays a very important role in this process, more so than many parliaments in parliamentarian democracies. Also, power is shared with the legal system in the United States to a higher extent than in many other countries.

4.2.3 Federal Departments and Agencies

Many departments and federal agencies are involved in the funding of research and development. Most departments finance R&D as part of their mission. Some agencies have R&D as their main objective, such as the NIH and the NSF. Most agencies, such as the Environmental Protection Agency (EPA) supports R&D as part of its overall objective. The most important departments and agencies in terms of the size of their R&D investments are:

Department/Agency Appropriations 2003	**Appropriations 2003 Millions of dollars**
The Department of Defense, DOD	58.6
The National Institutes of Health, NIH	26.2
The National Aeronautics and Space Administration, NASA	11.0
The Department of Energy, DOE	8.2
The National Science Foundation, NSF	3.9
The U.S. Department of Agriculture, USDA	2.2
The Department of Commerce, DOC	1.2
The Department of Transportation, DOT	0.8
The Environmental Protection Agency, EPA	0.6
The Department of the Interiors, DOI	0.6

There are two agencies, which are of particular interest in view of the purpose of this report. These are the NIH and the NSF. They will be introduced later on in this report. The NSF is the only U.S. agency, which has the support of basic research or general science as its main mission. It is the agency, which is most similar to the Swedish Research Council and also for that reason the NSF deserves particular attention. The way that these two actors fund research at universities and the criteria that they use in this process will be described in detail.

4.2.4 The National Academies

There are many organizations and institutions which contribute in the science policy processes in the United States. One is the National Academy of Sciences which was established by Congress in 1863. The Civil war was raging at the time. The Academy’s task was to “examine, experiment and report upon any subject of science or art whenever called upon by any department of the government”. Other institutions were created later on to meet the need for independent scientific advice. The National Research Council was established in 1916, the National Academy of Engineering in 1964, and the Institute of Medicine in 1970. Collectively, these organizations are called the National Academies. The National Research Council is the operative arm of the academies. It conducts the main part of the science policy studies of the academies. The Institute of Medicine also conducts policy studies on health issues. The academies are independent honorary societies which elect new members to their ranks each year, mainly American scientists, engineers and other experts but also associate foreign scientists and engineers.

The academies get the bulk of their funding from government agencies. In 2002, they received almost 180 million dollars in revenues from grants and contracts of federal agencies and almost 52 million dollars from private and nonfederal sources. They also undertake assignments from various agencies as agencies need their advice on issues at the programmatic level. They give unsolicited advice on issues in science, technology and medicine. They often work through committees where experts are gathered to analyze a particular issue. The academies´ projects are initiated in different ways. Congress may ask them to undertake a specific study and government agencies can ask them for advice. One example is a recent study on the organization of the NIH. The academies may also initiate projects or programs themselves. One example is the newly created International Visitors Office (IVO), which assists visiting scientists and national organizations in the United States with visa issues and attempts to help improving communication and coordination among the agencies and communities involved. Finally, the academies may undertake assignments from states, industry and foundations.

The work of the academies is very comprehensive. It covers every scientific area, as well as education, space, transportation, international issues, policy issues and innovation. It gives information and advice on topical issues, such as bioterrorism, intellectual property, stem cell research, etc. The academies undertake their work through consensus reports on particular issues, which normally takes 1.5 to 2 years. They can also produce reports in a few months in matters where fast action is needed, and they carry out studies on different disciplines.

The academies are engaged in the international arena where they work with their sister organizations abroad. A particular focus in recent years has been on international environmental issues and international security and arms control. The International Scientific and Technical Information Programs of the Academies are engaged in improving the management, accessibility and use of science and technology data and information by the research community, with special emphasis on developing countries.

4.2.5 Other Actors in Science Policy

There are a number of other actors which are influencing science policy in the United States. According to a report by the Carnegie Commission (Carnegie 1993) there are between 2000 and 4000 non-governmental organizations (NGO) which deal with science and technology. Most are located in Washington D.C. and they serve as a link between scientists and federal departments and agencies. Many of these organizations are trying to influence decisions about funding and other science policy issues in Congress. The mission of these organizations is different; some are there to promote science in general, such as the American Association for the Advancement of Science (AAAS), some represent a specific discipline, like the American Chemical Society (ACS), some are promoting the interests of universities and higher education, such as the Association of American Universities (AAU) and the Council of Graduate Schools (CGS). Think tanks are also involved in science and technology policy, such as the Brookings Institution, the Center for Strategic and International Studies (CSIS), the Carnegie Institution and the Council on Competitiveness. There are several thousands of lobbyists in Washington, who work for companies or NGOs. Universities sometimes engage lobbyists to influence decisions by members of Congress.

Of particular interest is The American Association for the Advancement of Science, "Triple A-S" (AAAS), which is the world's largest general scientific society with 140,000 individual and institutional subscribers and 272 affiliated organizations. It publishes the journal SCIENCE. The mission of the AAAS is to "advance science and innovation throughout the world for the benefit of all people." The broad goals are to foster communication among scientists, engineers and the public, to enhance international cooperation in science and its applications, to promote the responsible conduct and use of science and technology, to foster education in science and technology for everyone, to expand and improve the science and engineering workforce and infrastructure, to increase public understanding and appreciation of science and technology; and to strengthen the support for the science and technology enterprise.

There are particularly three programs at the AAAS that are relevant from a science policy perspective. They are all within the realm of the Directorate for Science & Public Policy Programs. The first is the analyses of R&D data, which include the federal budget for R&D, also in a historical perspective. Related to this is the yearly meeting, the AAAS Science and Technology Policy Colloquium, where the federal budget for R&D is analyzed and important science policy issues are presented and discussed. The second is the AAAS Science and Technology Policy

Fellowship Program. This program is intended to foster the links between science and government. During one year, about one hundred fellows are selected to work in a federal department or agency or in Congress. Eligible are those applicants who have a PhD or an equivalent degree in one of the social, physical or biological sciences, or who are engineers with a master's degree and at least three years of post-degree professional experience.

The third activity is the AAAS Center for Science, Technology, and Congress. The Center provides information to Congress on current science and technology issues and assists the science and engineering community in understanding and working with Congress. A newsletter, “Science and Technology in Congress”, is produced monthly covering new reports and publications and reports on S&T issues which are debated in Congress. The Center also supports a series of seminars on S&T policy issues, The Washington Science Policy Alliance.

Through these activities and others, the AAAS plays an important role in promoting the interests of science and those of the universities. Other important actors are the currently 219 national science and technology advisory committees which give advice to federal departments and agencies. 40 percent are within the HHS. There is recent concern in the science policy and scientific communities that the current administration has been biased in the appointments of members of advisory committees and that it has dissolved advisory committees which have not been “politically correct”. The controversy has triggered a comprehensive investigation by the General Accounting Office (GAO) in Congress. The report by the GAO, which is due in January 2004, will investigate six federal agencies to determine the role that the committees play in policymaking and how agencies ensure that scientifically sound and unbiased advice is obtained (Research USA, 2003).

4.3 Trends in Funding

It has been argued earlier in this report that the rationale for investments in research and development in the United States has most often been to achieve a societal mission, be it national defense, space exploration, energy, economic competitiveness or health. The development of the federal R&D spending shows such priorities.

In a presentation in July 2003 to the Science Counselors of the European Member countries, the President’s Science Advisor, Dr. John Marburger, gave a brief overview of the development of the federal engagement in research and development. He pointed to the fact that physical science was seen to be closely related to military capability and the life sciences for the potential cures for specific diseases. When the Cold War ended in the early 1990s, the rationale for federal support of science was questioned. Why support nuclear weapons laboratories in an era of nuclear disarmament and why support the many DOD laboratories? Funding of the physical sciences had already started to slow down and funding for the medical sciences had surpassed funding for physics. But the dot.com phenomenon rendered the debate about federal funding of physical science obsolete. Economists helped by showing that the productivity gains in the American economy during the 1990s mainly derived from technology rooted in federally funded research in physics. Dr. Marburger stressed that "*congressional support for science funding, which is today strong and bipartisan, is based on the premise that it is needed for economic competitiveness in a new era of technology intensive economies in the developed nations"* (Marburger 2003).

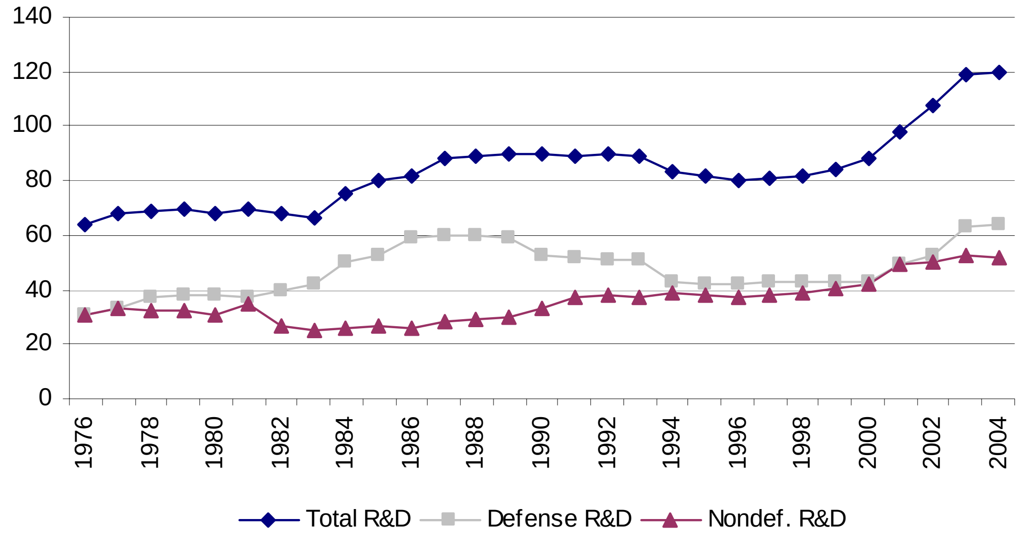
The NSF and the American Association for the Advancement of Science, AAAS, have been collecting R&D statistics and made analyses for decades. The presentation below relies heavily on these sources (AAAS 2003b).

In 2002, total R&D investments in the United States amounted to 2.8 percent of the Gross Domestic Product (GDP). Industry accounted for 66 percent of total R&D in 2002 and the federal government for 28 percent.

Nearly all federal R&D is funded through the discretionary portion of the budget, and although R&D has remained relatively constant as a share of all discretionary spending, R&D has declined as a proportion of the total budget as the discretionary share of the budget has declined. This is a result of growing entitlements spending. In the mid 1960s, R&D made up almost 12 percent of the federal budget compared to about 5 percent in 2003.

The relative size of different areas of federal R&D has varied over the years, reflecting changing national priorities. Spending on defense R&D has exceeded all other R&D spending for most of the past four decades, but the relative size has varied considerably over the years. Defense R&D amounted to approx. 42 billion dollars in 1993 compared to approx. 63 billion dollars in 2003. Space was the dominant mission in the 1960s; energy R&D has fluctuated in importance; health R&D, meanwhile, has shown practically uninterrupted growth and now represents the largest single share of the non-defense R&D portfolio.

GRAPH 1
Trends in federal R&D, FY 1976–2004 in billions of constant FY 2003 dollars

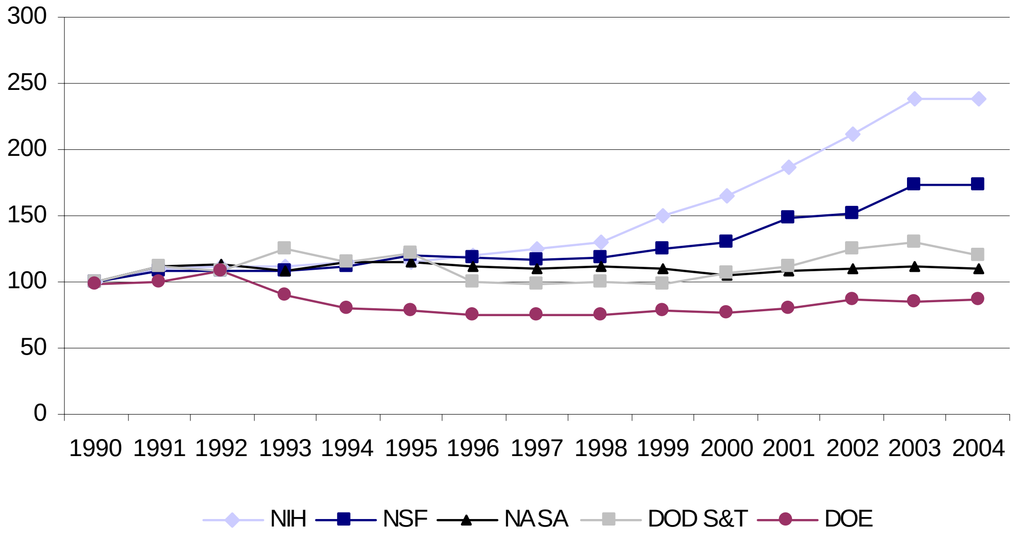


Source: AAAS 2003a

This development is also reflected when the trends in funding for federal agencies are shown. As can be seen from Graph 2 and Graph 3 below some agencies such as the NIH, NSF and NASA have had increases, but many others, such as DOD, DOT, EPA and USDA have seen their R&D budgets decline in the 1990s and early 2000s. In the FY 2004 request, some of the R&D funding agencies would receive increases but most would have their resources cut.

GRAPH 2

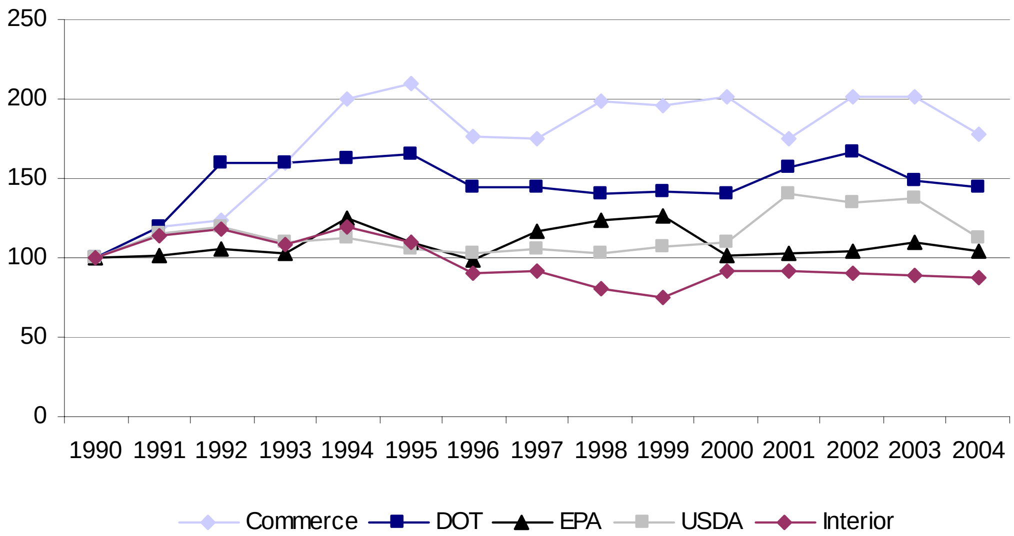
Trends in federal R&D, FY 1990–2004. Selected agencies in constant dollars, FY 1990=100



Source: AAAS 2003a

GRAPH 3

Trends in federal R&D, FY 1990–2004. Selected agencies in constant dollars, FY 1990=100



Source: AAAS 2003a

Even if basic research has not been the highest priority of federal investments it has increased dramatically during the last decades. It was about 7 billion dollars in 1976 compared to 26 billion dollars in 2003. This is largely due to the increases in the budget for the NIH. The NIH accounts for more than half of all basic research in the federal budget. Of the different performers of basic research that the AAAS presents; federal, industry, universities and colleges, FFRDCs (Federally Funded Research and Development Centers,) and other performers, all have increased their performance of basic research from 1970. Universities and colleges carry out about half of all federally funded basic research today.

The picture looks very different, though, when looking at the performance of all federally funded R&D. Table 1 below shows that federal agencies and laboratories, universities and colleges, and industry perform an almost equal amount of federally funded research.

TABLE 1
U.S. expenditures of R&D, by performing sector and source of funding FY 2002 (preliminary)

Performers	**Sources of funds (billion dollars)**				
	Federal government	Colleges & universities	Non-profit institutions	Industry	**Total**
Federal government	22				**22**
Colleges & universities	23	9.9	2.7	2.3	**37**
FFRDCs	10				**10**
Non-profit institutions	5.5		4.6	1.2	**11**
Total, excl. industry	60	9.9	7.3	4	**81**
Industry	21			190	**211**
Total	**81**	**9.9**	**7.3**	**193**	**292**

Source: NSF 2003C

It is also interesting to see what performers the different federal departments and agencies support and work with. The NIH finances mostly universities and colleges and to a lesser degree federal institutions and others, but not industry to any large extent. NASA is a heavy supporter of industrial research, the DOE mainly supports FFRDCs, and DOD Science and Technology supports industrial and federal research. The NSF stands out as the agency which supports mainly universities and colleges and FFRDCs, and the Department of Agriculture, not surprisingly supports research in federal laboratories.

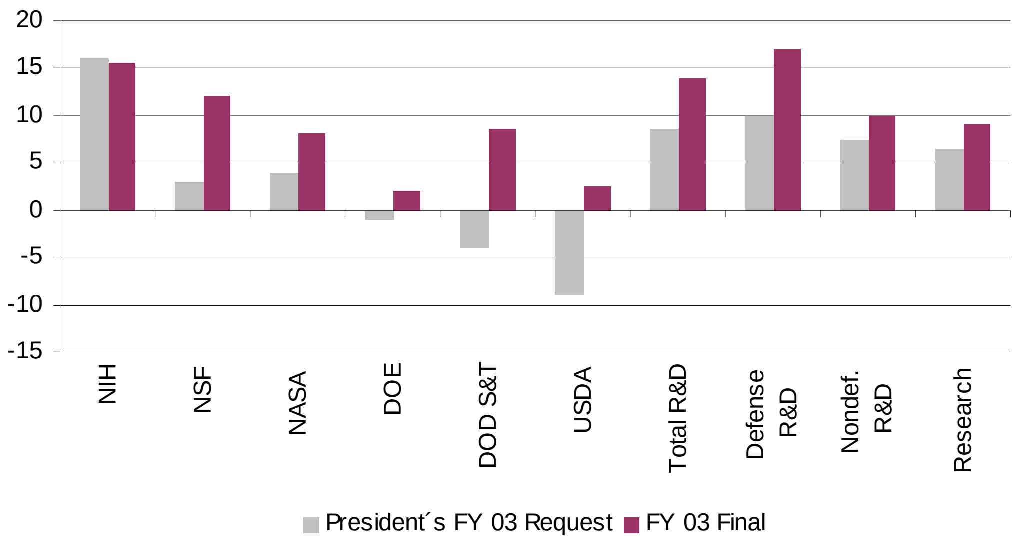
The current situation in terms of total U.S. funding of R&D and particularly federally funded research clearly shows the present priorities of the Administration and Congress.

The budget provided a record-breaking increase for defense R&D, nearly completed the campaign to double the NIH budget over five years, and offered a substantial increase for the NSF.

The federal investment in R&D reached 117.3 billion dollars in 2003. This was an increase of 14.2 billion dollars or 13.8 percent and is the largest dollar increase in history. Most government funding agencies were awarded increases but particularly the areas of defense, health, general science and homeland security. Defense R&D increased by 8.8 billion dollars, or 17.6 percent, reaching 58.6 billion dollars. The NIH received an increase of 15.5 percent reaching 26.2 billion dollars. The increase for the NSF reached 3.9 billion dollars or 11.4 percent.

GRAPH 4

FY 2003 R&D request and FY 2003 final appropriations. Percent change from FY 2002



Source: AAAS 2003a

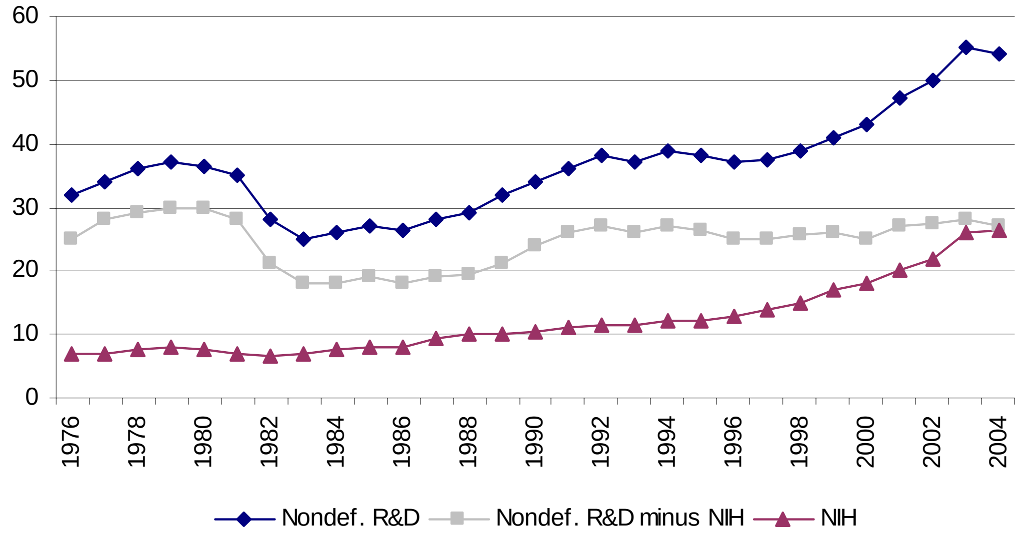
Of the total federal R&D budget, investments in *research* reached 52.9 billion dollars, which is 9.7 percent more than in 2002. NIH remained the largest single sponsor of basic and applied research; in 2003, NIH alone funded 47 percent of all federal support of research, its highest share in history. All federal departments except the Departments of Transportation and Commerce received increases for their research portfolios, with especially large increases for research at the NIH, NSF, and NASA.

The new Department of Homeland Security became a major player in federal R&D funding in 2003. R&D programs scheduled to transfer to the new department this year received $669 million dollars in R&D funding, nearly triple the 266 million dollars for comparable programs in 2002. In 2004, DHS R&D would jump to 1.0 billion dollars in the request.

Funding for nearly all the national missions increased in 2003, with especially large additions for defense and health R&D. In defense, DOD *science and technology investments* exceeded 11 billion dollars to reach 11.2 billion dollars (up 8.6 percent) but there were even larger increases for DOD *development projects*. In health, the NIH budget nearly doubled between 1998 and 2003 with a 3.5 billion dollars increase to 26.2 billion dollars for R&D, including substantial increases for bioterrorism research and bioterrorism research facilities. Another priority was general science programs, up 6.4 percent to 7.0 billion dollars, led by an 11.4 percent for NSF's R&D programs but moderated by flat funding for the DOE's Office of Science. Space R&D was also a big winner with a 9.2 percent increase to 10.1 billion dollars because of large increases in the Space Science program and a continuing shift from aeronautics R&D to space-related technology development.

The only area of R&D that declined was transportation (down 7.6 percent to 1.7 billion dollars) because of cutbacks in NASA aeronautics R&D and a decline in DOT R&D.

GRAPH 5
Selected trends in nondefense R&D, FY 1976–2004 in billions of constant FY 2003 dollars



Source: AAAS 2003a

Non-defense R&D reached another all-time high in 2003, the seventh year in a row that non-defense R&D has increased in inflation-adjusted terms. This was mainly due to the growth in the NIH budget, by approximately 15 percent for the last five years. As a result, NIH R&D has become nearly as large as all other non-defense agencies' R&D funding combined. Funding for non-defense R&D excluding NIH has stagnated in recent years; after steady growth in the 1980s, funding peaked in

FY 1994 and then declined sharply as a result of tight budget conditions in the mid-1990s. The FY 2003 increases for non-NIH agencies, while large, just barely bring these agencies back to the funding levels of the early 1990s.

Finally, R&D earmarks totaled 1.4 billion dollars in 2003, which equals 1.2 percent of total federal R&D. Four agencies, the USDA, NASA, DOE, and DOD, received nearly 75 percent of all earmarks for R&D. In 2003, R&D earmarks were down from approximately 1.5 billion dollars in 2002.

4.4 The National Institutes of Health and the National Science Foundation

4.4.1 The National Institutes of Health

In the previous overview on the development of the American science system a presentation on the history of the NIH was included. An in-depth presentation of the NIH is made in the special report on the structure and funding of medical research. In this section some pertinent features of the NIH will be presented with a focus on the ways of working of the NIH and some of the perceived concerns about its future direction.

The National Institutes of Health is the single largest funding agency of medical research in the world. The mission of the NIH is to uncover new knowledge that will lead to better health for everyone. NIH works toward that mission by conducting research in its own laboratories (intramural research), by supporting the research of non-federal scientists in universities, medical schools, hospitals, and research institutions and abroad (extramural research). It also assists in the training of investigators and in fostering communication of medical information. Like many other federal agencies, the NIH is engaged in technology transfer activities.

To meet its mission, the NIH supports both disease-specific research and basic research. Support for research on one disease is not limited to one institute but is often carried out by different institutes at the same time. Disease-oriented institutes also support basic research. Research results from NIH-funded projects are often relevant to more than one disease.

The funding of intramural or extramural medical research covers salaries of scientists and technicians, equipment, such as computers, supplies, such as chemicals and costs related to research patients. The NIH also pays for overhead costs which may run as high as at least 30 percent of the total cost of a research project. State universities usually get a lower reimbursement than private universities. The rate has been steady for about 15 years and is negotiated with a government agency, which has been assigned by the Office of Management and Budget (OMB) to do this on its behalf (Kirchstein 2002).

The budget for the NIH in 2003 amounts to 27 billion dollars. In 2002, the actual R&D budget of the NIH was 22.7 billion dollars. This is 97 percent of the total NIH budget (in 2002 estimated to 23.4 billion dollars). The remaining 3 percent is for training, management and support. As has been pointed out earlier, the NIH budget doubled in the last five years. No other civilian federal agency has seen its budget increase as much. NIH accounts for nearly a quarter of federal outlays for R&D and half of the civilian R&D budget. The NIH is the second largest contributor to federal R&D after DOD and the largest supporter of basic research, applied research, and R&D at colleges and universities (AAAS 2002b).

Of the total federal R&D obligations in 2000, NIH sponsored 30.1 percent of intramural research, 16.7 percent of industrial research, 63 percent of R&D at universities and colleges, 3.6 percent of R&D at nonprofit organizations and 9.9 percent of all other organizations. The NIH plays a major role within biological sciences where it supported 87.5 percent of total R&D. NIH funded 76.1 percent of the federal R&D obligations within the medical sciences. NIH support is also vital for psychology and chemistry research and important for physics as well (NSF 2002a).

Approximately 82 percent of the NIH budget goes to extramural activities, such as research grants, research and development contracts, and training and research centers. Approximately 20 percent of this goes to training activities. No more than 10 percent is allotted to intramural research programs. The proportion of the budget going to extramural and intramural research has changed in favor of the extramural programs (NIH Setting Priorities 2002).

NIH is a decentralized organization with 27 institutes and centers, employing about 17,700 full-time employees. More than 4,000 of them hold professional or research doctorate degrees. The staff includes scientists, physicians, and nurses, administrative and support personnel. The number of institutes is 20, including the National Library of Medicine, and the other seven are called centers. The NIH is the only government agency that has a separate item in the congressional budget for each institute and center. The budget of the NIH is thus the sum of the different institutes' budgets. Each institute or center conducts research and related activities on human health.

The institutes within the NIH are quite diverse in their mission and scope of activity and size, but they are similar in the way they are organized and the way they support researchers. The institutes are differently categorized. Several are disease-oriented, such as the National Cancer Institute (NCI). Some refer to a specific organ of the body, such as the National Heart, Lung and Blood Institute (NHLBI). Other institutes are geared towards a specific life stage, such as the Institute on Aging (NIA), and a few others are categorized by field of science or by profession or technology. Every institute and four centers award research grants, mostly to scientists at universities and non-federal research institutions.

The Center for Scientific Review (CSR) handles most of the peer review process at the other NIH institutes. In 2002, NIH gave out awards worth 19.074 billion dollars and the total number awards were almost 50,000. Of these awards, 43,520 were research grants worth 16.830 billion dollars. The average cost of research grants in 2002 was about 384,000 dollars. The average cost per year has increased notably since 1997 when the average cost was 275,000 dollars.

The NIH supports almost 47,000 extramural research project grants and more than 2,000 intramural research projects (NIH 2003a). The duration of some awards may be as short as three months and others as long as 10 years. The Research Project Grants (RPG), however, averaged 3.9 years. Therefore, new projects only constitute about 25 percent of the extramural projects (Greenberg 2003). The awards of the National Cancer Institute (NCI), has an average total length of eight to twelve years.

About 20 percent of the NIH extramural funds go to training. Training positions funded by the NIH reached 16,700 in 2002.

The main part of the extramural funding is distributed to investigator-initiated applications from individual scientists. These are the Research Projects Grants (RPGs), which are awarded across a spectrum from cellular and molecular research to finding new drugs to treat human illness. Within this category, the so called R01 is the most common. The R01 supports a single project and a single investigator. Some project grants are given to multi-disciplinary projects conducted by several researchers with different focus on the research problem and is called program project grants. Multi-disciplinary projects and collaborating researchers are also supported by research center grants. These grants are awarded to research institutions. For example, the NCI has large centers in clinical and basic research, e.g. at Columbia Medical School and at the University of North Carolina. Another supporter of research centers is the National Center for Research Resources (NCRR). The grants also support the development of research resources to integrate basic research with applied research and to promote research in clinical applications.

The NIH supports training of beginning scientists at pre-doctoral and post-doctoral level, either individually or via the institutions, i.e. the medical schools and universities. Most of this support is devoted to stipends to students. In later years, this support has focused on increasing and improving the opportunities of minorities. The NIH is providing National Research Service Awards (NRSA) either as fellowships (F) or as training grants. These are awarded to both individuals and institutions for research training. They are different for individuals having or earning a research doctorate and for individuals with or earning a health-professional doctorate. In medical schools, individuals can apply for short-term training grants and institutional training grants. In college, students can apply for institutional research training grants like Minority Access Research Careers (MARC) and pre-doctoral fellowships and training grants during graduate school. For both groups, post-doctoral fellowships and senior fellowships are available during post-doctoral/specialty or for independent researchers. Another kind of support is the loan repayment programs, which have been established to attract physicians to clinical research. Some programs reimburse almost all of the physicians' student loans.

All applications in the *extramural programs* are sent to the NIH and the Center for Scientific Review (CSR). CSR distributes them to the different institutes. About 52,000 – 55,000 applications are reviewed annually (Ehrenfeld 2003). The final decision whether an application is to be funded or not is made by the institutes. Before such a decision is made, the grant proposal has to go through several steps, a process which is standardized across the NIH institutes. These include rating criteria, policies and procedures in the conduct of review meetings and the use of standardized committees and special emphasis panels.

The CSR's Division of Receipt and Referral receives all grant applications. The Scientific Review Administrators (SRA) make the first important decision, which is to classify the proposal, assign it to an appropriate peer review group (Integrated Review Group, (IRG) or cluster) for the scientific review and to an appropriate institute or center for funding. Sometimes the application is multidisciplinary and is therefore submitted to more than one institute. The 125 study sections at the NIH meet approximately three times a year in meetings. These are not open to the public. To manage the workload at the CSR and at the institutes, the reviews are made in three cycles each year and are carried out in two steps.

Each application goes through a peer review process by the CSR to assess the scientific merit of the application. This is the first step. The study sections consist of 15–20 scientific experts, mostly researchers within the biomedical sciences. The SRAs nominate the members and in this process they look for diversity in gender, race, geography, etc. Temporary members are frequently brought into the study sections. The status and prestige that derive from being a NIH reviewer is the main reason for joining a study section, but also the chance to get insights into and learn about the review process.

The research proposal is reviewed by the following criteria: "the importance of the question, the innovation employed in approaching the problem; the adequacy of the methodology proposed, the qualifications and experience of the investigator; and the scientific environment in which the work will be done" (NIH 2002). Each application is normally assigned to two or more members of the study section for detailed written review comments. Other members are designed as readers. The application is ranked with a numeric score from 100 to 500, 100 being the highest The score reflects the potential impact of the project in terms of the five criteria mentioned above (significance, approach, innovation, investigator, and environment), and is arrived at through discussions and votes by all members of the group.

National advisory councils or boards at the institutes, including both scientists and public members interested in health issues and/or the biomedical sciences, carry out the second step. These councils also meet about three or four times per year. Each institute has its own advisory council, mandated by Congress. A council can never reverse the decisions of a study section. (Ehrenfeld 2003). However, it can recommend funding of applications that have not received the highest scores but which still seem to be very important.

About one third of all reviewed proposals are granted (NIH 2002). It is very rare that a first-time applicant is awarded funding. The success rate has declined due to a greater number of applications and reapplications.

Intramural research, both basic and clinical research, mostly takes place on the campus in Bethesda, Maryland. Most institutes have intramural programs. The intramural research is not always disease specific but serves a broad set of objectives within the NIH's mission. The intramural programs are organized and administered by scientific directors, who themselves are scientists, together with the institute director. They are also in charge of organizing and administering both laboratory and clinical research. The programs are peer reviewed by a Board of Scientific Counselors at each institute, which advice the institutes' directors of the importance and quality of the programs.

As has been pointed out earlier in this report, there has been a debate going on for many years about the organization and efficiency of the NIH. There has been a concern about scientific fragmentation in that there are so many institutes and centers, lack of oversight, lack of cross-cutting initiatives, high costs, etc. The structure of the NIH has been scrutinized in many reports over the years. Recently, two initiatives are worth mentioning. One is a study by the National Academy of Sciences which Congress initiated. The objective was to determine the optimal NIH organizational structure, given the context of 21^{st} century biomedical research. Some of the recommendations by the Committee, which included representatives of basic science, clinical medicine and health advocacy communities, were the following.

An increased centralization of management functions must not undermine NIH’s ability to identify, fund and manage the best research and training. A public process for considering proposed changes in the number of NIH institutes or centers should be created. The clinical effort should be strengthened and trans-NIH strategic planning and funding should be enhanced. The office of the Director should be strengthened. High-risk, high-potential payoff research should be supported through a special program and innovation and risk-taking in intramural research should be promoted. The special status of the National Cancer Institute should be reconsidered. The President appoints the NCI director and the NCI budget bypasses the NIH director which may lead to a rift between the goals, mission and leadership of NIH and those of NCI (NAS 2003).

The other initiative comes from the new director of the NIH, Elias Zerhouni, who took over the job as director in May 2002. Soon thereafter, Dr. Zerhouni convened a series of meetings to chart a “roadmap” for medical research in the 21^{st} century. The process was meant to identify major opportunities and gaps in biomedical research that no single institute at the NIH could tackle alone. The ultimate goal was “to transform scientific knowledge into tangible benefits for people”. The directors of NIH´s 27 institutes and centers have approved of the Roadmap strategy that features 28 initiatives. These can be grouped into three themes; new pathways to discovery, research teams for the future and re-engineering the clinical research enterprise. Included in the first theme is the need to understand complex biological systems and knowledge about the interconnected networks of molecules of cells and tissues, as well as better “toolboxes” for biomedical researchers, such as technologies and databases. The research teams of the future will have to combine skills and disciplines in both the physical and biological sciences. Truly innovative and high-risk research will be promoted. Clinical research needs to develop new partnerships, clinical trials should be conducted jointly by several academic centers and new ways have to be found to organize the way clinical research information is recorded, new standards for clinical research protocols, modern information technology and new strategies to re-energize the clinical research workforce. All in all, approximately 2.1 billion dollars will be spent over six years, starting in 2004 (NIH 2003a).

4.4.2 The National Science Foundation

The National Science Foundation was established in 1950. The mission of the NSF when it was created was to promote the progress of science; to advance the national health, prosperity and welfare and to secure the national defense; and for other purposes. The latter generic mission allows the NSF to get involved in very broad and specific issues connected with the federal government. The NSF is the only government agency which has the support of basic science and engineering as its objective. Therefore, the NSF plays a strategic role in American science and research, particularly in the funding of basic research.

However, it could be argued that the ultimate objective is to achieve other societal goals. The NSF has formulated four strategic goals: people, which means a diverse, internationally competitive and globally engaged workforce of scientists, engineers and well-prepared citizens; ideas, which means discovery across the frontier of science and engineering, connected to learning, innovation and service to society; tools, which means broadly accessible, state-of-the-art and shared research and education tools; and lately, organizational excellence, which means implementing state-of-the-art business and management practices and providing outstanding customer service (NSF 2003a).

The National Science Board (NSB) is the foundation’s policymaking board and advises the Office of the President on matters related to science and engineering research and education. The board is composed of 24 part-time members and the Director of the NSF (who also serves as ex officio NSB member; the present incumbent is Dr. Rita Colwell), each appointed by the President with the advice and consent of the U.S. Senate. Other senior officials include a Deputy Director who is appointed by the President with the advice and consent of the U.S. Senate, and eight Assistant Directors.

Within the NSF there is an Office of Inspector General, OIG. This is true of all federal agencies. What is unique about the NSF/OIG is that the Inspector General reports directly to the National Science Board and Congress. The IG is responsible for promoting economy and efficiency in the NSF administration and for conducting audits, inspections and investigations involving any of the NSF’s activities. It should prevent and detect fraud, waste, abuse and mismanagement in NSF programs and operations and should prevent, detect and handle cases involving misconduct in science.

The total budget for the NSF in 2003 amounted to approximately 5.3 billion dollars out of which 3.9 is for R&D. This is an increase of more than 11 percent compared to 2002. There has been action in Congress and elsewhere to follow the NIH example to double the budget for the NSF in five years.

The NSF represents less than four percent of the total federal funding for R&D but accounts for approximately 13 percent of all federal support for basic research and 40 percent of non-life-science basic research at U.S. academic institutions.

Of the total federal funds that the NSF receives, almost everything is spent on research, education and equipment. NSF spends about 5 percent on administration and management. In spite of increased funding for the NSF in recent year, the staffing level has remained flat. An increased use of information technology and a reliance on voluntary outside support from the scientific and engineering community has made this possible. The comparatively low spending on administration and management is an issue under debate. The number will probably soon be increased.

The NSF is authorized to engage in a number of activities. It can and does initiate and support scientific and engineering research through grants and contracts as well as education programs. The NSF is involved in supporting science and mathematics education from Kindergarten through high-school (K1–12). The NSF supports both basic and applied research and facilities but is not engaged in development. It awards graduate fellowships, postdoctoral fellowships and undergraduate training, either directly or indirectly through research grants. Part of NSF's mission is to support activities designed to increase the participation of women and minorities and others under-represented in science and technology. The NSF also serves as a clearing-house for science and engineering data, national and international, and for the collection, interpretation, and analysis of data on scientific and technical resources to be used also in policy formulation by other Federal agencies.

The NSF works with programs in mathematical and physical sciences, engineering, biological sciences, geosciences, computer and information sciences and engineering, social, behavioral and economic sciences, polar research, major research equipment, and education and human resources. It also promotes cross-cutting, integrative activities and international cooperation. International cooperation has been stressed lately. The budget has increased and a director of international activities is now included in the group of top officials at the NSF.

From a Swedish perspective it is particularly interesting to look at the award-granting process at the NSF and what crosscutting activities there are within the organization.

The Merit Review Process

The first thing to notice is that the NSF calls the process merit review instead of peer-review. The criteria used in evaluating the merits of a proposal were adopted by the NSB in 1998 and are as follows:

<u>The intellectual merit of the proposed activity.</u> How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

<u>The broader impacts of the proposed activity.</u> How well does the activity advance discovery and understanding while promoting teaching, training and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g. gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society? (NSF 2003a)

The NSF is concerned that enough attention be given to the second criterion which is harder to take into account than the first one. Also, principal investigators and reviewers seem to be unsure how the second criterion should be addressed. The NSF has been working with different methods to secure the inclusion of the criterion in the review process.

The proposals are received electronically and forwarded to the appropriate NSF program for review. They are reviewed by one of NSF's 400 program officers and usually by three to ten experts from outside the NSF. Program officers obtain external advice on applications by three methods: mail-only, panel-only or mail-plus-panel review. Since 1995, the percentage of NSF proposals reviewed by panel-only has increased from 39 to 50 percent of all proposals. Mail-only review has declined from 28 to 14 percent. The advantage with panel-only review is that the process permits proposals to be discussed and compared to one another and that it is more suited to evaluate multidisciplinary proposals.

External experts play an important role through their advice and recommendations. NSF program officers have to address factors dealing with portfolio balance when making a recommendation on proposals. They include how the proposal is expected to contribute to human resources and institutional infrastructure development, the balance of research approaches to significant research questions, the support for risky proposals with potential for significant advances in a field, achievement of special program objectives and initiatives and balance of the overall program portfolio. The final decision for awards or declines is taken by senior NSF staff.

The NSF makes about 10 000 new awards each year, and over 96 percent are selected through its competitive merit review process. The NSF Director submits a report on the NSF proposal review system every year. In 2002 the NSF took action on approximately 35 000 competitive, merit review research and education proposals. The overall funding rate was 30 percent, which is rather similar to previous years. There are standard grants, continuing grants and grant increments. The standard grants provide funding for the full duration of a project (usually 1–5 years) in one single fiscal year award. Continuing grants provide funds for an initial period (usually one year) of a multiple-year project with the intent to continue funding in yearly increments. 60 percent of awards in 2002 were standard grants. There has been a policy to increase the number of standard grants in order to increase flexibility to redirect resources to emerging science and engineering opportunities. The number of continuing grants has decreased by 5 percent since 1993.

The NSF has a strategy to broaden the participation from groups currently underrepresented in the science and engineering enterprise, i.e. minorities and women. In 2002, about five percent of awards were given to minority principal investigators. However the funding rate for them is 29 percent, slightly less than the overall rate of 30 percent. Percentage-wise, the awards to minority investigators have increased over the years. Female principal investigators were awarded 19 percent of total awards, which is a funding rate of 30 percent.

In order to make room for novel discoveries and ideas the NSF also attempts to increase the awards to new principal investigators. There is a wide disparity in the funding rates of new and prior investigators (22 percent and 35 percent, respectively).

Most of the NSF awards, 76 percent, go to academic institutions. The second largest receiver of NSF funds is non-profit and other institutions (15 percent), followed by industry with 7 percent and federal institutions with 2 percent. The top-ten funded institutions receive about 15 percent of NSF awards while over 25 percent goes to institutions which are not in the top-100 funded schools.

The average annualized award amount for research grants in 2001 was about 115,500 dollars. The median award was about 86,000 dollars. NSF has had an explicit strategy to increase the award size in order to attract high-quality proposals and enable the research proposed to be accomplished as planned. Longer award terms are seen as important to increase effectiveness of researchers and graduate students. The goal has been set at three years. In 2002, the actual result was 2.9 years. The long-term goal is 5 years at 250,000 dollars per year.

The NSF awards are smaller than those of the NIH. However, an important difference is that the NIH also pays for investigators´ salaries which is not true of the NSF.

The NSF is collecting data on the ratings of proposals. The data indicate that a number of potentially fundable proposals are declined each year, which can be viewed as unfunded opportunities. There is also a number of activities which have been established to secure the objectivity of the review process, such as conflict-of-interest training for program officers, reviews by a Director’s Review Board and the National Science Board for more expensive awards and possibilities for applicants to receive comments on their proposals and why they were declined and to challenge the decision of declination if they think that the process was unfair.

Cross-cutting Initiatives

There are a number of cross-Foundation programs that are designed to integrate NSF's strategic vision and to implement the NSF core strategies. They include programs to attract and retain more Americans into the science and engineering workforce. These include programs that focus on the diversification of that workforce. There are programs that focus on integrating research and education, cooperation between academia and industry, partnerships between local governments and industry, major research instrumentation and development with industry, nanotechnology, environmental research, science and technology centers, engineering research centers, science of learning centers, and small business and innovation research. The Office of Integrative Activities (OIA), an office of the Director, has management responsibility for some of these activities. A few of these programs will be presented in the following.

The ADVANCE program aims at increasing the participation of women in the scientific and engineering workforce through the increased representation and advancement of women in academic science and engineering careers. New and creative approaches to facilitating women's advancement to the highest ranks of academic leadership are sought. The program awards opportunities for both individuals and organizations and members of underrepresented minority groups and individuals with disabilities can also apply. Within the program, there are institutional transformation grants supporting eight universities addressing new organizational strategies to make access by women to leadership positions a priority (NSF 2003b).

The Faculty Early Career Development (CAREER) program is offering awards to new faculty at all eligible institutions. Awards are given to those individuals who are most likely to become the future academic leaders in this century. Applicants must submit creative career-development plans that effectively integrate research and education within the context of the mission of their institution (NSF 2003b).

The Integrative Graduate Education and Research Traineeship (IGERT) program has been in place since 1997 and covers approximately 100 award sites. The goal of the program is to educate U.S. Ph.D. scientists, engineers, and educators with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become the leaders and creative agents for change. New, innovative models for graduate education and training should be stimulated in multi-disciplinary environments. Greater diversity in student participation and preparation is another goal (NSF 2003b).

A large number of research opportunities for undergraduate students are funded through the Research Experience for Undergraduates (REU) program. An REU Site is composed of about ten undergraduates who work in the research programs of the host institution. Each student is linked to a specific research project, and works closely with the faculty and other researchers. In this case, undergraduate students must be citizens or permanent residents of the United States but the REU Site may be at either an American or foreign location (NSF 2003b).

There is also Research at Undergraduate Institutions (RUI) where the objectives are to support high-quality research by faculty members at predominantly undergraduate institutions, to strengthen the research environment in academic departments that are oriented primarily toward undergraduate instruction, and to promote the integration of research and education. Undergraduate students are brought into research-rich learning environments. The support of faculty both in teaching and in research is however the main objective of the program (NSF 2003b).

The NSF has a mandate to promote scientific progress nationwide. The Experimental Program to Stimulate Competitive Research (EPSCoR) is designed to fulfill this goal. The program is directed at those jurisdictions that have historically received lesser amounts of NSF R&D funding. Twenty-two states, the Commonwealth of

Puerto Rico and the U. S. Virgin Islands currently participate. Through this program, NSF establishes partnerships with leaders in the state government, higher education and industry to effect lasting improvements in a jurisdiction's research infrastructure and its national R&D competitiveness (NSF 2003b).

The Grant Opportunities for Academic Liaison with Industry (GOALI) initiative aims to synergize university-industry partnerships by making funds available to support a mix of university-industry linkages. The program supports faculty, postdoctoral fellows and students to conduct research and gain experience with production processes in an industrial setting, industrial scientists and engineers to bring industrial perspective and integrative skills to academe, and interdisciplinary university-industry teams to conduct long-term projects. This initiative targets high-risk/high-gain research with a focus on fundamental topics that would not have been undertaken by industry, new approaches to solving generic problems, development of innovative collaborative university-industry educational programs, and direct transfer of new knowledge between academe and industry.

4.5 The Performers

4.5.1 Government Laboratories

There is comparatively little information about R&D laboratories in the United States. This is surprising as there were more than a total of 16 000 public and private R&D laboratories in the United States, with more than 25 employees in 1998 (Crow & Bozeman 1998). There is reason to believe that this number is considerably lower today as many companies have dismantled their laboratories. American R&D laboratories are mainly engaged in applied research and development. Furthermore the system is dominated by small, private industrial laboratories with few connections to other institutions and organizations.

Government laboratories or federal laboratories have typically been established to serve a mission of a particular government agency. They include government-owned but contractor-operated (GOCO) labs and Federally Funded R&D Centers (FFRDCs). In 2002, government laboratories received about 25 of a total of 81 billion dollars of total federal investments in R&D. The biggest recipients are those under the DOD, followed by the DOE and the DHHS.

The number of government labs is somewhere between 500 and 800, depending on whether the FFRDCs, small agricultural labs and university-based federal research establishments are included. Most people and policymakers have the large DOD and DOE national labs in mind when referring to government R&D labs. Actually less than 10 percent of the federal labs accounted for more than 75 percent of scientific publications, patents, licenses and other research awards (Crow & Bozeman). According to the NSF, there are about 700 federal labs in the United States.

TABLE 2
Budget resources (preliminary) for federal lab R&D spending in relation to total obligations FY 2002. Intramural costs include the administration of intramural and extramural programs as well as the actual intramural R&D performance

	Total obligations (billion dollars)	Obligations – federal labs (billion dollars)		
		Intramural R&D	FFRDCs	Total
Department of Defense	34.2	7.90	0.88	**8.78**
Department of Energy	6.32	0.51	4.03	**4.54**
Department of Health and Human Services	23.8	4.13	0.38	**4.51**
National Aeronautics and Space Administration	7.26	1.81	1.20	**3.01**
Department of Agriculture	1.80	1.27	0	**1.27**
Other department and agencies	7.22	2.68	0.24	**2.89**
Total	**80.6**	**18.3**	**6.73**	**25.0**

Source: NSF 2002b

The FFRDCs have evolved from the research facilities which were established to meet the needs of World War II. The basic criteria for their operation were set in 1967. An FFRDC receives its major financial support (70 percent or more) from federal sources (usually from one agency) and performs R&D results that are directly monitored by the government. 36 FFRDC were registered under 8 departments and agencies in 2003 and they are organized in three categories: university and college-, non-profit organization-, or industry-administered. Most of them (26) are R&D laboratories and the others are focusing on systems engineering and integration, and study and analysis.

In 2002, it was estimated that FFRDCs performed federally funded R&D for about 7 billion dollars. R&D centers administered by universities and colleges accounted for the majority of this sum (63 percent). FFRDCs administered by universities and colleges accounted for the majority of basic and applied research (NSF 2002a). The NIH under the Department of Health and Human Services has one industry-administered FFRDC - the National Cancer Institute at Frederick, Maryland.

4.5.2 Universities and Colleges

There are 4 200 universities and colleges in the United States. Most of the research is carried out at the 263 doctoral/research universities and at the specialized institutions, such as medical schools and centres. Universities play an important role in American research. They perform about 13 percent of total R&D in the United States. Their role in the financing of R&D is much smaller, however. In 2002, they accounted for about 3.4 percent of the total investments in R&D.

Total expenditures by universities and colleges for R&D in 2002 were 37 billion dollars. The federal government was the largest source of funding with 23 billion dollars, which is 62 percent of total academic expenditure (NSF 2002a). Of total academic R&D expenditure approximately 75 percent is devoted to basic research. Universities and colleges perform close to half of all federally funded basic research.

Medical sciences account for the largest share by far of the total R&D expenditures by universities and colleges. In 2001, 10 billion dollars (30 percent of the total amount) was invested in medical sciences while bio- and biomedical engineering received a smaller amount of 211 million dollars. The largest institutions in terms of medical sciences expenditures are the San Francisco and Los Angeles campuses of the University of California with 487 million dollars and 462 million dollars in R&D spending respectively (NSF 2002a).

As has been pointed out before, it was only after World War II that the federal government became the most important source of academic research funding. The early funds were for defense but funding has been broadened into a number of other fields since then. Federal funding of academic R&D expenditures was about 55 percent in 1953, reached a peak of more than 70 percent in the late 1960s, and has stabilized around 60 percent since the mid 1980s. Universities and colleges themselves have increased their share of academic R&D investments to approximately 20 percent (AAAS 2003a). Industry accounts for 6 to 7 percent of academic R&D.

Looking at the federal support for R&D, there are nowadays three federal agencies which are responsible for most federal obligations for academic R&D. These are the NIH with 60 percent, the NSF with 15 percent and the DOD with 9 percent (figures are from 2000). This means that the main thrust of federal funding at the universities and colleges are in the life sciences with about 15 billion dollars in 2003, way ahead of all other scientific areas, such as physics, engineering, environmental sciences, mathematics and computer sciences, the social sciences, etc. Federal funding for these areas has been pretty static in thirty years.

Federal support for R&D in the United States is very concentrated to a few research universities. 82 percent of federal funding goes to 100 universities. About ten universities receive somewhat more than 20 percent, twenty universities get 34 percent and fifty get approximately 70 percent of total federal support for academic R&D. Most universities and colleges receive very little money from the federal government. Also, federal support to the states partly reflects population size, the location of competitive research universities and of federal institutions and laboratories, and the existence of large industries, mainly in the defense field. California, Maryland, Virginia, Texas and Massachusetts together receive half of all federal R&D resources, California only almost 20 percent.

Some universities are also hosting Federally Funded Research and Development Centers, FFRDCs. An FFRDC receives its major financial support (70 percent or more) from federal sources (usually from one agency) and performs R&D which is monitored by the government. The federal government, in particular the DOE and the NSF are the main sponsoring agencies. They invested almost 5.8 billion dollars in 17 FFRDCs in 2001.

Part of the federal funding for academic R&D goes to directed, noncompetitive appropriations, also called earmarks or pork-barrel projects. In 2003, Congress directed more than 2 billion dollars for pork-barrel projects, including R&D projects, up from 1,837 in 2002. This is an increase of 10 percent. The number of academic institutions receiving such earmarks also rose by 7 percent, from 668 to 716. Much of the increase was for homeland security and anti-terrorism projects, which grew from 126 to 223 million dollars. Congressional earmarks to academic institutions are not subject to peer review and are therefore questioned by many academicians and officials at government agencies. (For a discussion on earmarks cf. AAAS 2002).

The federal government also allots other resources which are important to higher education. These are the grants and loans to students, mainly for students from low-income families.

State and local governments provided about 7 percent of academic R&D funding in 2000 (NSF 2002a). Since the 1980s state and local funding of academic R&D has fluctuated between 7 and 8 percent. States, however, have a crucial role in the financing of public higher education. Also, state and local governments are very much engaged in economic development issues of their states or communities. In the 1980s, several states started to create science and technology offices. During the 1990s, states increasingly included S&T in their economic development plans and several states have developed strategic plans for science and technology.

There are few recent studies on the role of state funding in academic R&D. According to a study in 1998 by the Batelle Memorial Institute, which covered state funding in 1995, relatively few states – Texas, California, New York, Florida and Pennsylvania – reported more than 200 million dollars in R&D and R&D plant expenditures. These states, which were also the most populous at the time, accounted for almost 45 percent of total R&D expenditures by all states. However, smaller states may spend more on R&D relative to their population.

Funding to universities and colleges by industry in 2001 accounted for about seven percent of total academic R&D expenditures. The funds provided for academic R&D by the industrial sector grew faster than funding from any other sources during the past three decades but industry is still not a major contributor to academic research (NSF 2002a). However, these figures may be less important than the fact that the research relationships between academic institutions and industry have expanded in recent years. There are more than thousand university-industry R&D centers in the U.S. Several government agencies are involved in fostering cooperation between academia and industry. One is the NSF, which supports so called Industry-University Cooperative Research Centers (IUCRC).

Cooperation between universities and industry has always been strong in the United States, particularly in engineering research and at particular institutions, such as the Massachusetts Institute of Technology (MIT). Even closer ties with industry have been created through the technology licensing activities of academic institutions, which were enhanced through the Bayh-Dole Act in 1980 and consecutive legislation. These reforms created a uniform system in the regulation of patents, which made it possible for universities, among others, to keep the right to inventions which were being made with the support of federal grants. Before 1980, less than 250 patents had been awarded American universities and colleges. Since 1993, the universities have been granted 1600 to 2000 patents every year. About 200 universities and colleges are engaged in technology transfer projects. All in all, it is estimated that this legislation has contributed to 2200 new enterprises, 260 000 employment opportunities and 49 billion dollars to the U.S. economy.

At the same time, it should be stressed that the economic returns of patents and licensing activities of universities and colleges are relatively minor. Most technology transfer offices at universities barely break even and it normally takes about seven years before they do so. Approximately 70 percent of university discoveries need further R&D before patents can be filed. Many university researchers are simply not interested in commercializing their research results. The greatest benefits from the Bayh-Dole Act is probably that incentives have been created for the universities to work with technology transfer issues and that cooperation with industry is viewed as something natural. Some argue, however, that the commercialization of research and higher education in general has gone too far. This issue will be brought up later in this report.

Endowments and development (i.e. fund-raising) play an increasing role in the funding of higher education. Voluntary support accounted for about 8 percent of higher education expenditures during 2002 which is approximately 24 billion dollars. Individuals (alumni and non-alumni) accounted for 48 percent, evenly divided between those two groups. Foundations accounted for 26 and corporations for 18 percent. The top-five higher education institutions (University of Southern California, Harvard, Stanford, Cornell and University of Pennsylvania) raised 2.2 billion dollars in 2002. Voluntary support grew considerably in the late 1990s when the stock markets were high but declined slightly for the first time in 2002.

Private donors establish university endowments as permanent sources of funds for scholarships, professorships and other university programs. Funds are invested and earnings are made available to the university or college or reinvested for future use. From a European perspective, the endowments of American universities are huge. A 2002 survey by the National Association of College and University Business Officers showed total endowment holding of 222 billion dollars for the 654 participating higher education institutions. Public institutions accounted for 27 percent and private institutions for 73 percent. The top ten ranking institutions accounted for 30 percent of all reported assets. Among them is Harvard University with 17.2 billion dollars, Yale University with 10.5 billion dollars and University of Texas System with 8.6 billion dollars. For the second consecutive year, the average college and university endowment lost in value – down about 6 percent in

2002 compared to 2001. However, a recent survey showed that during the fiscal year 2001–02 the typical endowment posted a return of negative 5.4 percent but the average total return for the fiscal year 2002–03 was 2.9 percent (CHE 2003a).

According to the Almanac 2003–04, (CHE 2003b), comparing revenues of 4-year public and 4-year private institutions, private gifts, grants and contracts amounted to 5.6 percent and 12.9 percent of total revenues. Endowment income at 4-year colleges constituted 0.9 percent and investment return 31.5 percent.

Higher education institutions in the United States also play an economically important role as they employ almost 3 million people, which is approximately 2 percent of the American labor force. 15.3 million students are enrolled at U.S. universities and colleges (2-year colleges included).

There are a number of policy issues in American higher education and research. These concern the balance between R&D investments in different scientific areas, doctoral studies, the situation of post-docs, the academic career system and tenure, the recruitment to science and engineering in higher education, the dependence on foreigners in teaching and research, the recent visa restrictions and the tracking of foreign students at academic institutions. These issues will be dealt with later in this report.

4.5.3 Business and Industry

R&D performed by private industry in the U.S. reached 211 billion dollars in FY 2002. About 21 billion dollars or 10 percent of that amount was funded by the federal government and the rest was self-financed by the industry. Industry R&D has steadily grown in importance since the 1950s and its share of the total U.S. R&D enterprise has increased from 44 percent in 1953, to 55 percent in 1990, and to 72 percent in 2002. This long-term trend can be explained in part by changes in the federal support in the defense and space areas. Other factors include increased R&D spending in areas such as information technology and biotechnology, where industry plays a dominant role. According to the Industrial Research Institute (IRI), there is an emerging recognition that internal R&D has the potential to create new businesses, possibly more cost-effectively than acquisition.

During the last two years, there has been less growth in R&D investments by industry, with 2002 showing barely more spending than 2001 in current dollars and slightly less in constant dollars. The level of investment varies considerably between industrial sectors, with pharmaceuticals and biotechnology firms at the high end, and telecommunications, computer makers and chemical industries at the low end. In addition to the economic slowdown and the end of the dot.com boom, the stagnating rate of investment can be explained by advances in research methods, information handling as well as by outsourcing of R&D to foreign companies, predominantly in Asia.

Two additional general trends can be observed regarding company R&D during the last two decades: the increase of service-sector R&D and the increase of small company R&D. In the beginning of the 1980s, non-manufacturing industries accounted for less than five percent of the total industry R&D – by the year 2000, it had reached almost 40 percent. This pattern can partly be explained by industry's increasing reliance on outsourcing and contract R&D, where performed R&D is defined as a service. The largest non-manufacturing R&D sector was trade (25 billion dollars), followed by professional, scientific and technical services (18 billion dollars). The growth of small firm R&D has been most significant in the non-manufacturing sector.

In 2000, three sectors dominated manufacturing industrial R&D: computer and electronic products, transportation equipment, and chemicals. In these categories, R&D in the areas of motor vehicles amounted to 18 billion dollars, pharmaceuticals and medicines to 13 billion dollars and semiconductors and other electronic components to 13 billion dollars. This pattern is confirmed by the ranking of the major R&D performing firms in the U.S. General Motors and Ford Motor Company ranked first and second in 1998 when they spent 7.9 and 6.3 billion dollars on R&D respectively. They were followed by IBM, Hewlett-Packard, Motorola and Intel. There were six firms in the category medical substances and devices on the lower end of the top-20 list of R&D performing firms. Pfizer spent 2.3 billion dollars followed by Johnson & Johnson, Merck, Eli Lilly and others.

Company-funded R&D in pharmaceuticals and medicines grew rapidly in real terms from 4.7 to 10.4 billion dollars between 1985 and 1995, but then declined to 9.3 billion dollars by 1998.

5 Competitive Research Environments

To secure the future quality of research in Sweden is an issue of highest priority to the Swedish government. By supporting and nurturing creative research environments, Sweden has a better chance of staying competitive in science and technology. How funding agencies can help universities and colleges create internationally competitive research environments is of central importance. In the following, some experiences from the United States will be presented.

What then is a competitive research environment? Can funding agencies contribute to creating or strengthening such environments? Do university administrations have a role to play in this regard? These questions were put to a few people, who were interviewed for this report.

It should be pointed out that the respondents often answered these questions by arguing why American science is so competitive. There seemed to be general agreement on the importance of such factors as leadership – both in administration and in the specific departments or centers, interdisciplinarity, multiple funding sources, autonomy and freedom of universities and scientists, international recruitment of scientists, mobility of researchers, fierce competition between American universities and the way graduate studies are organized in the United States. Several respondents also pointed out that government agencies, such as the NIH and the NSF have a role to play in help creating and sustaining competitive research environments and that they have actually played an important role over the years.

Studies about creative research environments have been made by J. Rogers Hollingsworth, Professor of Sociology, History and Industrial Relations at University of Wisconsin – Madison. His research included a four-nation study of major breakthroughs in biomedical science during the 20th century. (Hollingsworth 2000). A major breakthrough is defined as “a finding or process which leads to a new way of thinking about a problem. This new way of thinking is extremely useful for numerous scientists in addressing problems in diverse fields of science. Historically, a major breakthrough in bio-medical science was a radical or new idea, the development of a new methodology, a new instrument or invention, or a new set of ideas” Hollingsworth relied on experts to make the judgment as to whether a particular discovery was a major one or not. He relied on discoveries associated with major prizes as a strategy for defining major discoveries. These were the Copley Medal by the Royal Society of London, the Nobel Prize in Physiology or Medicine, the Nobel Prize in chemistry and discoveries resulting in 10 nominations in any three years prior to 1946 for a Nobel Prize in Physiology or Medicine, or in Chemistry (there was no access to records of Nobel Prizes after that; only after 50 years are the Nobel Archives open, and then only to scholars).

It would take too far to go into detail as to the methodology used in this research. Suffice it to say that 285 major breakthroughs or major discoveries were identified in this population and 200 different organizations were studied. Hollingsworth identified both organizational concepts facilitating and hampering the making of major discoveries.

The facilitating concepts were:

- *Scientific diversity*: the variety of biological disciplines and medical specialties and subspecialties and the proportion of people in the biological sciences with research experience in different disciplines and/or paradigms.
- *Communication and Integration among the Scientific Community:* The bringing together of different cognitive perspectives through frequent and intense interaction in joint publications, existence of journal clubs and sharing of meals and leisure time activities.
- *Leadership Capacity to Understand Direction in which Scientific Research is Moving and to Integrate Scientific Diversity:* They include both task-oriented and socio-emotional activities, among them a strategic vision of integrating diverse areas and for providing focused research, the ability to secure funding for these activities, the ability to conduct recruitment of sufficiently diverse personnel so research groups are constantly aware of what are significant and "doable" problems and the ability to provide rigorous criticism in a nurturing environment.
- *Organizational Adaptiveness:* The ability of an organization not only to acquire new knowledge but also to process it among actors from diverse fields of science.
- *Organizational Flexibility:* The ability of an organization to shift rapidly from one or more main subjects of scientific research to different areas.

The hampering concepts were:

- *Differentiation:* Differentiation is concerned with sharp boundaries among areas, i.e. with formal, structural properties of unites, such as the number of bio-medical departments and other kinds of units, the delegation of recruitment exclusively to department or other subunit, and sole responsibility for extramural funding at departmental or other subunit level.
- *Hierarchical Authority:* Centralized budgetary controls, centralized decision-making about research programs and centralized decision-making about number of personnel.
- *Bureaucratic Coordination:* Standardization or rules/procedures.
- *Hyperdiversity:* The presence of diversity to such a deleterious degree that there cannot be effective communication among actors across divers fields of science.

One result of Hollingsworth studies is that major discoveries have tended to take place primarily in organizations which are quite small. According to Hollingsworth, large universities do not have the organizational characteristics which facilitate major breakthroughs time and time again. Today's research organizations have become increasingly fragmented and scientists occupy very narrow niches. Such organizations can be highly productive but major breakthroughs do not occur.

One example of a very creative research environment during a certain period of time which Hollingsworth is referring to is the Rockefeller University in New York City. The characteristics of Rockefeller were its small size, the lack of academic departments and disciplines and the focus on labs as an alternative structure, and the flexibility to adapt to a rapidly changing larger world of science. It had extraordinary leaders, able to recruit people who internalized scientific diversity, and, not the least, the capability to recruit young scientists willing to engage in high-risk research. And scientists at Rockefeller did not have to worry as much about external funding as their colleagues at other American universities.

Hollingsworth points out that there are many productive American universities in the sense that they have outstanding scientists who publish successfully but that they are engaged in incremental, narrow science, i.e. science which does not really lead to major breakthroughs.

Hollingsworth's studies seem to indicate that government agencies can help creating such enabling environments at universities or research institutes, where funding is ample, scientists are internalizing scientific diversity, where disciplines meet in a natural environment, where young people can be nurtured, where leadership is strong, and where researchers are engaged in high-risk research.

Many actors in the science policy world have for a long time been aware of the importance of these factors for the success of the scientific enterprise. This is true both of the United States and Europe. During the last few years many European countries have established so called centers of excellence. The European Union has established an instrument in the Sixth Framework Programme termed Networks of Excellence. Such networks are designed to strengthen scientific and technological excellence in Europe on a particular research topic by creating a critical mass of resources and by networking the expertise needed to provide European leadership in the area. The underlying motive is to be able to compete with the best research environments in the United States.

Some of the enabling factors mentioned earlier are more prevalent in the United States than in other countries. For example, international recruitment of scientists as well as mobility of researchers is higher in the U.S. than in most other countries. Both factors most certainly also contribute to the diversity that is supposed to be of central importance for innovative and creative environments, such as the ones you find in different clusters around the United States.

There is also a multiplicity of funding sources in the U.S. The federal government is the largest provider of research resources for the American universities but there are a number of other sources, such as foundations, States, local governments, donations from individuals and contributions from industry. It is common in the United States that scientists are funded from different sources during their careers.

When it comes to the conditions for young researchers the situation is somewhat mixed. There are several opportunities for young people to be funded through their doctoral training and as post-docs but to receive actual funding before the age of 35 for their own research projects is much harder. This is not only a problem for them but for science itself as scientific discoveries and breakthroughs are often made at a younger age. The grant review processes are often such that awards are given only to those scientists who have already done a lot of the research before applying for the grant, which makes it very difficult for young scientists to compete with established researchers.

The lack for tenure is sometimes said to discourage young people from choosing careers in science. On the other hand, some people would argue that tenure does not promote creativity. As there is no retirement age in the U.S., tenured academic staff can stay on way beyond the traditional European retirement age, i.e. 60–65 years. But even before that age, creativity may be less than in individuals aged 25 to 40. As is pointed to elsewhere in this report, young people are less likely to get tenured positions today than what used to be the case. But this varies a lot between scientific disciplines.

According to most scientists, peer review is the preferred and sometimes only way of securing high quality in research. The peer review process, however, with all its advantages in sustaining high quality, is less likely to promote high-risk research and interdisciplinarity. New, original ideas which cross scientific borders are less likely to win approval than those which follow traditional disciplinary trajectories.

Some funding agencies and organizations in the U.S. use other means to secure innovative ideas in R&D. The Defense Advanced Research Projects Agency (DARPA), the R&D funding arm of the DOD, in its funding of R&D does use the traditional peer review process where applications for grants are evaluated by peers. The founding principles of DARPA when it was established in 1958 continue to be adhered to. It is a rather small, flexible and flat organization. It has substantial autonomy and freedom from bureaucratic impediments. It draws its technical staff from world-class scientists and engineers with representation from all performers of R&D for a limited period of time in order to assure fresh thinking and perspectives. The projects last for 3–5 years with strong focus on end-goals. And the philosophy guiding the funding is a complete acceptance of failure if the payoff of success was high enough.

Approximately 240 people work at DARPA. Its operating budget is about 2 billion dollars. A typical project receives between 10 and 40 million dollars over four years, but variations range from projects under 1 million dollars to projects in the hundreds of million dollars. But the management is the same. The emphasis is on small teams of high quality people (DARPA 2004).

Another example of a different way of funding is the Howard Hughes Medical Institute (HHMI). The Institute is a nonprofit medical research organization that employs more than 300 leading biomedical scientists. Through its grants program and other activities, HHMI is also supporting science education at all levels. The institute has laboratories across the United States and grants programs throughout the world. HHMI's endowment in early 2002 was approximately 11 billion dollars.

The HHMI does not award grants through peer review but supports individual scientists at universities and academic health centers nationwide. It solicits nominations from these institutions through national competitions. The institute looks for investigators who are creative, risk-taking, and productive. The selected investigators continue to work at their institutions, generally in teams of 10–25 students, postdoctoral associates and technicians. A lot of freedom is given to the investigators; they can change the direction of their research and follow their ideas to fruition even if that takes a very long time (HHMI 2003).

The NSF has a special program for small-scale, exploratory, and high-risk research (SGER) in the fields of science, engineering and education. Grants can be given for preliminary work on untested and novels ideas, ventures into emerging research ideas, the application of new expertise or new approaches to established research topics, etc. Proposals are subject to internal NSF merit review only. The maximum SGER award amount does not exceed 100,000 dollars and the project's duration is normally one year but may be extended to two years. Award extensions of six months are allowed.

In the "roadmap" for medical research, which was presented as a core document by the NIH Director in the fall of 2003, it is stated that "truly innovative and high-risk research will be promoted".

High-risk research and scientific breakthroughs may also be fostered by longer-term and larger grants so that as little time as possible is spent working out grant applications. The NSF has an explicit strategy to increase the award size in order to attract high-quality proposals and enable the research proposed to be accomplished as planned. The goal has been set at three years. In 2002, the actual result was 2.9 years. The long-term goal is 5 years at 250,000 dollars per year.

In an international comparative perspective, the present grants of both the NSF and the NIH are pretty large. The average annual grant of the NIH in 2002 was about 385,000 dollars, which is much larger than the average annual grant of the Medical Research Council in Sweden. For the NSF it was 115,500 dollars in 2001. In contrast to the NSF, the NIH pays for the salaries of the principal investigator.

Interdisciplinarity, both in terms of communication between scientists from different fields and in terms of individual scientists integrating research experience in different disciplines, is an important characteristic of successful research environments. Two of the Nobel laureates in 2003 have a background in several scientific disciplines. Interdisciplinarity between scientists has for a long time been promoted by government agencies both in the United States and elsewhere.

The NSF, for example, has a number of crosscutting programs which include interdisciplinary programs, programs that multiple directorates at the NSF support, and programs which are jointly supported by the NSF and other Federal agencies. Among the latter can be found the partnership with the EPA for Environmental Research, the Global Change Research Program and Nanotechnology (where the NSF is the lead agency in both programs), the High Performance Computing and Communications and the NSF Scholar-in-Residence at the NIH. The NSF currently supports more than twenty major crosscutting initiatives. Some of them are described in the section on the NSF in this report.

In 2003, five new interdisciplinary funding opportunities were listed on the NSF home page: Human and social dynamics, Presidential awards for excellence in science, mathematics and engineering, Sensors and sensor networks, Information technology research for national priorities and Quantitative systems biotechnology. The Directorate for Mathematical & Physical Sciences has established an Office of Multidisciplinary Activities (OMA) which is charged with facilitating and supporting opportunities that cross traditional disciplinary boundaries.

The Science and Technology Centers Program (STC) was established in 1987 to fund important basic research and education activities and to encourage technology transfer and innovative approaches to interdisciplinary activities. STCs are created in areas of research which require a Center mode of support to achieve its goals. The research is carried out in partnerships among academic institutions, national laboratories, industrial organizations and/or other public/private entities.

Centers undertake long-term scientific and technological research and education activities in order to improve ways to educate students and to ensure the timely transition of research and education advances made into benefits for society. An initial commitment of five years is made through a cooperative agreement between the partners. Support from the NSF can last for up to ten years. The limit on the number of proposals that a single institution may submit is five but the lead institutions may be involved as a partner in proposals made by other institutions. Partnerships may include multi-institutional collaborations or cooperation with other higher education institutions, national laboratories, research museums, private sector research laboratories, state and local government laboratories and international collaborations.

So far four national competitions have taken place to establish such centers. As a result of the first two 25 Science and Technology Centers were established which no longer receives support from the NSF. Currently there are 11 centers running.

6 Issues and Priorities in American Science Policy

When discussing issues and priorities in American science policy it is necessary to look at the developments over a longer period of time. Issues and priorities develop over time, and they cannot be understood without a historic perspective.

The priorities in American science policies can be seen from the funding patterns shown in the previous sections. The issues partly depend on these priorities but are also dependent on other factors. Somewhat simplified it could be argued that there are three main driving forces underlying the priorities of R&D funding in the United States: National Defense and Security, the wish to promote health and eradicate illnesses, and economic competitiveness. The first two are reflected in the substantial funding of R&D. Economic competitiveness is seldom an explicit criterion in R&D funding but is a strong underlying motive in the mission-oriented focus of American science policy,.

These driving forces have been there for a long time and are likely to continue to influence priorities in R&D funding. Another strong motivation for investments in science is national pride. When the United States feels challenged by another nation it is likely that resources will increase to meet that challenge. Space research and development is a case in point. The explorations in space also have a military connotation, however. Others, such as the need to solve problems in the areas of energy and environment, transportation, agriculture, education are also important motives for R&D investments but cannot be compared to the other driving forces.

The issues which will be presented in the following include national security and the openness of the research system, the balance between resources for different scientific areas, workforce development issues, stem cell research and some specific issues in higher education and academic R&D.

6.1 National Security and the Openness of the Science System

Since September 11, 2001, science has again come into focus in the United States. Increased investments in science and technology are aimed at contributing to the fight against terrorism and making the nation safe. Defense spending is up even if that trend already started before September 11, with the decision by the Bush Administration to develop an anti-ballistic defense system. But new resources are also devoted to homeland security, not the least in the biological and medical sciences. The current situation is somewhat similar to the increased funding of R&D during the Cold War or during the Reagan Administration, when the national security was perceived as threatened. Again, the driving forces to invest in science and technology are not science for science sake but developments outside the science system.

The American science system has been affected by the events of September 11 and some events afterwards in several ways. In addition to the increased funding for national homeland security, the openness of the science system has been affected. New rules and processes have been established for visas, publication of scientific articles has been affected, and a new system, SEVIS, for tracking foreign students in the United States has been introduced. Because of these changes, access by foreign students and scholars to U.S. institutions and to scientific conferences has become more difficult. Return visas for student and researchers have sometimes been denied. According to the Association of American Universities (AAU), federal agencies are using grants and contracts to insert points of control or government clearance prior to publication of research data. New terms have been developed by federal agencies for certain categories of information. "Sensitive but unclassified, "controlled but unclassified", or "sensitive homeland security information" are examples, and there are no legal definition of these terms. The world's leading journal editors and scientist-authors have called for renewed vigilance and personal responsibility among their ranks whenever potentially "dangerous" research is presented for publication. This was felt necessary to avoid government review of forthcoming journal articles.

What has upset the American scientific community more than maybe anything else is the difficulties for scientists and students to enter the United States. Since 9/11 more checks have been introduced in the visa process. Checks are made automatically using a data base but in addition there are several other screening processes, such as whether the applicant is going to engage in an activity involving any of the sensitive technologies on the Technology Alert List. This has led to long delays because of the difficulty for American embassies abroad and their consular sections to make informed decisions. Consular officers can be held responsible for any mistake made so it is often felt necessary to check with relevant authorities in the United States before giving clearance to an applicant.

It has been most difficult for applicants from non-visa-waiver countries. But even for visa-waiver countries, problems have arisen, particularly for scientists who visit U.S. laboratories on a continuous basis. It may take four to five months to get clearance and also, when a person has been cleared, the embassy abroad does not always get this information. There are also examples of embassies keeping the passports of people while applications are processed which they should not do.

Students and scientists are being favored in the sense that embassies have been instructed to give priority to their applications. However, students and scientists have to be interviewed which adds to the time-consuming process.

According to the State Department, 90 percent of visa applications today are being processed within 30 days and many long-standing visa cases are being resolved. Even if most cases are eventually clearing, this has caused considerable harm to the American educational and scientific enterprise. How many students and scientists have been caught up in the process is hard to know but according to reliable sources the total number of visa applications is down from 10 to 7 million since the new rules were introduced (students and scientists included). According to the Council of Graduate Schools there has been a 20 percent drop of foreign graduate students attending American universities and colleges. During the 2003 academic year, which ended September 3, 214,331 student visas were issued by the State Department, down from 234,322 in 2002 and 293,357 in 2001 (New York Times, 2003).

The number of foreign students who enrolled at American colleges was 586,323 in the 2002–03 academic year. This was an increase of less than one percent from the previous year, following a five-year average annual growth rate of 5 percent (Institute of International Education, 2003). The slight increase is due to significant increases from countries such as China, India and South Korea and masks a serious decline in the number of students from many Muslim countries, such as Kuwait and Saudi Arabia where the numbers dropped by 25 percent last year. The tuition increases also seem to play a role in the decrease of foreign students at American universities and colleges.

The National Academy of Sciences has set up an International Visitors Office which is providing advice for visa applicants and where information is collected about the different problems of individual applicants. The office is also in close contact with the State Department and other relevant authorities in the U.S.

The National Academies have also been engaged in a number of other issues pertaining to national security and the openness of the research system. Early October 2003, a report "Biotechnology Research in an Age of Terrorism: Confronting the "Dual Use" Dilemma" was published. The report addresses the issue of experiments in biotechnology that could help terrorists or hostile nations make biological weapons. The academy panel behind the report proposes that research applications in seven areas of biology should be reviewed by both a scientist's local biosafety committee and by the national Recombinant DNA Advisory Committee, known as the R.A.C. The panel also proposes an independent National Science Advisory Board for Biodefense, made up of top scientists and national-security experts. The board would provide expert scientific advice on the relative risks and benefits of new technologies and alerting the government to new opportunities for the development of vaccines and antibiotics. As many other countries are pursuing advanced biotechnology research, the report proposes a coordinated international system to regulate the possession of dangerous pathogens and toxins.

Academic institutions are not only affected negatively by the new rules and regulations but are also benefiting from the increased investments in bioterrorism research. For example, the NIH announced in September 2003 that it is awarding large multi-year grants totaling 350 million dollars to seven universities nationwide for research to protect against a terrorist attack involving biological weapons and for research on infectious diseases. Each institution will receive an average grant of 9 million dollars a year for five years, which is significantly larger than the usual NIH awards. The NIH received a total of 1.7 billion dollars in 2003 for bioterrorism-related research.

6.2 The Balance between Resources for Different Scientific Areas

The priority given to biomedical research in recent years with the doubling of the NIH budget has lead to a discussion about the balance between the resources for biomedical research and other sciences, such as chemistry, physics, computer sciences, etc. This debate started during the Clinton Administration when Dr. Neil Lane was the science advisor to the President. The argument for increases in other scientific areas than biomedicine is that advances in the biomedical sciences cannot be fully utilized unless sufficient resources, i.e. increasing funds, are also made in other areas of the natural sciences and engineering.

This issue has also been discussed in Congress. In December 2002, a National Science Foundation authorization bill calling for a doubling of the NSF budget between FY 2002 and 2007 was signed into law. That does not mean, however, that the NSF will receive this increase. As of beginning October 2003, the proposed appropriations by the House and Senate as well of the Administration would fall nearly 1 billion dollars short of the authorized funding level. The authorized funding amounts to 6.6 billion dollars (AAAS 2003a).

It should be pointed out that it is not only the NSF that funds other sciences. Physics is also funded by the DOE, the National Institute of Standards and Technology (NIST), the DOD and NASA; chemistry also by the NIH, DOE, NIST, DOD, EPA. This is also true of most other sciences, such as astronomy, earth sciences, atmospheric sciences and climate change programs, ocean sciences, biological and ecological sciences and the behavioral and social sciences, mathematical sciences, computer research, etc.

One way to release resources for the NSF would be to do away with the earmarks. Earmarks for university projects totaled 2 billion dollars in 2003. Almost 60 percent of the funds went for research projects in the natural or social sciences and 13 percent for buildings or equipment (CHE 2003c). The Administration has taken aim at research earmarks as “the use of earmarks signals to potential investigators that there is an alternative to creating quality research proposals for merit-based consideration, including the use of political influence or by appealing to parochial interest”. But it seems unlikely that research earmarks will disappear, as they are a means for members of Congress to support requests from their constituencies.

In his remarks at the 27th Annual AAAS Colloquium on Science and Technology Policy in April 2002, the director of the OSTP, Dr. John H. Marburger, addressed the issue of balance in science funding. Dr. Marburger stated that “balance” is a misleading term. He argued that “perhaps the recent large increases for the NIH have simply enabled health researchers to exploit the same fraction of opportunities for discovery in their field as physical scientists can in theirs under existing budgets”. Support should be given to those areas which hold the greatest potential for discovery, such as biotechnology and nanotechnology. The word balance should rather be used to denote a balance among the different parts of the machinery of science. What is meant by that, among other things, is a “balance” between resources for research projects and investments in the technical infrastructure of science, i.e. instrumentation and computational and information technologies.

Instrumentation is not currently identified as a priority in the federal R&D budget and there is, according to Dr. Marburger, a need to focus more on and assess the quality of the infrastructure. In the "balance" issue is also included a balance between disciplinary and interdisciplinary research, between basic disciplines, etc.

6.3 Work Force Development Issues

In the publication Science and Engineering Indicators 2002, the NSF writes: "The sine qua non of a modern economy is a well-educated, versatile workforce able to conduct R&D and to convert its results into innovative products, processes and services". The natural sciences and engineering deserves particular attention as they are of the greatest importance for the total research enterprise and for the development of industrial innovations. The stress on the individual rather than groups or collectivities is strong in the United States. It is generally agreed that well-educated and talented people play a decisive role for the successful development of society and the economy.

The United States has always been a country of immigration. The United States has continued to attract people from all over the world even after the large cohorts of immigrants came to the United States in the late nineteenth and early twentieth centuries. There is a long tradition in the U.S. to depend on immigration and foreigners to meet the need for qualified manpower in the sciences and engineering. It started in the 1930s when many scientists fled from Nazi-Germany to the United States.

Foreign students account for about one third of the total number of doctoral degrees in the natural sciences and engineering in the United States. Many foreigners stay in the United States after completion of their degrees to work in industry or as post-docs at American universities. The events of September 11, 2001 have already affected and will continue to influence the possibilities to recruit students and faculty to the U.S. Universities and colleges are worried also because foreign students account for a substantial income for the institutions of higher education in the United States. It is estimated that foreign students bring in 13 billion dollars to the United States in expenditures for tuition and related costs. As has been pointed out before, one issue is how many foreigners will want to apply to academic institutions in United States due to the stricter visa rules and because of dramatically increased tuition fees. In the last year, tuition has increased by an average of 9.6 percent at 4-year colleges and 5.8 percent at private universities, way more than the consumer price index. Competition from other countries in attracting students has also increased, for example from the United Kingdom, Australia and New Zealand.

The composition of the American population and the American workforce are changing. The minority populations; African-Americans, Hispanics, Asians and Native Americans, will increase. They will be entering college and subsequently the labor force to a higher degree in the next decade. Therefore, it has been important for the United States to entice these groups to start a college education. A number of programs have been launched to help minority groups and women enter higher education, particularly in the sciences and engineering, to make them graduate from college, to recruit to graduate education, and to enhance their careers in science and engineering at universities and colleges.

The concern is particularly about the supply of manpower to science and engineering. Minority groups represent 24 percent of the American population but only 7 percent of the total labor force in science and engineering. Today African-Americans and Hispanics have a lower educational background compared to Whites and Asians. To a certain degree, minorities and women choose different careers than white males. Women, for example, are less likely to work in industry than in higher education. African-Americans choose social and computer sciences and mathematics rather than engineering. Among Asians there are comparatively many engineers and computer scientists. How these patterns will affect the labor market in the future is hard to say but there may be imbalances which did not exist before.

Also, recruitment of minorities to higher education has been threatened by anti-affirmative action. At some universities minority students have been given extra credit in the admission process. In the last year a debate has been going on whether this preferential treatment is in line with the American constitution. In June 2003, the Supreme Court, when acting on two cases involving the University of Michigan at Ann Arbor, upheld the use of affirmative action in college admissions, but struck down the mechanics of Michigan's undergraduate admissions policy. In this case the university had been using a point system, awarding black, Hispanic and American Indian applicants a 20-point bonus on its 150-point scale. In the other case, which involved the law school at the university, the admissions policy gave more individual consideration to applicants, but considered race and ethnicity in an attempt to enroll a critical mass of underrepresented minority students on the campus. The Court described this as "flexible enough to ensure that each applicant is evaluated as an individual and not in a way that makes race or ethnicity the defining feature of the application". Many colleges and universities have now changed their admissions policies to reflect the rulings of the Court.

There are other worrying signs. American school children have lesser knowledge in mathematics and in the natural sciences than many of their peers abroad. According to the Third International Math and Science Study, American fourth graders did relatively well in both subjects but by the time they reached their senior year in high school, U.S. students ranked very low compared to students in other countries (NSF 2003a). According to estimates by the Department of Labor, 60 percent of new jobs being created today will require technological literacy while only 22 percent of young people entering the labor market now actually possess those skills. Related to this is the need to recruit 2.2 million new teachers to the American school system during this decade. The need for new teachers in mathematics and natural sciences in secondary school and in high school amounts to 240 000.

At the same time, many people in the U.S. expect tougher competition from other countries when it comes to the number of individuals enrolled in the sciences and engineering in higher education. Already today, Asia is educating six times as many engineers as the United States. Twice as many doctorates are awarded every year in Europe as in the U.S.

The National Science Board of the NSF has recently released a draft report for comment of National Workforce Policies for Science and Engineering. In the report a number of recommendations are made. Substantial new support should be granted to undergraduate education in S&E; scholarships, quality-enhancing measures of S&E programs, support to community colleges to increase the success of students transferring to 4-year colleges and universities and funding for programs that benefit women and minorities. Federal support should also be given to research and graduate education to promote a wider range of educational options. Furthermore, the report addresses the pre-college teaching workforce for mathematics, science and technology, proposing increased efforts to attract and retain well-qualified teachers through compensation comparable to other trained S&E professionals and integrating faculty and curricula of schools of science and engineering with schools of education. In view of the recent visa regulations and other policies concerning the mobility of scientists and engineers, increased support is recommended for U.S. students and faculty to participate in international education and research and to maintain the ability of the U.S. to attract international competitive researchers, faculty and students. Related to this is the recommendation to the federal government to substantially increase its investment in research to understand the dynamics of the international S&E workforce. A data base of information on the status of national S&E skill needs and strategies for attracting high-ability individuals to S&E careers is also proposed.

However, all these concerns are maybe less worrisome now or in the next few years than in the future. It is very difficult to make predictions about the future labor market demand. In the NSF Science and Engineering Indicators 2002, it is estimated that there will be an increase of the S&E workforce in the next few years provided that there are no major decreases in the number of degrees and/or no major increases in the rate of retirements. The number of people who take degrees in these areas is substantially higher than those who are getting close to retirement. But in the next twenty years the number of retirees will increase dramatically, unless many more choose to stay in the workforce. It should be noted, however that the Indicators report was made before September 11, 2001.

There are also those who question the need for more scientists and engineers. In an article in the Public Interest, the author, Michael S. Teitelbaum, argues there are few - if any – signs that there is such a need. First of all earlier predictions about shortages, starting with a report by the NSF in the 1980s and followed by many others, have been wrong. Predictions of future shortfalls are virtually impossible to make. “Few, if any, of the market indicators signaling shortages exist. Strong upward pressure on real wages and low unemployment rates relative to other education-intensive professions are two such indicators conspicuously absent from the contemporary marketplace”. Teitelbaum refers to a RAND study in 2003, which arrives at the conclusion that there is no evidence of shortages in most areas. Most statistics underlying the arguments in previous studies are from 1999 and 2000. Recent statistics from the first and second quarter from the Bureau of Labor Statistics indicates unusually high unemployment rates in science and engineering, from 5.4 to 7.5 percent. The average for the whole U.S. work-force was about 6 percent.

However, there are no statistics or data in the article on the demographic development in the United States and the changing pattern of the student population and work force. What is particularly interesting with the article, though, is the argument that solutions to overcome “shortages” are misdirected. They focus only on the supply side; remedial measures in elementary and secondary education, informational activities for students about employment opportunities and role models for women and minorities, etc. The focus should rather be on the science and engineering careers themselves, according to Teitelbaum. It is doubtful whether they are attractive enough relative to other career opportunities. The length of the studies in science and engineering, the often huge financial debts incurred by the long education and training, the comparatively low salaries are factors which should be addressed. The extreme case is the biosciences where half of all PhDs are to be found. It normally takes seven to eight years after an undergraduate education to get a doctorate and then time is often spent as a post-doc during another two to five years. Another conclusion in the article is that more attention should be given to innovations in higher education and continuing education. According to Teitelbaum, much could probably be achieved in solving these problems if you focus on the existing workforce, using the talent which is already there.

6.4 Research on Stem Cells

The debate in the United States about research on stem cells has been going on since the cloning of the sheep Dolly in 1997. It has become particularly intense since President Bush announced his stem cell research policy in a nationally televised address on August 9, 2001. The policy allows federally funded stem cell researchers to work only on those stem cell lines which were in existence before that date, in the U.S. or elsewhere in the world. All in all, it was appreciated that there were 78 existing stem cell lines at the time, and – incidentally – more than twenty of those were to be found in Sweden. There is no legislation in the U.S. which prohibits stem cell research using money from private sources.

The debate involves a number of mostly bioethical issues and is similar to the debates in many other countries; human reproductive cloning, the use of left over embryos from in vitro fertilization, the production of embryos for research purposes, somatic cell nuclear transfer, the use and promise of adult stem cells versus embryonic stem cells, the viability of the approved stem cell lines, and – related to this – the potential danger of those lines because of the use of mouse cells as “feeder cells” to keep the stem cells from differentiating into more specialized tissue.

Congress has debated these issues several times. There is nearly unanimous opposition in Congress that human reproductive cloning should be banned. But when it comes to other issues, such as somatic cell nuclear transfer, attitudes vary, and therefore no decision on human reproductive cloning has yet been taken. Hearings with proponents and opponents of stem cell research have taken place on several occasions and legislation has been introduced by members of Congress. The House has already passed a bill, known as the Weldon-Stupak bill, which criminalizes nuclear cell transfer in humans, both for reproductive and research objectives. In the Senate, a similar bill was introduced, the Brownback-Landrieu bill. However, the view in the Senate is generally more pro stem cell research and this bill has not been passed. Another bill has been introduced, the Specter-Feinstein bill, which would prohibit reproductive cloning but allow nuclear transplantation research to go forward. It would impose criminal penalties on anyone who attempts to implant the product of nuclear transplantation into a woman's uterus.

It should also be noted that the attitudes towards stem cell research in the Senate do not follow party lines (for example Senator Specter is a republican). There are also republican members of the House of Representatives who are concerned that the President's policy will prevent research discoveries to move forward. Eleven moderate House republicans sent a letter to the President in May, 2003 urging the President to review his stem cell policy to determine "if enough lines have been made available for this fast-growing research community and whether changes should be made to allow for the creation of new sterile, uncontaminated stem cell lines".

So far only eleven of the approved stem cell lines have been made available to the scientific community. Also, it is unclear how viable they are and whether they are virus-free as mouse cells have been used as feeders. In March 2003, researchers at Johns Hopkins University announced the discovery of a new way of growing stem cell lines. In this case human bone marrow cells are used instead of mouse cells.

Science organizations, patient groups and the biotechnology industry are proponents of a ban on reproductive cloning but want to allow nuclear transplantation research. They want to benefit from the research opportunities in this area and they fear that the United States will be lagging behind other countries if such research is not allowed. Some people have been worried about a brain drain of stem cell scientists from the U.S. Also, researchers join in with patient groups and industry in the search for cures for serious illnesses that human embryonic stem cell research could bring forward.

The views and legislation in the states vary from one state to another. Utah and Louisiana have banned research on stem cells altogether. Others, such as California, have introduced or are considering legislation to allow stem cell research from human embryos. Last year California adopted its own law on funding and expanding embryonic stem cell research. As of January 2003, the California Law requires institutional review board approval for any research involving derivation and use of human embryonic stem cells, human embryonic germ cells and human adult stem cells from any source, including somatic cell nuclear transplantation. In October 2003, Governor Davis signed two additional measures. They cover ethical and legal guidelines for stem cell research, clear up rules for the use of donated eggs and embryos, and create an anonymous registry of material available for such research.

Several universities in California are setting up programs or centers in stem cell research with the use of state or private money. University of California at San Francisco is establishing a Developmental and Stem Cell Biology Program and Stanford University has revealed plans for an Institute for Cancer/Stem Cell Biology and Medicine (Nature, 2003). Several Foundations are also involved in financing stem cell research, such as the The Juvenile Diabetes Research Foundation in New York.

These efforts by individual states and private actors can be expected to continue as long as there is no relaxation of the rules for federally funded research. Pressure on the Congress to change the rules will continue, particularly if and when successful treatments of patients can be proven. There is also a need to pass legislation in Congress to ban human reproductive cloning. In view of the close links between human reproductive cloning and stem cell research, the difficult bioethical and legal issues involved and the slow development in Congress so far, it is questionable whether legislation on human reproductive cloning will be passed. The wars in and reconstruction of Afghanistan and Iraq are also factors which inhibit or slow down Congress´ attention to and dealing with other pressing issues.

6.5 Higher Education Issues

The above-mentioned issues all affect the research and administration of American universities and colleges. U.S. higher education institutions have had to deal with the openness of higher education and research a number of ways, among them the new system for tracking foreign students, SEVIS. The priorities of the federal government and Congress, for example the heavy focus on biomedical research and homeland security R&D, clearly influence university research as so much of the federal funding, particularly for basic research, goes to the universities. In the area of human resources and the workforce, colleges and universities play the most important role as they are the institutions that train the workforce for their own teaching and research needs and also for the rest of the labor market. The policies on stem cell research affect the opportunities of universities to engage in such research.

But there are also other issues which are high on the agenda for colleges and universities. Three such issues are presented in the following; resources for higher education, commercialization of higher education and the career system, including PhD training, post-docs and tenure.

6.5.1 Resources for Higher Education

Higher education in the United States expanded rapidly in the second half of the twentieth century. The overall enrollment increased from seven million in 1967 to 15 million in 1992 where it remained through 1997. Enrollment is expected to expand in the first decade of the 21st century as the college-age cohort will increase by 13 percent.

Resources for higher education have increased as a consequence. States are providing resources for public colleges and universities for undergraduate education and the federal government provides money for the bulk of the research, both at public and private institutions. Tuition is also a source in the financing of undergraduate education, particularly at private institutions. Private money also play an important role in funding research and facilities.

Academic R&D spending rose by 240 percent between 1972 and 2000, from 8.3 billion dollars to 28.1 billion dollars. Federal funding grew by 180 percent and funding from other sources by almost 350 percent (NSF 2003c). The federal government, however, still provides the bulk of the funds for R&D at academic institutions, about 62 percent in 2002. This is a decrease from 1972 when it was 68 percent.

What is at stake now is the funds for undergraduate education and the sharp increases in tuition both at public and private colleges and universities, particularly in the last year.

Most states have huge budget deficits at the moment. This is partly due to the sluggish economic development during the last couple of years and the decreasing tax revenues. California, the biggest state, has a deficit of 38 billion dollars. Many states must, according to their constitution, have a balanced budget. Therefore, cut-downs in the expenses for higher education have been introduced in many states.

Tuition has increased by 38 percent between 1992/93 and 2002/03. Only in the last year, the increase has been 9.6 percent at 4-year public and 5.8 percent at 4-year private colleges. According to a recent report, initiated by some republican members of Congress, universities and colleges raise tuition both in good and bad times. Representatives for higher education institutions have argued that most public universities and colleges do not even decide on their own tuition as the state governments take those decisions.

According to the Association of American Universities (AAU) about 80 percent of full-time students at 4-year colleges pay less than 8,000 dollars per year in tuition. But if loans and fellowships are included, 58 percent of students pay less than 3,000 dollars per year. But there are big differences between public and private institutions.

The question which is high on the agenda is how universities and colleges should be able to cater for the needs of a growing number of high school graduates and particularly for low-income students. In California, for example, law-makers have warned public institutions that they will not be able to pay for an increase in the number of college students in 2004/05. Appropriations have been cut by 10 percent which means 322 million dollars for the University of California and 188 million dollars for California State University and 4 percent for the community colleges. This comes at a time when undergraduate enrollment is projected to increase by 16.5 percent by 2011. Officials at the University of California have announced that they will not be able to make room for the top one-eighth of the state's high school graduates which has been a commitment since 1960. Also, transfer requests from students at community colleges will not be considered. Officials at California State

University have decided to close out about 30,000 prospective students. Community colleges have reduced 8,200 courses which is estimated to have led to a loss of 90,000 students (CHE 2003d).

Another response, and a very different one, comes from the public University of North Carolina at Chapel Hill. In order to meet the needs of low-income students, the university has decided to cover the full education costs of low-income students (from families with a yearly income of about 28,000 dollars for a family of four), including tuition and room and board. Under this program, students will be required to work ten to twelve hours a week to help cover the costs. Annual tuition at UNC-Chapel Hill for in-state students is 4,072 dollars, and total annual cost is about 13,000 dollars. About 300 students are expected to benefit from the program and the total costs will be 1.38 million dollars (Washington Post 2003).

According to the article, it will be difficult for other universities to follow suit. The state of North Carolina has more generous state subsidies to higher education than many other states. The program does not cover lower-middle-income families who are also feeling the squeeze by tuition costs. The debate over tuition is likely to continue.

6.5.2 Commercialization of Higher Education

There is widespread agreement in the United States that cooperation between academia and industry is generally beneficial. There are, however, some concerns about these ties and also about the increasing commercialization of higher education in general in the U.S. The technology licensing activities of universities which have been made possible by the Bayh-Dole Act have also contributed to this concern as well as the genomics revolution, decisions supporting patent protection for bioengineered molecules, and other laws strengthening intellectual property rights worldwide (Ashby Sharpe 2002). Closer ties to industry have also been established through consulting by university scientists, clinical trials which are paid for by pharmaceutical companies in most cases and stockholdings in companies by scientists for which they are carrying out research as university professors.

Derek Bok, the former President of Harvard University, warns in his new book “Universities in the Market Place: The Commercialization of Higher Education” that universities may be jeopardizing their fundamental mission in their eagerness to make money by agreeing to more and more compromises with basic academic values. What is at stake here according to Dr. Bok, is conflict of interest and conflict of commitment, lack of openness through the suppression of research results or delays in publication, the credibility of research institutions, and possibly the direction of research, i.e. more applied research at the expense of basic research.

Is there a need to worry? The answer depends on what indicators are used. Looking at the statistics, it is clear that the relationship between basic and applied research has been pretty stable since the 1970s. It does not seem as if the closer ties to industry have led to a diminishing share of basic research. Funding from industry of university research has increased in relative terms, but is still under ten percent. Within the life sciences, approximately 25 percent of the scientists get some funding from industry and this share has been relatively constant since 1985. Also, less than half of them get more than 25 percent of their total research support from industry. The number of researchers within the life sciences who consults for industry has not increased very much. Few scientists consult more than the recommended amount, i.e. one day a week.

Other studies point in another direction, however. Conflicts of interests are there and they arise when financial or other personal regards influence or seem to influence the professional judgment of researchers or in the reporting of research results. Such conflicts have been particularly discussed in clinical trials. 60,000 tests are carried out in the United States each year, involving 14 million people, and they cost billions of dollars. Some studies have shown that scientists who have a personal interest in a company tend to report more positive results from clinical trials than scientists without such ties. In some cases, researchers have been discredited when they have disclosed unfavorable results in drug testing.

It also appears that there is a lack of guidelines from the universities how to deal with the individual scientists´ ties to industry. According to one study in 2000, only three out of 250 university hospitals had a policy that requested researchers to disclose their ties to industry to the patients and only seven percent demanded that such ties should be transparent in scientific journals. Only one out of ten major medical research universities has a policy banning researchers from holding stock, stock options or company positions related to their research (Lo 2000).

The question is how independent oversight can be achieved when individual researchers, universities, scientific journals and members of science advisory boards have ties to industry. Even if guidelines on disclosure and behavior exist, these have to be adhered to. Scientific oversight bodies are accountable ultimately to the public and to those placed at specific risk (Sharpe in cited article).

A final matter in this regard is that increasing corporate funding of university research may lead to less funding from the federal government and other sources. As has been shown earlier, this has already happened to a certain degree.

6.5.3 The Career System; PhD Training, Post-docs and Tenure

In the United States, approximately 41,000 doctorates are awarded every year. Even if there has been a slight decrease in the last couple of years, overall growth since the end of the 1950s has been considerable, averaging about 3.3 percent every year. In 2001, there were an all-time high of 416 institutions granting a doctorate. At the same time, only 48 universities granted more than half of all doctorates. The life sciences had the highest number of doctorates and the physical sciences, life sciences, social sciences, and engineering awarded approximately 65 percent of all doctorates.

The median time span from baccalaureate to doctorate was ten years. The shortest was in the physical sciences, where it was eight years; the longest was in education with 19 years. On average the median age at receipt of the doctorate was 33.3 years. (Survey of Earned Doctorates 2002). The NIH and the NSF support most of the S&E graduate students, whose primary support comes from the Federal Government, 17,000 and 14,000 students, respectively (NSF 2002).

Women received 44 percent of all doctorates granted in 2001, including those awarded to foreigners in the United States, and 50 percent of all doctorates awarded to U.S. citizens. Women earn more than half of all doctorates in the life sciences, social sciences, humanities, and education, and less than half in business. Much fewer women earn doctorates in the physical sciences and engineering, about 25 percent and 17 percent. (Survey of Earned Doctorates, 2002). Minority groups in the U.S. earned 16 percent of all doctorates in 2001, of which Afro-Americans earned the most, followed by Asians, Hispanics, and American Indians. Both minority groups and women have substantially increased their share of the total doctorates awarded in the last two decades. However, as has been pointed out before, women and minorities earn their doctorates in somewhat different areas than the traditional PhD. recipients, i.e. white males.

During the last decade, there have been discussions about and initiatives taken to reform doctoral studies in the United States. The actual length of the studies, the drop-out rates, the lack of interest from American citizens and the content and direction of the studies are some issues. The training has traditionally been geared towards the needs of academia, whereas today industry employs more PhDs in science and engineering than academia. Recommendations of reform have been made and programs have been set up by, among others, the NSF. Recommendations have focused on broadening the training to better prepare for careers in non-academic employment, making the studies more interdisciplinary and promoting team work, and to foster the communicative skills to non-specialists. The NSF has set up a new project on how to “re-envision the Ph.D.” to meet the needs of society in the 21st century and how to make reforms without prolonging the time to a degree. This project provides a national forum for discussion on doctoral reforms with many stakeholders involved. Some of the recommendations so far have been to shorten time to degree acquisition, increase underrepresented minorities among doctoral recipients, improve the use of technology for research and instructional purposes, prepare students for a wider variety of professional opportunities, incorporate understanding of the global economy and international scientific enterprise, and provide doctoral students with an interdisciplinary education (NSF 2002).

Closely related to the careers of PhDs is the availability of tenure-track appointments and of other non-tenure-track positions at colleges and universities (tenure means permanent employment). During the last decade there has been a great increase in the number of post-doc appointments, which are not included in the tenure-track faculty. This growth has been made possible largely by the increased resources for biomedical research in the U.S. It is part of a general trend by universities and colleges to employ teachers and researchers outside the tenure track system. Non-faculty positions increased by 62 percent from 1989 to 1999 and positions for post-docs by 61 percent (NSF 2002).

The problem with the growth of post-doc appointments is that there is a lack of standardized rules across higher education institutions and specific fields governing such appointments. The institutional status of post-docs are often poorly defined, benefits are set by individual institutions, salaries are low, the length of post-doc appointments vary from two to five years, sometimes even more, which means that the PhD is often older than 40 before getting a permanent appointment.

American universities have to compete with other universities around the world for Ph.D. students. They have been successful in doing so. Approximately one third of American doctorates in S&E are awarded to foreigners. When it comes to faculty they have to compete not only with other countries but also with industry, government and other private employers. Generally speaking, an individual with a PhD will be better paid in business and industry than in academia.

One of the ways that academia has been able to compete with industry for talent is by offering tenure. Tenure usually comes when a person goes from a post as assistant professor to associate professor. Tenure is important to safeguard academic freedom and to provide sufficient economic security for academicians.

At least 60 percent of current college and university faculty members have tenure. The increase in the number of full-time tenured faculty between 1989 and 1999 was only six percent, however. There are several reasons for the decline in tenure-track positions during the last decade; among them rising costs in higher education, insecurities about state and government funding and a need to enhance flexibility in research direction. Some also argue that tenure leads to less creativity as academic posts are occupied by older people. Scientific discoveries and breakthroughs are often made at a younger age. Related to this is the fact that it is hard for young people to get grants from government agencies, such as the NIH and the NSF before the age of 35 (Alberts 2003).

According to one recent study, about two-thirds of all higher education institutions had tenure systems in place in the fall of 1998 and almost nine out of ten of all full-time faculty worked at those institutions. Most institutions had made changes to their tenure system for full-time faculty and instructing staff during the previous five years. These changes included early or phased retirement, stricter standards for granting tenure and a decrease in their tenured faculty. Fix-term contracts were also used as an alternative to tenure. Other measures in recent years include a fixed percentage of tenured or senior faculty and granting tenure only when vacancies occur. Some institutions are offering attractive alternatives to tenure, such as offering multiyear contracts with higher salaries or other benefits (ACE 2001).

One study on non-tenure-track positions has been undertaken by the Association of American universities (AAU) at a sample of their member universities. According to the study, there is great variation between research universities and between departments in the role that non-tenure-track faculty play in terms of the time, intensity and content of the engagement but also in terms of institutional policies regarding non-tenure-track faculty (AAU 2001). Another finding was that there are different motivations for the increase in the hiring of non-tenure-track faculty. One important finding was that only one fourth of tenure-track faculty was women but almost half of non-tenure-track was female.

7 Similarities and Differences between the American and Swedish Science Systems and Policies

According to the terms of reference for this study, the facts and findings should be presented in a comparative perspective. In spite of the very different sizes of Sweden and the United States there are similarities in their relationship to science and research, to the structure of the science systems and to policies. But evidently, there are also big differences. In the following, some of these similarities and differences will be highlighted.

Among the similarities, it should first of all be mentioned that both the United States and Sweden belong to those countries which have the highest spending on R&D in relation to the Gross Domestic Product (GDP). For the U.S. it is 2.8 percent and for Sweden 4.3 percent. Industry’s share of total R&D is also large in both countries, 66 percent in the U.S. and 78 percent in Sweden (OECD 2003). Every OECD country, which is high on total R&D spending, has a substantial part from both industry and the government.

The use of information technology is also more widespread in both countries than in many others. The development of biotechnology and biotechnological companies has been remarkable in both countries, partly due to outstanding medical research at the universities. Strong clusters in information technology and biotechnology have developed in both countries.

Quality of research is also high in both countries. In a previous section chapter, the competitiveness of the United States has been presented. The number of scientific publications and citations of scientific articles are very high in both countries.

Another similarity is that universities receive substantial funding from the governments in both Sweden and the U.S. In the United States, universities are the greatest receivers of money for basic research; about half of federal funding for basic research is awarded to universities. In Sweden, universities and colleges receive 61 percent of their total R&D funding from the government in direct grants or via research councils and mission-oriented agencies. A difference, however, is that the federal support for research to universities is very concentrated. More than 80 percent of the funds goes to only 100 universities (out of 4,200 universities and colleges).

Not surprisingly, the differences between the U.S. and Sweden seem to be greater than the similarities. The first and very important one is the rationale for investments in research and development by the governments. As has been pointed out before, science for science´ sake was never a strong motive in the U.S., whereas this was the main reason for supporting research for a long period of time in Sweden. Similar to the situation in the U.S. was the growth of mission-oriented research in Sweden during the 1970s and 1980s. Sweden spent huge resources on energy-related R&D in the 1970s. The social problems became more imminent in the United States as well as in Sweden in the 1970s and 1980s, and the question was asked how science and research could contribute to alleviating them or even solving them.

Another notable difference is the heavy focus on biomedical research in the United States, even if this is a rather recent trend. The resources for biomedical research consume half of the federal civilian research budget. In most other countries, the balance between different scientific areas is more even. In Sweden, the government resources for medical research have increased less than resources for other scientific areas in the last ten years.

The rationale for supporting medical research in the U.S. and Sweden and the organization of that support are also somewhat different. In both cases the investments in medical research are there to help curing diseases and in this sense the research is mission-oriented. There is however a stronger focus on disease-orientation at the NIH than at its counterpart in Sweden, the Research Council for Medicine. There is only one institute at the NIH, which has the explicit mission to support basic medical science. In Sweden, the focus is rather on basic medical sciences. Another difference, which does not only apply to medical research but is very pronounced in this area, is the influence that lobbying organizations have in the U.S. on political decisions in Congress. In the medical field, a “coalition” between patient organizations, representatives of the NIH conglomerate and some members of Congress has been very successful in securing resources for research on different diseases, such as cancer and aids. The public also seems to be more involved in medical research in the United States than in Sweden. At the NIH, there is a Council of Public Representatives (COPR) which meets with the Director of the NIH to discuss the overall development of the NIH’s policies and research programs.

The way that the research agencies in Sweden and in the U.S. work is also somewhat different. The NSF is the one American research agency which can be compared to the Swedish Research Council (VR) as they both have the support of basic research as their main mission. The NSF has a broader mandate as the ultimate objective for the activities of the NSF is to achieve other societal goals. The NSF’s strategic goals include not only discovery (basic research) but also people and tools. The Swedish Research Council also supports Ph.D. training through its grants and also instrumentation, but stresses the support for basic research through peer review more than the NSF. The NSF supports both basic and applied research and is more engaged in developing the science and engineering workforce than the VR. The process of awarding grants and contracts at the NSF is called “merit review process” where both the intellectual merit of the proposed activity and its broader impact is taken into account. Factors such as how a research activity contributes to teaching, training and learning are taken into account as well as how the participation of underrepresented groups is enhanced, the contribution of the activity to the development of infrastructure, and finally, how society may benefit from the activity.

There are also similarities between the missions and working methods of the NSF and the VR. Both are engaged in promoting interdisciplinary and multidisciplinary research, participation of underrepresented groups (in Sweden particularly women), new promising research fields, such as nanotechnology and ethical issues in research.

Another, more specific difference between government agencies in the United States and Sweden is the support to small and medium-sized enterprises, SMEs. In the U.S., federal agencies with external R&D obligations above 100 million dollars must set aside 2.5 percent for Small Business Innovation Research (SBIR) projects. In 1999, ten government agencies participated in the program.

Research laboratories in the United States play a more important role than in Sweden. They accounted for approximately 30 percent of federal investments in R&D in 2002. Sweden, on the contrary, has few research laboratories or institutes outside of higher education. The principle has been not to split scarce resources on too many actors and to keep research and education together. It was only in the defense sector that a large research institute was created. In some R&D research areas of mutual interest to government and industry, approximately 30 industrial research institutes were established, which are co-financed by government and industry.

There are great differences between the United States and Sweden when it comes to the higher education sector. The U.S. higher education system is decentralized and diverse. The states have primary responsibility for higher education. The U.S. Department of Education is involved in the regulation of education in a limited way. The United States has no equivalent to a centralized national ministry of education, like the Swedish Ministry for Education and Science.

Many universities and colleges in the United States are private and many of them are very well known. They are the ones that are most well-known in Sweden; Harvard, MIT, Cornell, Columbia, Princeton, Yale, Stanford, Caltech, etc. In Sweden only a few higher education institutions are private. There is no tuition at Swedish institutions whereas in the United States tuition and fees can be substantial. Also, the tradition in the United States for alumni to support institutions of higher learning with substantial donations is unique and the Swedish higher education institutions have recently started to intensify activities in this area. Tax regulations encourage donations in the United States whereas a private person in Sweden cannot deduct gifts to charitable causes in the income declaration. There are also differences in the rules and regulations, which govern universities and colleges and in the way that they are managed. It would take too far to compare the systems in this regard in this report.

Another aspect, which is worth mentioning in the comparisons between American and Swedish universities. That is the legislation regarding commercialization of research. In the U.S., the Bayh-Dole Act in 1980 and consecutive legislation made it possible for universities to keep the right to inventions made with the support of federal funds. This is mostly regarded as very positive in the U.S. and has lead to an increase in the number of patents, new enterprises and employment. In Sweden, university professors have full ownership of intellectual property rights from their research (called “the teacher exception”). The argument is to safeguard academic freedom and give incentives to researchers to commercialize their inventions. Swedish universities and colleges have a third priority, in addition to their primary obligations of teaching and research, which includes technology transfer, regional economic development and public service. In both countries, university researchers are within certain limits allowed to do consulting.

Generally speaking, it can be argued that American universities are more dependent on their own institutional funds which often derive from private sources (included are for example general-purpose grants from industry, foundations, tuition fees, endowment income, unrestricted gifts, incomes from patents or licenses and income from patient care revenues, (NSF 2002). In 2000, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, an estimated 20 percent. Swedish universities and colleges are more dependent on direct grants from the government or money from government agencies. Direct funding from industry is similar in both countries; in the U.S. industry accounted for approximately 8 percent of academic R&D funding in the year 2000; in Sweden the percentage was about 7 percent of the total R&D performed in 2001.

Some policy areas of particular concern in the United States have been presented above. In Sweden, the debate in recent years has been focusing on other issues; the balance between resources for mission-oriented and basic research, the number and functions of the research agencies, the role of the research foundations created in 1994, issues of gender (the lack of women at higher posts in university research and the gender perspective in research), direct funding to universities and colleges vs. competitive funding through the research councils, graduate training, and ethical issues in research. More recently the concern has been how to stimulate young people to choose careers in science, how to support young researchers and how to deal with the generation shift when a large share of university faculty will retire in the next five to ten years. However, the main priority for the Swedish government in recent years has been the expansion of higher education. Between 1997 and 2003 the number of study places in higher education has increased by 100,000. During the autumn semester of 2002, 330,000 students were enrolled in higher education in Sweden. The rationale behind the expansion has been the conviction that it is essential for the Swedish society and the economy to raise the level of competence of the population.

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Sammanfattning

USA används ofta som riktmärke i den svenska forskningsdebatten. Anledningen till detta är omfattningen och kvalitén på amerikansk forskning och vetenskapligt arbete, förmågan att omvandla forskningsresultat till nytta för samhället, särskilt i ekonomiskt hänseende, entreprenörsandan och det höga antalet utlänningar som bidrar till vetenskapliga och teknologiska framsteg i USA.

Mot denna bakgrund har den svenska regeringen gett Institutet för tillväxtpolitiska studier (ITPS), i uppdrag att göra en studie av forskningssystem och forskningspolitik i USA med särskilt fokus på medicinsk forskning. Studien genomfördes av ITPS kontor vid svenska ambassaden i Washington. Rapporten ska ligga till grund för nästa proposition om forskning som ska presenteras för den svenska riksdagen 2004/2005.

Amerikansk forskning i ett internationellt perspektiv

- USA har en världsledande ställning inom vetenskapen sedan sextiotalet. Av Nobelpristagarna är amerikaner i klar majoritet. Andelen amerikanska pristagare inom naturvetenskaperna sedan 1950 överstiger 70 procent.
- USA:s utgifter för FoU uppgick till 292 miljarder dollar för 2002, vilket motsvarar 44 procent av OECD:s totala FoU-utgifter. FoU-kostnaderna räknat som andel av BNP var 2,8 procent för USA respektive 2,3 procent för OECD.
- Den näringslivsfinansierade forskningen inom OECD-området ökade avsevärt under 1990-talet, med 50 procent på tio år. De offentliga utgifterna för FoU ökade med 8,3 procent.
- Antalet forskare i förhållande till det totala antalet sysselsatta i OECD-området var 6,5 per tusen. Japan är det forskartätaste landet följt av USA.
- Samarbete mellan den privata och den offentliga sektorn är vanligt i USA. Det är viktigt för produktutveckling av forskningsresultaten. Det var i USA som innovationskluster först utvecklades.
- USA var också ett av de första länder som stödde små och medelstora företag genom SBIR-programmet (Small Business Innovation Research). Amerikanska universitet har varit ledande när det gäller kommersialisering av forskningsresultat. Den s.k. Bayh-Dolelagen blev avgörande eftersom den gav universiteten möjlighet att behålla äganderätten till den immateriella egendom som utvecklas inom federalt finansierade forskningsprogram.

- USA är konkurrenskraftigt när det gäller export av högteknologiska produkter, antal patent, vetenskapliga publikationer och citeringar. Mer än hälften av de cirka 150 000 patent som beviljades i USA under 1999 gick till amerikanska forskare. USA är även ledande när det gäller patentbeviljningar i andra länder. USA svarade för 36 procent av patentfamiljerna som har utvecklats av OECD. I förhållande till befolkningsmängd återfinns dock Sverige längre upp i listan med 107 jämfört med 52 för USA. Den ekonomiska vinsten av immateriella rättigheter i USA uppgick till 23 miljarder dollar 1999.
- Även om publikationen av vetenskapliga artiklar inte ökade lika mycket i USA som i till exempel Europa, stod USA för cirka en tredjedel av de totalt 530 000 publicerade artiklarna år 1999. Av de amerikanska artiklarna avsåg 55 procent de biomedicinska vetenskaperna. Merparten av publikationerna producerades vid universiteten, som svarade för över 70 procent av artiklarna år 1999.
- Även om amerikansk forskning är konkurrenskraftig och avkastningen på investeringarna fortsätter att vara god, finns det vissa farhågor inför framtiden. Oron gäller de federala investeringarna i FoU, behovet av personal, studenternas färdigheter, bristen på kompetenta lärare i matematik och naturvetenskap samt underrepresentationen av kvinnor och minoriteter inom vetenskap och teknologi.

Det amerikanska forskningssystemets utveckling

- I slutet av artonhundratalet fanns det cirka 250 högskolor runt om i USA. De blev tidigt centra för amerikansk vetenskap och forskning. Högskolorna var till en början inriktade på praktisk och affärsinriktad utbildning. Vissa högskolor utvecklades till universitet vid den här tiden. De var beroende av privat finansiering.
- Det federala engagemanget i FoU började under och efter andra världskriget. På bara fem år ökade den statliga FoU-finansieringen från knappt 20 till 75 procent. De federala myndigheterna blev de viktigaste sponsorerna av akademisk forskning efter kriget. 1960 hade de federala investeringarna i akademisk forskning stigit till 60 procent av den totala akademiska finansieringen.
- Efter kriget inrättades ett antal federala laboratorier, huvudsakligen inom försvarssektorn och kärnkraftsforskning.
- Försvarets behov var pådrivande för de federala FoU-investeringarna. Vid mitten av 60-talet svarade den försvarsinriktade forskningen för 50 procent av de federala FoU-utgifterna. Försvarsdepartementet svarade för 44 procent av de totala federala utgifterna för akademisk forskning 1958. Denna andel minskade de följande decennierna och var 1980 nere i 9 procent.

- Under president Reagans mandatperiod ökade de försvarsrelaterade forskningsanslagen och uppgick till 75 procent av de totala federala FoU-utgifterna. Försvarssektorns FoU i den federala budgeten för 2003 uppgår till 54 procent. I slutet av 80-talet och början av 1990-talet oroade sig USA för konkurrensen från Japan och teknologiöverföring blev det främsta syftet med de federala investeringarna.
- Ett annat utmärkande drag i de amerikanska federala investeringarna i FoU är den stora satsningen på forskning inom hälsoområdet. Det federala engagemanget har sin grund i försvarets behov. National Institutes of Health (NIH) var från början ett militärt laboratorium. Det utvecklades till ett ”hygieniskt” laboratorium på Staten Island i New York som sedan i sin tur omvandlades till NIH på 30-talet.
- På tjugo år ökade NIH:s budget från ett par miljoner dollar till över en miljard i mitten av 1960-talet. Under denna period inrättades flera nya NIH-institut. Resurserna fortsatte att öka under 1970-talet efter det att president Nixon förklarat ”krig mot cancern”.
- På fem år fördubblades NIH:s resurser och nådde 27 miljarder dollar 2003.
- Drivkraften bakom de federala investeringarna i FoU har varit att fylla en samhällsuppgift. Vetenskap för vetenskapens skull har aldrig varit huvudmålet. Den enda myndighet som har grundforskning som huvuduppgift är National Science Foundation (NSF) som inrättades 1950. År 1954 beslutade kongressen att även andra federala myndigheter kunde stödja grundforskning.
- NIH är den viktigaste myndigheten när det gäller grundforskning. NIH finansierar 54 procent av de totala federala anslagen till grundforskning jämfört med 13 procent för NSF. Men NSF spelar en mycket viktig roll i finansieringen av annan grundforskning än livsvetenskaperna.

Det nuvarande forskningssystemet

- Det amerikanska forskningssystemet är omfattande och komplext och insatserna inte alltid samordnade. Många är inblandade i beslutsfattandet: presidentens administration, kongress, myndigheter, näringsliv, delstater, stiftelser, universitet, högskolor, federala laboratorier, akademier och organisationer med särintressen.
- Office of Science and Technological Policy (OSTP) inom Vita huset svarar för rådgivning i flera frågor inom vetenskaps- och teknikområdet, däribland budgeten, och samordnar de federala myndigheternas och andra aktörers insatser. Chef för OSTP är presidentens vetenskaplige rådgivare.

- National Science and Technology Council (NSTC) har en strategisk position eftersom det gör prioriteringar och samordnar de federala riktlinjerna och interdepartementala insatserna för vetenskap, teknologi och rymdfrågor. I NSTC ingår presidenten, vicepresidenten samt chefer för statliga departement och fristående myndigheter. Arbetet sker i utskott och underutskott.
- Presidents Council of Advisors on Science and Technology (PCAST) är presidentens rådgivare i vetenskaps- och teknologipolitiska frågor och inkluderar personer från handel och industri, den akademiska världen och andra organ.
- Office of Management and Budget (OMB) samordnar och sammanställer presidentens budget och är därför en maktfaktor i FoU-frågor. Det finns däremot ingen formell FoU-budget. Alla departement och myndigheter har egna FoU-budgetar. American Association for the Advancement of Science (AAAS) sammanställer och analyserar de årliga förslagen från kabinettet.
- USA är inte en parlamentarisk demokrati. Kongressen har mer makt än parlamenten i många andra länder. Kongressen beslutar om de flesta poster och delposter i budgeten för departementen och myndigheterna. FoU-relaterat arbete sker inom många utskott och underutskott, däribland godkännande- och anslagskommittéer.
- Kongressen har många biträdande organ till sitt förfogande. Ett av dem är General Accounting Office (GAO) som granskar och utvärderar federala program och aktiviteter. Congressional Budget Office (CBO) förser kongressen med löpande budgetinformation och framställer årsrapporter om ekonomins och budgetens utveckling.
- Det förekommer ofta utfrågningar av representanter för presidenten och hans administration, externa experter och enskilda medborgare.
- Många departement och federala myndigheter är inblandade i finansieringen av forskningen. Vissa myndigheter har FoU som enda uppgift, till exempel NIH och NSF. De flesta andra stödjer forskningen som en deluppgift. Fem myndigheter, DOD (försvarsdepartementet), NIH, NASA (den amerikanska rymdflygstyrelsen), DOE (energidepartementet) och NSF, svarar för 93 procent av de federala FoU-anslagen.
- National Academies, USA:s vetenskapsakademi, spelar också en viktig roll inom vetenskapspolitiken. National Academies finansieras huvudsakligen av federala myndigheter. Akademierna genomför studier för kongressen, regeringen och federala myndigheter men initierar även egna projekt inom samtliga vetenskapsområden och är involverade i policy- och innovationsfrågor.

- Frivilligorganisationer är också viktiga aktörer, och det finns tusentals, särskilt i Washington D.C. American Association for Advancement of Science (AAAS) har 140 000 medlemmar och dess uppgift är att främja vetenskap och innovationer över hela världen. Tre program är viktiga ur ett forskningspolitiskt perspektiv: analyserna av FoU-data, S&T Policy Fellowship Program samt Center for Science, Technology and Congress.

Finansieringstrender

- De totala FoU-investeringarna i USA uppgick i mitten av 1960-talet till cirka 2,7 procent av BNP. År 2002 var andelen 2,8 procent av BNP. Näringslivet har ökat sin andel och svarade för 66 procent och de federala organen för 28 procent.
- FoU utgör en viktig men minskande post i den federala budgeten. I mitten av 1960-talet utgjorde FoU närmare 12 procent av den federala budgeten jämfört med 5 procent 2003. Detta beror främst på ökningen i utgifterna av andra reglerade federala utgifter.
- Utgifterna för den försvarsinriktade FoUn har alltid varit högre än övriga FoU-utgifter de senaste fyrtio åren, men dess andel har varierat väsentligt genom åren. Rymdprojekt dominerade under 1960-talet; energiforskningen har däremot varierat i betydelse. FoU inom hälsoområdet har emellertid ökat stadigt hela perioden och står numera för den enskilt största andelen av de icke-försvarsrelaterade FoU-anslagen (cirka 50 procent).
- Grundforskningen har ökat enormt de senaste decennierna, från 7 miljarder dollar 1976 till 26 miljarder dollar 2003, främst beroende på budgetökningar för NIH, som står för över 50 procent av all federalt finansierad grundforskning. Samtliga FoU-aktörer har ökat stödet till grundforskningen sedan 1970. Omkring hälften av all federalt finansierad grundforskning utförs på universiteten.
- Federala departement och myndigheter finansierar olika aktörer. NIH stödjer huvudsakligen de akademiska institutionerna, NASA är en tung bidragsgivare till industriell forskning, energidepartementet stödjer främst Federally Funded Research and Development Centers (FFRDC) medan NSF främst stöder universitetsvärlden och FFRDC..
- Federala investeringar i forskning och utveckling uppgick till 117,3 miljarder dollar 2003. Det är en ökning med 14,2 miljarder dollar eller 13,8 procent sedan 2002, den största ökningen i absoluta tal hittills. De flesta regeringsfinansierade myndigheter fick större anslag, särskilt till forskning inom försvar, hälsovård, allmän vetenskap och nationell säkerhet och krishantering (homeland security). Försvarets FoU ökade med 8,8 miljarder dollar eller 17,6 procent till 58,6 miljarder dollar. NIH:s anslag ökade med 15,5 procent och uppgår därmed till 26,2 miljarder dollar. NSF:s ökning var 3,9 miljarder dollar eller 11,4 procent.

- Av den totala federala FoU-budgeten stod investeringar i forskning för 45 procent och i utveckling för 55 procent. NIH finansierar 47 procent av alla federala forskningsutgifter och är den enskilt största sponsorn av grund- och tillämpad forskning.
- Det nya departementet för nationell säkerhet och krishantering fick en stor anslagshöjning för FoU år 2003. Myndighetens anslag 2003 var cirka 670 miljoner dollar jämfört med 266 miljoner dollar året innan.
- På hälsoområdet nästan fördubblades NIH:s FoU-budget mellan 1998 och 2003, från 2002 till 2003 med 3,5 miljarder dollar till 26,2 miljarder dollar, däribland betydande ökningar till forskning på bioterrorism och anläggningar för sådan forskning. Ett annat prioriterat område var allmän vetenskaplig utveckling som ökade med 6,4 procent till 7,0 miljarder dollar mellan 2002 och 2003, varav NSF:s FoU-program fick 11,4 procent. Rymdforskningen var också den stora vinnaren med en ökning på 9,2 procent till 10,1 miljarder dollar till följd av utökade rymdprogram och en fortlöpande växling från flygteknikforskning till rymdrelaterad teknikutveckling.
- Däremot har FoU för icke-militära ändamål, med undantag för NIH, stagnerat under senare år efter en stadig tillväxt under 1980-talet. Även om anslagen till andra myndigheter ökade 2003 kommer dessa myndigheter knappast upp i samma nivå som de hade i början av 1990-talet.
- Öronmärkta medel (”R&D Earmarks”) för FoU, uppgick till totalt 1,4 miljarder dollar, det vill säga 1,2 procent av den totala federala forskningen och utvecklingen. Fyra myndigheter delar på närmare 75 procent av dessa medel, nämligen USDA (jordbruksdepartementet), NASA, DOE och DOD.

National Institutes of Health (NIH)

- National Institutes of Health är världens enskilt största finansieringskälla av medicinsk forskning. NIH:s uppdrag är att främja forskning som leder till bättre hälsa för alla. NIH medverkar till detta genom forskning i egna laboratorier (intern forskning), genom stöd till icke-federala forskare på universitet, medicinska fakulteter, sjukhus, forskningsinstitut och utomlands (extern forskning). NIH bistår även vid utbildning av forskare och försöker skapa gynnsammare förutsättningar för utbyte av medicinsk information. Liksom många andra federala myndigheter är NIH engagerat i teknologiöverföring.
- Budgeten för 2003 uppgår till 27 miljarder dollar. NIH svarar för närmare en fjärdedel av de federala FoU-utgifterna och hälften av den civila FoU-budgeten. NIH är även den näst största bidragsgivaren till federal FoU efter försvarsdepartementet och den största bidragsgivaren till grundforskning, tillämpad forskning och forskning på högskolor och universitet.

- Av den totala federala FoU-budgeten 2000 sponsrade NIH 30,1 procent av den interna forskningen, 16,7 procent av den industriella forskningen, 63 procent av universitets- och högskoleforskningen, 3,6 procent av FoU i icke-vinstdrivande organisationer samt 9,9 procent av alla övriga organisationers forskning. NIH spelar därmed en betydande roll för de biomedicinska vetenskaperna där 87,5 procent av forskningen bekostas av NIH. NIH finansierade 76,1 procent av de federala FoU-utgifterna inom medicingrenarna. NIH:s stöd är av avgörande betydelse för psykologi- och kemiforskningen, men också betydelsefull för fysikområdet.
- NIH är en decentraliserad organisation med 27 institut och centra som sysselsätter cirka 17 700 personer (omräknat till heltidsanställda). Av de anställda har mer än 4 000 akademisk examen eller doktorsexamen. Instituten som är samlade under NIH är ganska olika om man ser till uppgift, verksamhetens omfattning och storlek. Däremot är verksamheten och bidragen till forskarna organiserade på liknande sätt.
- Center for Scientific Review (CSR) handhar den övervägande delen av den vetenskapliga granskningsprocessen vid de övriga NIH-instituten. År 2002 uppgick NIH:s anslag till 19 074 miljarder dollar och det totala antalet anslag var närmare 50 000. Den genomsnittliga kostnaden per forskningsanslag år 2000 var 384 000 dollar. Genomsnittskostnaden per år har ökat anmärkningsvärt sedan 1997 då genomsnittskostnaden låg på 275 000 dollar.
- Cirka 20 procent av NIH:s externa finansiering går till utbildning. Under 2002 finansierades 16 700 utbildningsposter.
- Huvuddelen av den externa finansieringen går till enskilda forskare som ansökt om bidrag. Vissa projektbidrag ges till tvärvetenskapliga projekt som genomförs av flera forskare med olika infallsvinklar på forskningsämnet och kallas ”program project grants”. Tvärvetenskapliga projekt och samarbetande forskare får även stöd genom anslag till forskningscentra. Sådana anslag delas ut till forskningsinstitutioner.
- National Center for Research Resources (NCRR) är en av bidragsgivarna till forskningscentren. Anslagen går även till resurser för att integrera grundforskningen med den tillämpade forskningen och för att stödja forskning i kliniska tillämpningar.
- Ansökningar om extern finansiering skickas till NIH och CSR. CSR fördelar anslagen på de olika instituten. Cirka 52 000–55 000 ansökningar behandlas varje år. Det slutliga beslutet om finansiering tas av instituten.
- Forskningsansökningarna bedöms enligt följande kriterier: ämnets betydelse, nytänkande i problemformulering och tillvägagångssätt, lämpligheten i den föreslagna metodiken, forskarens kvalifikationer och erfarenhet samt inom vilken vetenskaplig miljö arbetet kommer att utföras.

- Cirka en tredjedel av alla granskade ansökningar beviljas anslag. Det är ovanligt att den som söker första gången beviljas finansiering. Andelen beviljade anslag har minskat eftersom antalet ny- och återansökningar har ökat.
- En debatt rörande NIH:s organisation och effektivitet har pågått under många år. Många rapporter har publicerats i detta ämne. NAS genomförde nyligen en studie på initiativ av kongressen. NAS rekommenderade att den kliniska forskningen förstärks och att den övergripande strategiska planeringen och finansieringen inom NIH förbättras. Högriskforskning och forskningsprojekt med möjligheter till ekonomiska vinster bör ges anslag via ett specialprogram och innovation och riskforskning bör uppmuntras i den interna forskningen.
- Det andra initiativet kommer från NIH:s nye chef. En ”karta” för medicinsk forskning under 2000-talet har utarbetats. Förslagen kan indelas i tre områden: nya vägar till upptäckter, forskningsteam för framtiden och omstrukturering av den kliniska forskningsverksamheten. Behovet av att förstå komplexa biologiska system och kunskap om molekylernas strukturer i celler och vävnader liksom bättre verktyg för forskare inom biomedicin, till exempel teknik och databaser, är några inslag i denna vägledning.
- Framtidens forskningsteam kommer att behöva arbeta över gränserna både inom fysiken och inom biologin. Innovations- och högriskforskning bör också uppmuntras. Inom klinisk forskning ska nya partnersamarbeten utvecklas och kliniska studier bör genomföras i samarbete mellan flera akademiska centra. Man måste även hitta nya vägar att dokumentera klinisk forskning, införa nya standarder för kliniska forskningsprotokoll, använda moderna IT-resurser och dra upp nya strategier för att stödja och motivera den kliniska forskningspersonalen. Totalt kommer cirka 2,1 miljarder dollar att avsättas under sex år fr.o.m. år 2004.

National Science Foundation (NSF)

- NSF:s ursprungliga uppdrag var att stödja vetenskapliga framsteg, att förbättra nationell hälsa, välstånd och välfärd samt göra det nationella försvaret säkert. Dessa mål gäller fortfarande. NSF är den enda federala myndighet som har stöd till grundforskning som sin huvuduppgift.
- National Science Board (NSB) är stiftelsens styrelse och policyorgan. Dess 24 medlemmar utses av Presidenten och godkänns av senaten. NSB rapporterar till OSTP.
- NSF:s totala budget för 2003 uppgick till cirka 5,3 miljarder dollar varav 3,9 miljarder dollar avsåg FoU. Det är en ökning med över 11 procent jämfört med 2002. I kongressen och på annat håll har man agerat för att följa NIH-exemplet med fördubblad budget för NSF på fem år. Kongressens godkännande finns men tilldelningsbesluten har ännu inte fattats.

- NSF:s anslag utgör cirka fyra procent av den totala federala FoU-budgeten men svarar för cirka 13 procent av allt federalt stöd till grundforskningen och hela 40 procent av grundforskningen inom andra vetenskaper än naturvetenskap vid USA:s akademiska institutioner. NSF spelar således en central roll i amerikansk vetenskap och forskning.
- NSF har breda befogenheter, bland annat initierar och stödjer stiftelsen vetenskaplig och teknisk forskning genom anslag och kontrakt samt genom utbildningsprogram. NSF stödjer både grund- och tillämpad forskning och anläggningar men är inte engagerat i ren utveckling. NSF delar även ut stipendier till doktorander, post-doktorer samt stöder dessa genom forskningsprojektanslag.
- En av NSF:s uppgifter är att stödja verksamhet som syftar till att öka andelen kvinnor och minoriteter inom vetenskap och teknik. NSF fungerar även som informationscentral för vetenskapsmän och tekniker samt svarar för insamling, tolkning och analyser av data om vetenskapliga och tekniska resurser till stöd för andra federala myndigheter i deras policybeslut.
- Ansökningarna bedöms utifrån den vetenskapliga kvalitén på det föreslagna projektet och dess bredare inflytande, t.ex. samhällsrelevans. Det senare kriteriet är svårare att bedöma än det förra.
- Externa experter spelar en viktig roll genom sina anslagsrekommendationer. NSF:s programansvariga måste emellertid även ta hänsyn till andra faktorer när de lämnar rekommendationer. Det slutliga beslutet om beviljande eller avslag fattas av NSF:s ledningspersonal.
- NSF delar ut omkring 10 000 nya anslag varje år och drygt 96 procent av dessa väljs ut genom granskningsprocessen. År 2002 beslutade NSF om cirka 35 000 forsknings- och utbildningsanslag. Totalt beviljades 30 procent av ansökningarna, vilket är i nivå med tidigare år.
- NSF har en strategi för att öka andelen underrepresenterade grupper, det vill säga minoriteter och kvinnor, i vetenskaps- och teknikforskningen. Forskare i dessa grupper erhöll år 2002 cirka fem procent av anslagen. Av dessa ansökningar beviljades 29 procent, något mindre än de genomsnittliga 30 procenten. Kvinnliga forskare fick 19 procent av de totala anslagen vilket ger en anslagsnivå på 30 procent. Anslagsnivåer för forskare som tidigare fått anslag, resp. de som är ”nya” uppgick till 35 resp. 22 procent.
- Merparten av anslagen, 76 procent, gick till akademiska institutioner. De tio institutioner som erhåller mest bidrag får cirka 15 procent av NSF:s anslag medan 25 procent går till institutioner som inte är bland de 100 största bidragstagarna.

- Det genomsnittliga årliga forskningsanslaget 2001 var cirka 115 500 dollar. Mediananslaget uppgick till cirka 86 000 dollar. NSF har en uttalad strategi att öka anslagsstorleken för att attrahera ansökningar av hög kvalitet.
- Det bedrivs flera tvärgående program inom NSF. Det handlar om specialprogram för kvinnor och minoriteter, integration mellan utbildning och forskning, samarbete mellan den akademiska världen och näringslivet, vetenskapliga instrument, nanoteknik, miljöforskning, utbildnings-, vetenskaps- och teknikcentra, forskning inom små företag mm. Office of Integrative Activities ansvarar för flera av dessa program.

Federala laboratorier

- Federala laboratorier har vanligen inrättats för att stödja en viss myndighets uppdrag. De omfattar federalt ägda men uppdragsdrivna laboratorier (GOCO) och federalt finansierade FoU-centra (FFRDC). Under 2002 fick de federala laboratorierna cirka 25 (31 procent) av de totalt 81 miljarder dollar som gick till federala FoU-investeringar. Detta ska jämföras med cirka 10 miljarder dollar till de akademiska institutionerna. De största mottagarna är laboratorierna som lyder under försvarsdepartementet, följda av energi- och sjuk- och hälsovårdsdepartementet.
- FFRDC var ursprungligen forskningsinstitut som etablerades inför andra världskrigets behov. De grundläggande riktlinjerna för verksamheten drogs upp 1967. FFRDC får sitt huvudsakliga ekonomiska stöd (70 procent eller mer) från federala källor. 2003 fanns det 36 FFRDC under åtta departement och myndigheter. De kan delas in i tre kategorier: sådana som drivs av universitet och högskolor, icke vinstdrivande organisationer samt näringslivet.
- FFRDC utförde under 2002 federalt finansierad FoU för cirka 7 miljarder dollar. FoU-centra administrerade av universitet och högskolor svarade för huvuddelen av denna summa (63 procent).
- Mindre än 10 procent av de federala laboratorierna svarade för över 75 procent av de vetenskapliga publikationerna, patenten, licenserna och andra forskningsbidrag som producerades vid federala laboratorier.

Universitet och högskolor

- Det finns 4 200 universitet och högskolor i USA. Merparten av forskningen utförs vid 263 universitet (doctoral/research universities) och vid specialiserade institutioner, såsom sjukhus medicinska centra. Universiteten spelar en viktig roll i den amerikanska forskningen. De utför cirka 13 procent av all FoU i landet. Deras roll i finansieringen av FoU är mycket begränsad. De svarade under 2002 för cirka 3,4 procent av de totala FoU-investeringarna.

- De totala FoU-utgifterna för universitet och högskolor år 2002 uppgick till 37 miljarder dollar. Den största finansieringskällan var federala myndigheter med 23 miljarder dollar, vilket utgör 62 procent av de totala akademiska utgifterna. Av de totala akademiska FoU-utgifterna avser cirka 75 procent grundforskning. Universitet och högskolor svarar för nästan hälften av all federalt finansierad grundforskning.
- Medicingrenarna står för den klart största andelen av de totala FoU-kostnaderna vid universitet och högskolor. År 2001 investerades 10 miljarder dollar (30 procent av totalbeloppet) i de medicinska vetenskaperna medan bio- och biomedicinsk teknik fick ett mindre belopp på 211 miljoner dollar.
- Universitet och högskolor har ökat sin andel av akademiska FoU-investeringar till cirka 20 procent. Näringslivet svarar för 6–7 procent av den akademiska FoUn.
- Tre federala myndigheter står bakom huvuddelen av de federala utgifterna för akademisk forskning, nämligen NIH med 60 procent, NSF med 15 procent och försvarsdepartementet med 9 procent.
- Det federala FoU-stödet i USA är koncentrerat till ett litet antal forskningsuniversitet. 82 procent av de federala anslagen går till 100 universitet. Tio universitet får mer än 20 procent, tjugo universitet får 34 procent och femtio får cirka 70 procent av de totala federala anslagen. De flesta universitet och högskolor erhåller mycket små anslag från federalt håll.
- Kalifornien, Maryland, Virginia, Texas och Massachusetts tilldelas sammanlagt hälften av alla federala FoU-anslag.
- En del av anslagen till akademisk forskning gäller ansökningar som inte är konkurrensutsatta, så kallade öronmärkta projekt. Sådana projekt fick under 2003 över 2 miljarder dollar av kongressen, däribland FoU-projekt, en ökning från 1 837 miljoner dollar 2002. Öronmärkta pengar till akademiska institutioner ifrågasätts av många akademiker och tjänstemän på myndigheterna.
- Delstats- och lokala myndigheter svarade för cirka 7 procent av FoU-finansieringen inom universitet och högskolor år 2000. Sedan 80-talet har delstatliga och lokala myndigheters bidrag till den akademiska forskningen varierat mellan 7 och 8 procent. Delstaterna spelar emellertid en mycket viktig roll i finansieringen av offentlig högre utbildning.
- Näringslivets bidrag till universitet och högskolor 2001 motsvarade sju procent av de totala akademiska FoU-kostnaderna. Näringslivets finansiering av den akademiska FoU:n har vuxit snabbare än någon annan finansieringskälla under de senaste trettio åren men näringslivet är således ännu inte någon stor bidragsgivare.

- Samarbetet mellan universitet och näringsliv har alltid varit starkt i USA, särskilt när det gäller teknikforskning. Ett ännu starkare band till näringslivet har skapats genom de akademiska institutionernas tekniklicensiering, vilken möjliggjordes genom Bayh-Dolelagen 1980 och även senare lagstiftning. Omkring 200 universitet och högskolor deltar i teknologiöverföringsprojekt. Lagen beräknas ha bidragit till 2 200 nya företag, 260 000 anställningstillfällen och 49 miljarder dollar till den amerikanska ekonomin.
- Den ekonomiska förtjänsten av patent och licenser är förhållandevis liten. Teknologiöverföringskontoren går sällan med vinst och det tar oftast sju år innan sådana projekt börjar gå med vinst. Ungefär 70 procent av upptäckterna vid universiteten kräver vidare forskning innan patentansökningar kan inges.
- Bidrag från allmänheten svarade för cirka 8 procent av utgifterna för högre utbildning och forskning under 2002 motsvarande cirka 24 miljarder dollar. Det frivilliga stödet ökade betydligt i slutet av 1990-talet när aktiemarknaden var på topp, men avtog för första gången 2002.
- Högre utbildningsinstitutioner i USA har ekonomiskt en mycket viktig roll i och med att de har närmare tre miljoner anställda, vilket utgör cirka två procent av arbetskraften i USA.

Företag och näringsliv

- Forskning och utveckling i det privata näringslivet i USA uppgick till 211 miljarder dollar år 2002. Cirka 21 miljarder dollar eller 10 procent av denna summa finansierades av federala myndigheter medan övriga medel kom från näringslivet. Den privata forskningen har vuxit i betydelse sedan 1950-talet och dess andel av den totala FoU-verksamheten har ökat från 44 procent 1953 till 55 procent 1990 och utgjorde 2002 72 procent.
- De två senaste åren har FoU-investeringarna i näringslivet inte ökat i samma takt. FoU-utgifterna 2002 låg på knappt över 2001 års nivå i aktuell dollarkurs och knappt under denna nivå räknat i konstant dollarvärde. Investeringsnivån varierar påtagligt mellan olika sektorer. Överst på skalan återfinns läkemedels- och bioteknikföretag och i den andra ändan IT-, telekom- och kemiföretagen.
- Två andra trender kan iakttas avseende företagens FoU de senaste två decennierna: ökningen av FoU inom tjänstesektorn och inom små företag. I början av 1980-talet stod tjänsteföretagen för mindre än fem procent av den totala företagsforskningen. År 2000 var motsvarande siffra närmare 40 procent.
- Företagsfinansierad forskning och utveckling i läkemedelsföretag ökade snabbt i realvärde från 4,7 till 10,4 miljarder dollar mellan 1985 och 1995 för att sedan minska till 9,3 miljarder dollar 1998.

Frågor och prioriteringar i den amerikanska forskningspolitiken

- Sju vetenskapspolitiska frågor diskuteras för närvarande: nationell säkerhet och öppenhet i det vetenskapliga systemet, resursfördelningen mellan olika vetenskapsområden, personal- och arbetsrelaterade problem, forskning om stamceller, resurser till högre utbildning, kommersialisering av högre utbildning och doktorandutbildning, postdoktorala utbildningar och befattningar.

Slutsatser – likheter och skillnader mellan vetenskapssystem och politik i USA och Sverige

- Storleksskillnaderna till trots finns det likheter mellan Sverige och USA när det gäller kopplingen mellan vetenskap och forskning, mellan vetenskapssystemens organisation och politiken. Naturligtvis föreligger det även stora skillnader.
- Bland likheterna ska först nämnas att både USA och Sverige hör till de länder som satsar mest pengar på FoU i förhållande till respektive lands BNP. Användningen av IT är också mer allmänt utbredd än i många andra länder. Utvecklingen av bioteknik och bioteknikföretag har varit påfallande i båda länderna, delvis beroende på högt framstående medicinsk forskning vid universiteten. Starka kluster runt IT och bioteknik har utvecklats både i Sverige och USA. Kvaliteten på forskningen är också hög i de båda länderna. Antalet vetenskapliga publikationer och citeringar av vetenskapliga artiklar är mycket högt såväl i USA som i Sverige.
- En annan likhet är att FoU vid universiteten huvudsakligen finansieras av statliga anslag. I USA är universiteten de största bidragsmottagarna beträffande grundforskning där cirka hälften av de federala anslagen till grundforskning går till universiteten. I Sverige erhåller universiteten och högskolorna 61 procent av sina totala FoU-anslag från staten i direkta anslag eller via forskningsråd och uppdragsinriktade myndigheter.
- Skillnaderna mellan USA och Sverige är emellertid större än likheterna. Den första är bakgrunden till statens engagemang i forskning och utveckling. Vetenskap för vetenskapens skull har aldrig varit någon stark drivkraft i USA, medan detta under lång tid har varit en av huvudanledningarna att stödja FoU i Sverige.
- En annan tydlig skillnad är den tunga fokuseringen på biomedicinsk forskning i USA. Grundvalen för det medicinska forskningsstödet i USA och Sverige, liksom organisationen av detta stöd, skiljer sig delvis åt. I båda fallen är stödet avsett att bota sjukdomar och i denna mening är forskningen behovsinriktad. NIH har dock en starkare sjukdomsinriktning på sin forskning än Ämnesrådet för medicin, som är den svenska motsvarigheten.

- En annan skillnad, som inte enbart avser medicinsk forskning men som är mycket påfallande inom det området, är det inflytande lobbyorganisationer har på de politiska besluten i kongressen.
- De svenska forskningsmyndigheternas arbetssätt skiljer sig också från de amerikanska. NSF har ett bredare mandat eftersom det yttersta målet för dess verksamhet är att uppnå andra samhällsmål. NSF:s strategiska mål omfattar inte bara upptäckter (grundforskning) utan även människor och verktyg. Vetenskapsrådet stödjer även doktorandutbildning och instrumentinvesteringar genom sina anslag, men betonar stödet till grundforskning genom forskargranskning mer än NSF. NSF stödjer både grundforskning och tillämpad forskning och engagerar sig mer i utbildningsfrågor än Vetenskapsrådet gör. NSF:s beviljande av anslag och kontrakt sker i en process som kallas ”merit review process” där man tar hänsyn till såväl vetenskapligt som ett bredare mervärde av forskningsprojekten.
- En annan skillnad mellan myndigheterna i de två länderna är stödet till forskning inom små och medelstora företag. I USA måste federala myndigheter med en FoU-budget på över 100 miljoner dollar avsätta 2,5 procent till SBIR-projekt. År 1999 deltog tio myndigheter i detta program.
- I USA spelar forskningslaboratorierna en större roll än i Sverige. De svarade för cirka 30 procent av de federala FoU-anslagen 2002. Sverige däremot har få forskningslaboratorier eller forskningsinstitut utanför den akademiska sfären. Inom vissa FoU-områden av ömsesidigt intresse för stat och näringsliv har omkring 30 forskningsinstitut etablerats som samfinansieras av stat och näringsliv. De slås nu samman till färre institut.
- Det finns stora skillnader mellan länderna när det gäller högre utbildning. USA:s system för högre utbildning är decentraliserat och skiftande. Det finns till exempel ingen motsvarighet till det svenska utbildningsdepartementet.
- Många universitet och högskolor i USA är privata och flera av dem är mycket välkända. I Sverige är det endast ett fåtal lärosäten som är privata. De svenska lärosätena tar inte ut några avgifter medan dessa kan vara betydande i USA.
- Traditionen i USA att tidigare studenter stöder sina lärosäten genom donationer är unik och vissa svenska lärosäten har nyligen påbörjat aktiviteter inom detta område. Skattelagstiftningen uppmuntrar donationer i USA medan sådana gåvor till välgörande ändamål inte är avdragsgilla för privatpersoner i Sverige. Det finns även skillnader i lagstiftning och förordningar som reglerar universitets- och högskoleverksamheten och det sätt på vilket verksamheterna leds.

- Lagstiftningen kring kommersialisering av forskningsresultat är annorlunda i USA, där Bayh-Dolelagen från 1980 med senare tillägg har gjort det möjligt för universiteten att behålla äganderätten till de upptäckter som gjorts med statliga medel. I Sverige har universitetsprofessorer full äganderätt till immateriell egendom som härrör från deras forskning (s.k. lärarundantag). I båda länderna har universitetsforskare viss begränsad rätt att arbeta som konsulter.
- Amerikanska universitet är ofta mer beroende av egna institutionella medel, som oftast kommer från privata källor. År 2000 utgjorde de institutionella medlen från universitet och högskolor den näst största finansieringskällan för akademisk forskning, cirka 20 procent. Svenska universitet och högskolor är i stället beroende av direkta anslag från stat eller myndigheter. Direktfinansieringen från näringslivet är jämförbar. I USA stod näringslivet för cirka 8 procent av den akademiska forskningen år 2000 medan samma siffra i Sverige var cirka 7 procent av den totala forskningen 2001.

ITPS, Swedish Institute for Growth Policy Studies
Studentplan 3, 831 40 Östersund, Sweden
Telephone: +46 (0)63 16 66 00
Fax: +46 (0)63 16 66 01
info@itps.se
www.itps.se
ISSN 1652-0483

SWEDISH INSTITUTE
FOR GROWTH POLICY
STUDIES