VINNOVA ANALYSIS
VA 2009:15

LIFE SCIENCE RESEARCH AND DEVELOPMENT IN THE UNITED STATES OF AMERICA

An overview from the federal perspective

EVA HUNNIUS OHLIN & MARTIN A. WIKSTRÖM
ITPS WASHINGTON D.C.

SWEDISH INSTITUTE FOR GROWTH POLICY STUDIES

Title: Life Science Research and Development in the United States of America - An overview from the federal perspective
Author: Eva Hunnius & Martin A. Wikström - ITPS Washington D.C.
Series: VINNOVA Analysis VA 2009:15
ISBN: 978-91-85959-64-8
ISSN: 1651-355X
Published: June 2009
Publisher: VINNOVA - Swedish Governmental Agency for Innovation Systems / Verket för Innovationssystem
VINNOVA Case No: 2008-02274

About VINNOVA

VINNOVA, Swedish Governmental Agency for Innovation Systems.

VINNOVA´s mission is to *promote sustainable growth*
by funding *needs-driven research*
and developing *effective innovation systems*.

Through its activities in this field, VINNOVA aims to make a significant contribution to Sweden´s development into a leading centre of economic growth.

The VINNOVA Analysis series includes publications of studies, analyses, official reports and evaluations that have been produced or commissioned by VINNOVA´s Strategy Development Division.

Research and Innovation for Sustainable Growth.

VINNOVA´s publications are published at www.VINNOVA.se

I VINNOVAs publikationsserier redovisar bland andra forskare, utredare och analytiker sina projekt. Publiceringen innebär inte att VINNOVA tar ställning till framförda åsikter, slutsatser och resultat. Undantag är publikationsserien VINNOVA Policy som återger VINNOVAs synpunkter och ställningstaganden.
VINNOVAs publikationer finns att beställa, läsa och ladda ner via www.VINNOVA.se. Tryckta utgåvor av VINNOVA Analys, Forum och Rapport säljs via Fritzes, www.fritzes.se, tel 08-690 91 90, fax 08-690 91 91 eller order.fritzes@nj.se

Life Science
Research and Development
in the United States of America

An overview from the federal perspective

by

Eva Hunnius Ohlin and Martin A. Wikström
ITPS Washington D.C.

Preface

In December 2006, VINNOVA was assigned by the Swedish government to conduct an international benchmarking of the Swedish sectorial innovation systems in pharmaceuticals, biotechnology and medical technology. Case studies and international comparisons of activities in different countries are important in assessing and understanding the Swedish conditions for life science research and innovation. The by far most influential country globally is the United States considering the size of the science base, R&D-investments and industry. The trends in the U.S. therefore tend to have a strong influence on the global development. VINNOVA has thus commissioned ITPS (today the Swedish Agency for Growth Policy Analysis) to analyse and describe the situation for a number of life science areas in the U.S.

This study which is one of the above mentioned studies is based on data and information concerning primarily policy trends in the U.S. Life Science research and innovation system. The U.S. research-funding situation as well U.S. life science R&D in relation to the rest of the world is thus described as well as the large heterogeneity within the U.S. in terms of R&D intensity between states. Major federal funding agencies of R&D in the life sciences are described, their funding levels, as well as some of their prioritized areas. How agencies work to stimulate innovation at universities is also discussed. The attitude to international collaborations from the White House and agencies, in particular the NIH, is of special interest as is the impact of the new Administration.

The report is based on published studies and information, searches in databases, interviews as well as analysis of the gathered materials. We would like to express our gratitude to those who have freely shared their time, experience and views with us. The report was written by Eva Hunnius Ohlin and Martin A. Wikström (project leader), ITPS Washington D.C. The Project Manager for the international benchmarking project is Anna Sandström, VINNOVA.

VINNOVA in June 2009

Gunnel Dreborg
Acting Director and Head,
Strategy Development Division

Contents

1 Sammanfattning 9

2 Abstract 11

3 Introduction 13

4 The United States and the world 15

5 Distribution of R&D funding within the United States 18
- 5.1 Federal R&D funding 19
  - 5.1.1 What will Barack Obama do? 23
  - 5.1.2 The American Recovery and Reinvestment Act (ARRA) 24
- 5.2 Funding of research and development by non-profit organizations and individuals 25
- 5.3 Industry R&D 26
- 5.4 The States 27

6 The Department of Health and Human Services 29
- 6.1 The Agencies of the Department of Health and Human Services 30
  - 6.1.1 The Biomedical Advanced Research and Development Authority (BARDA) 31

7 National Institutes of Health (NIH) 32
- 7.1 NIH researchers 33
- 7.2 Individual institutes 35
- 7.3 The Common Fund and the NIH Roadmap 37
  - 7.3.1 Brief descriptions of a number of Roadmap Initiatives 39
- 7.4 The Fogarty International Center 44
- 7.5 Examples of federally prioritized disease areas 46
  - 7.5.1 Obesity 46
  - 7.5.2 Cancer 47
  - 7.5.3 Heart Disease and Stroke 48

8 The Food and Drug Administration 49
- 8.1 The Critical Path 50
- 8.2 Research activities 50
- 8.3 Budget 52

9 The Center for Disease Control (CDC) 55
- 9.1 The Coordinating Center for Environmental Health and Injury Prevention (CCEHIP) 55
- 9.2 The Coordinating Center for Health Information and Service (CCHIS) 56
- 9.3 The Coordinating Center for Health Promotion (CCHP) 56

9.4 Coordinating Center for Infectious Diseases (CCID) ... 57
9.5 Coordinating Office for Global Health (COGH) ... 57
9.6 The Coordinating Office for Terrorism Preparedness and Emergency Response (COTPER) ... 58
9.7 Office of Strategy and Innovation (OSI) ... 58
9.8 The National Institute for Occupational Safety and Health (NIOSH) ... 59

10 The Agency for Healthcare Research and Quality (AHRQ) ... 60

11 The National Science Foundation (NSF) ... 62

12 The Department of Defense (DOD) ... 64
12.1 Defense Advanced Research Project Agency (DARPA) ... 65
12.2 Other Defense research agencies ... 66

13 The National Nanotechnology Initiative (NNI) ... 68

14 The Network and Information Technology Research Development program (NITRD) ... 69

15 The Institute of Medicine of the National Academies ... 70

16 Innovation, research and technology transfer ... 71
16.1 The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs ... 71
16.2 Overall technology transfer trends from academic institutions ... 74
16.3 Biotechnology patents* ... 78

17 International collaborations in the life sciences ... 79
17.1 Office of Science and Technology Policy (OSTP) ... 79
17.1.1 Criteria for U.S. participation in international scientific collaborations ... 80
17.2 Department of State ... 82
17.3 National Institutes of Health (NIH) ... 82
17.3.1 Collaborations between Swedish actors and the NIH ... 83
17.3.2 Fogarty International Center ... 84
17.4 National Science Foundation (NSF) ... 84
17.5 Discussion ... 85

18 The Universities ... 87
18.1 What U.S. universities are best in the life sciences? ... 87
18.1.1 U.S. News and World report ... 87
18.1.2 The Times rankings ... 88
18.2 The wealthiest U.S. universities ... 90
18.3 Descriptions of life science research and development at two universities ... 91
18.3.1 Duke University (North Carolina) ... 92
18.3.2 University of Massachusetts ... 96

18.4 Private or public 102

19 Discussion and Conclusion 104

Appendix 1 107

Appendix 2 111

References 113

1 Sammanfattning

USA är och har länge varit ledande inom biomedicinsk forskning och utveckling. Många av världens ledande akademiska institutioner finns i landet och en kultur med en mycket positiv attityd till innovation har resulterat i ett antal regioner med starka universitet och företag. Några exempel på delstater med sådana regioner är Massachusetts, Kalifornien, Maryland och New York. De amerikanska regioner som har högst andel bioteknologiska (i bred bemärkelse) patent finns i Kalifornien, Massachusetts och New York. Det är dock relativt få universitet som har stora patentinkomster. Den farmakologiska/medicinska industrin utgör den största industrigruppen inom den kemiska industrisektorn som är speciellt prominent i New Jersey, Pennsylvania och Connecticut. Biomedicinskt aktiva företag finns också inom servicesektorn för forskning och utveckling (FoU). FoU-anläggningar inom sektorn finns i hög grad i Massachusetts, Kalifornien och Pennsylvania.

USA står för ungefär hälften av världens FoU-investeringar och spenderar ca 2,6 % av BNP på forskning och utveckling. Landet är dock heterogent och forskningsintensiteten varierar stort mellan delstaterna. Den federala staten är den största finansiären av FoU vid universitet och högskolor. Den största andelen av federala investeringar i biomedicinsk FoU görs genom Department of Health and Human Services (HHS) och dess myndigheter. National Institutes of Health (NIH), den största civilt orienterade federala forskningsfinansiären bedriver forskning vid både egna anläggningar och genom att finansiera verksamhet vid framför allt universitet och högskolor. För 2009 har NIH fått sin första (inflationsjusterade) ökning av budgeten sedan 2003 och tilldelades dessutom över 10 miljarder USD extra i ”the American Recovery and Reinvestment Act” (ARRA). NIH’s totala budget kommer därmed att nå nära 41 miljarder USD under 2009. Många andra forskningsmyndigheter har också tilldelats budgetökningar 2009 och den nya administrationen verkar se investeringar i FoU som en viktig åtgärd för att bekämpa den ekonomiska krisen. NIH bedriver FoU genom sina 27 institut och centra även om vissa breda och/eller speciellt viktiga strategiska initiativ sker genom ”the NIH Common Found” och ”the NIH Roadmap”. Ett exempel på ett område som bedöms som speciellt viktigt är investeringar i forskning med hög risk och hög potentiell nytta. Andra federala myndigheter involverade i biomedicinsk FoU inkluderar "the Center for Disease Control”, “the Food and Drug Administration”, “the Defense Advanced Research Program Agency”, “the National Science foundation” med flera.

Den federala regeringen stimulerar forskning och innovation i mindre företag på flera sätt. Ett av de viktigaste är de “Small Business Innovation Research” (SBIR) program som alla federala forskningsmyndigheter med en budget för externa forskningsprogram överstigande 100 miljoner USD måste driva. SBIR-programmen utvärderades nyligen och förlängdes fram till halvårsskiftet 2009. Programmen kommer dock med all sannolikhet att fortsätta efter det även om mindre justeringar kan komma att ske.

Amerikanska universitet kan vara antingen privata eller delstatliga. I rapporten beskrivs kortfattat biomedicinska initiativ vid två välkända universitet; Duke University (privat) och University of Massachusetts (delstatligt). Båda dessa universitet visar på den rådande trenden att investera i translationell forskning. Det har framkommit att privata universitet kan nå en större autonomi jämfört med delstatliga. Detta är sannolikt beroende på en lägre grad av aktiv styrning från delstaten. Man bör dock vara medveten om att förhållandena för privata universitet varierar mycket, inte minst vad gäller förmögenhet och tillgångar som kan användas för att profilera universitetet. Det är också intressant att notera att vissa delstatliga universitet får en relativt liten del av sin budget från den egna delstaten.

2 Abstract

The United States (U.S.) has long been, and still is, world leading in life science research and development (R&D). Many of the best academic institutions are located in the country and a culture positive to innovation as well as the presence of venture capital has led to the emergence of a number of regions with top universities and businesses. Examples of states with such regions include Massachusetts, California, Maryland and New York. The U.S. regions that have the highest shares of biotechnology (in a broad sense) patents are located in California, Massachusetts and New York. However, incomes to universities from patents come from relatively few patents and few universities enjoy large patent incomes.

The pharmaceutical/medical industry is the largest industry within the U.S. chemical industry sector although life science companies are present also in the R&D services sector. Chemical industry is in particular prominent in New Jersey, Pennsylvania and Connecticut while R&D performed by the R&D service industry is strong in Massachusetts, California and Pennsylvania.

The U.S. is responsible for around one third of the world's investments into R&D and spends approximately 2.6% of GDP on R&D. The country is, however, heterogeneous and the research intensity varies strongly between the states.

The federal government is the largest investor into R&D at universities and colleges. Most federal life science investments are made through the Department of Health and Human Services (HHS) and its agencies. The National Institutes of Health (NIH) performs biomedical R&D both intramurally and extramurally and is the largest non-defense federal research funder. In 2009, the NIH received its first funding increase (adjusted for inflation) since 2003 and also received more than 10 billion USD in extra funding through the American Recovery and Reinvestment Act (ARRA). In total, the 2009 NIH budget reaches nearly 41 billion USD and many other agencies have also received budget increases for 2009. The new administration appears to see investments in R&D as one important way to counter the current economic crisis. NIH performs R&D through its 27 institutes and centers although some broad and/or in particular urgent strategic initiatives are managed through the NIH Common Found and the Roadmap. One area that the Roadmap and other initiatives address is the stimulation of high risk high reward research. Other federal agencies involved in life science R&D include the Center for Disease control, the

Food and Drug Administration, the Defense Advanced Research Program Agency, the National Science foundation and others.

The federal government stimulates small business research and innovation in a number of ways including through the successful Small Business Innovation Research (SBIR) programs that all federal agencies with an extramural R&D budget exceeding 100 million USD are required to apply. The SBIR programs were recently evaluated and are likely to be continued, although with some adjustments.

U.S. universities may be either private or public and in this report we briefly describe life science initiatives at two well known universities; Duke University (private) and the University of Massachusetts (public). Both these universities demonstrate the current trend to invest in translational research. It appears that private universities may have a greater degree of autonomy compared to public universities. This is likely due to less active regulation by the state. However, the conditions vary strongly for private universities including the endowment levels. This is important as the fortune and assets of the institution may be used to make strategic investments. Furthermore, it is interesting to note that some public universities receive a relatively small part of their budget from the state government.

3 Introduction

Similar to the situation in Sweden, the majority of R&D in the U.S. is performed by industry[1] and the private sector is responsible for approximately two thirds of all R&D funds. However, as in many countries, R&D activities in industry are heavily development-oriented.

The federal government and its agencies normally use approximately 140 billion USD for R&D funding annually[2]. Universities and colleges are the largest recipient of federal R&D funds and also receive the largest proportion of the funding for R&D from the federal government[3] through its multitude of agencies.

Biomedical research is high up on the political agenda in many countries, not least in Sweden and the United States of America (U.S., USA).

The U.S. is a leading Research and Development (R&D)-nation in many scientific and engineering areas[4]. One out of many examples is the biomedical fields or the life sciences[5]. The American research and educational structures are very different from the Swedish structures as, in the U.S. system, a large number of federal agencies and departments are required to perform and fund R&D within their specific areas of responsibility. Examples include the federal Department of Energy[6] (DOE) which is required to perform and fund research relevant for energy production including new and sustainable technologies and the Department of Defense[7] (DOD) which is responsible for defense-related research and development including not only weapons development but also areas such as the physiological impact on the soldier. Other examples of departments, agencies and institutes that perform R&D are the National Institute of Standards and Technologies (NIST) that belong to the Department of Commerce (DOC), the National Science Foundation (NSF), and, for

[1] http://www.nsf.gov/statistics/nsf08318/pdf/tab1.pdf
[2] http://www.aaas.org/spp/rd/09ptbi1.pdf
[3] http://www.nsf.gov/statistics/nsf08318/pdf/tab1.pdf
[4] http://www.nsf.gov/statistics/seind08/c4/c4h.htm#c4h6
[5] The term “life sciences” is clouded by some confusion. The life sciences can be said to deal with sciences aimed at improving health and also activities that deal with agricultural R&D, production of biofuels, animal health and genetic modifications of organisms for a multitude of reasons. In this text we have chosen to use the term “life science(s)” as synonymous with biomedical sciences unless otherwise stated.
[6] http://www.doe.gov
[7] http://www.dod.gov

biomedical research, the National Institutes of Health (NIH), the Center for Disease Control (CDC) and the Food and Drug Administration (FDA).

The NIH, CDC and FDA are all agencies that belong to the Department of Health and Human Services[8] (HHS). The NIH is, by far, the most important federal research organization in the biomedical field and performs research both intramurally (in house) and extramurally (through funding of R&D outside the NIH). NIH consists of 27 individual institutes and centers and is the largest federal civilian R&D funder in the U.S. with an annual budget of around 30 billion US dollars (USD). Because of the special circumstances during 2009 and in particular the America Recovery and Reinvestment Act[9], the NIH budget will however most likely exceed 40 billion USD this year.

In addition to NIH funding, life science R&D is financed by many organizations in the public and private sectors including foundations, universities and colleges, other non-profit organizations and industry.

In this report, we describe the U.S. research-funding situation as well U.S. life science R&D in relation to the rest of the world. In addition, we discuss the large heterogeneity within the U.S. The R&D intensity varies strongly in between the different states and Massachusetts, Maryland and California are examples where there are strong investments in R&D. Major federal funding agencies of R&D in the life sciences are described, their funding levels, as well as some of their prioritized areas. We also discuss how the agencies work to stimulate innovation at universities. The attitude to international collaborations from the White House and agencies, in particular the NIH, is of special interest. A number of rankings of life science activities at universities as well as the economic situation of major top-level universities are described. This is of interest not least as high endowment levels make it easier for universities to act independently and enjoy a large degree of autonomy. Furthermore, although rankings often are difficult to interpret, they have a large impact in themselves. Life science initiatives at the private Duke University and the public University of Massachusetts are described. The descriptions illustrate how universities can take various interesting initiatives not least with regard to the translation of research results and clinical medicine. The university-studies also illustrate some of the differences between private and public universities including some problems and benefits of being on or the other.

In addition, we briefly describe the life science industry situation including the geographical locations.

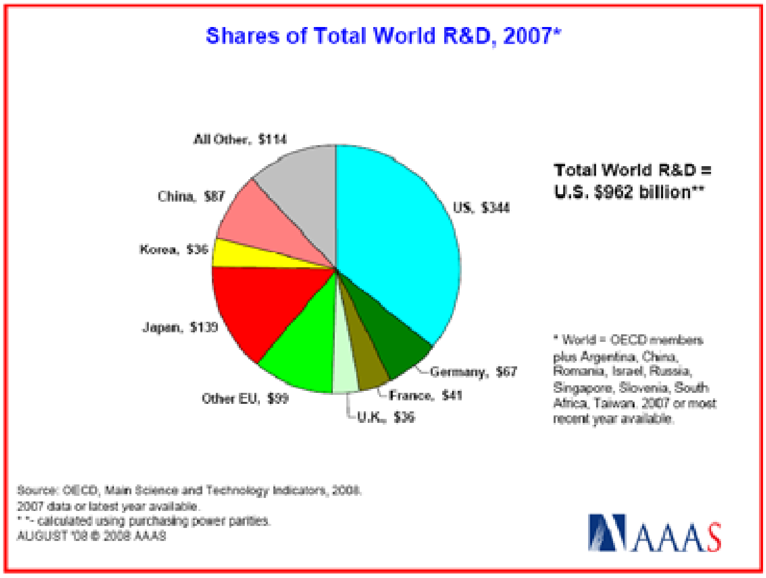
---

[8] http://www.hhs.gov
[9] http://www.nih.gov/recovery/index.htm

4 The United States and the world

The world's total R&D expenditures were at least 962 billion USD in 2007 [1] of which the United States stood for approximately one third (fig. 1). The U.S. and the second largest R&D investor Japan together accounted for around 50%.

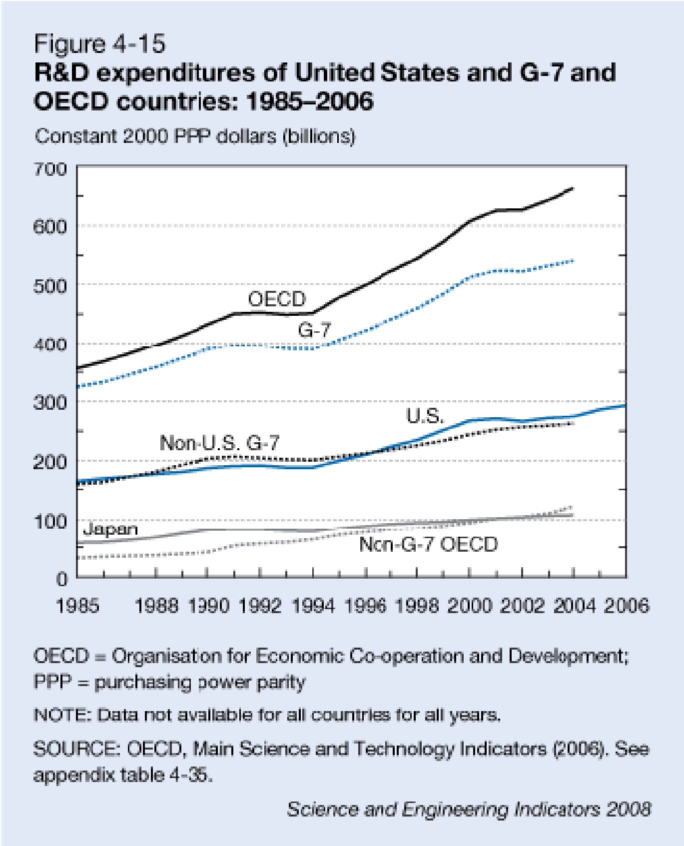
Figure 1 Distribution of the worlds R&D investments



Sources: American Association for the Advancement of Science (AAAS) and the OECD Main Science and Technology Indicators (2008)

The OECD-countries were responsible for R&D investments accounting for 726 billion USD in 2004 of which the G-7 countries accounted for 83% [2]. The U.S. made more than 50% of the G-7 investments in 2004, a level that has been relatively consistent during the last 25 years (fig 2). Some developing countries like China have made large investments in R&D. In 2000, China invested 45 billion USD which had grown to an estimated 115 billion USD in 2005 [2].

Figure 2 R&D expenditures by the U.S., Japan, the OECD and the G-7 countries (constant 2000 PPP dollars)



Source: OECD Main Science and Technology indicators

Overall the U.S. invested 2.57% of its GDP into R&D in 2006 [2]. However, the level of investments varies significantly in between U.S. states. Massachusetts, a state with many prominent universities and an economy larger than Sweden's had an R&D intensity of approximately 5% in 2001. The nations investing most in R&D per GDP were:

1 Israel (4.7%, 2005)
2 Sweden (3.9%, 2005)
3 Finland (3.5%, 2006)
4 Japan (3.2%, 2004)
5 South Korea (3.0%, 2005)

The U.S. basic research funding by GDP ratio was 0.5% in 2004, similar to France, Denmark and Iceland. Interestingly, according to the National Science Foundation [2], Switzerland had the largest funding for basic research by GDP (0.8%) followed by Israel. It is however important to be aware that many countries (including Sweden) do not report basic research funding separetely. China is at the other end of the spectrum and invested only 0.07% of its GDP in basic research or 6% of its total R&D investments

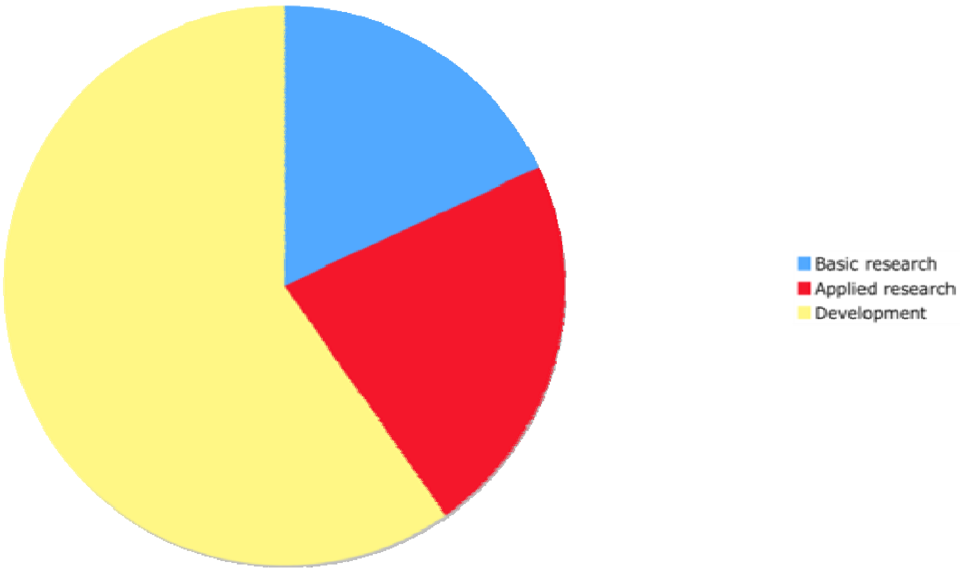
(2004). In many cases, it is difficult to define “basic science” and definitions may therefore vary.

5 Distribution of R&D funding within the United States

Funding for research and development in the United States comes from many sources. The most important ones are the federal government, the states, private organizations including industry, universities and non-profit organizations, as well as private individuals.

In 2006, the U.S. R&D funding was approximately 340 billion USD of which industry was responsible for approximately 66% while it was responsible for 71% of R&D performance [2]. The federal share of R&D funding was around 28% (2006) while colleges, universities, private foundations, non-profit organizations and non-federal public entitities (including states and local governments account for approximately 7% of the investments [2]. The relative investments in basic research, applied research and development can be seen in fig 3.

Figure 3 Distribution of U.S. R&D investments (2006)



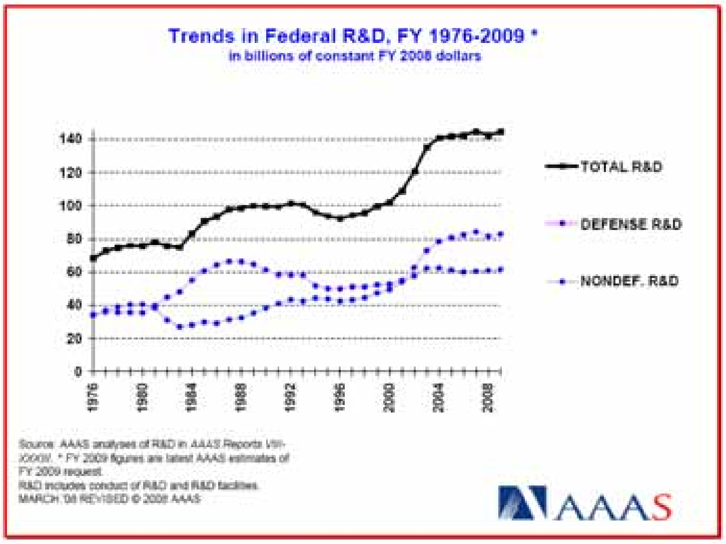
Source: National Science Foundation (NSF), Science and Engineering indicators 2008

The U.S. investments in basic research amounted to 62 billion USD of which 59% was federally funded while applied research was funded with approximately 75 billion USD (2006). Universities and Colleges were responsible for 56% of all basic research. 16% of the total U.S. R&D was defense-related [2].

5.1 Federal R&D funding

The federal funding for R&D was approximately 140 billion USD in 2008 [1,2]. Defense-related R&D increased sharply after the terrorist attacks of 2001 while non defense R&D remained largely unaffected. Approximately 60% of the federal R&D investments were defense related in 2008 (fig 4) and funded by the Department of Defense, Department of Energy and the Department of Health and Human Services [2].

Figure 4 Federal investments in defense related and non defense related R&D



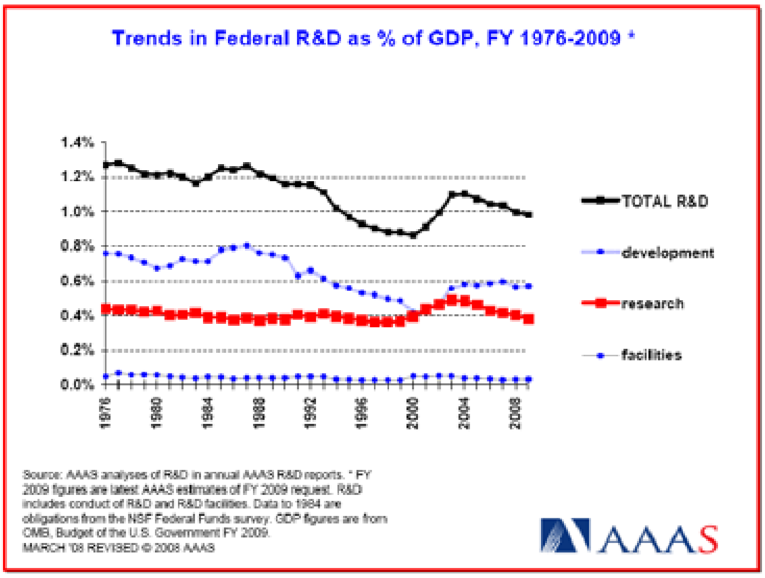
Source: American Association for the Advancement of Science (AAAS, 2008)

Expressed as fraction of GDP, the total federal investments in R&D declined between 2004 and 2008 when it was around 1.0 % [1]. In particular, the funding for research has been diminished since the top year 2003 while development has been less affected (fig 5).The situation is however likely to change with the newly inaugurated President Obama. In addition, the conditions for 2009 are exceptional as a consequence of the America Recovery and Reinvestment Act (ARRA). The ARRA and likely consequences of the new administration are discussed in separate chapters and the description here primarily concerns the budget proposal for 2009.

According to President Bush's budget proposal for 2009, the federal government would spend 147.4 billion USD on research and development [1] which would constitute an increase of 3.4 % or 4.9 billion USD compared to 2008. Of the total amount, approximately 80 billion USD is defense related in a broad sense.

57.3 billion USD is marked for research which constitutes a decline of 0.3 % compared to the previous year. Development will however see strong gains in some areas. As mentioned above the funding for research has declined during the last five years after a high in 2003 (fig 5).

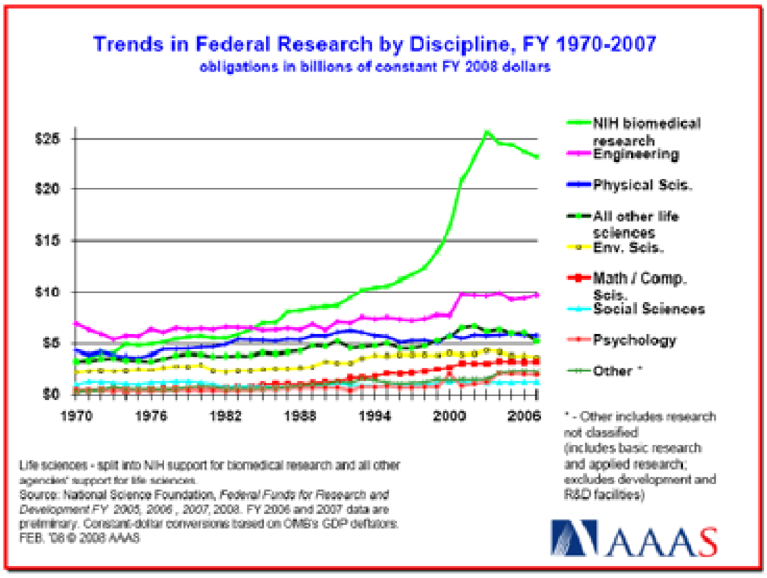
Figure 5 Trends in federal investments in R&D expressed as fraction of GDP



Source: American Association for the Advancement of Science (AAAS, 2008)

In all, the reduction since 2004 amounts to 9.1 % in constant dollars (adjusted to inflation). Biomedical research saw large funding increases (fig 6) from 1998 to 2003 due to a strategic investment in biomedical R&D at NIH. Since 2003, NIH funding has been in a negative trend. With the new President, the situation is however likely to improve for research at many agencies including the NIH.

Figure 6 Trends in federal research funding broken down by discipline



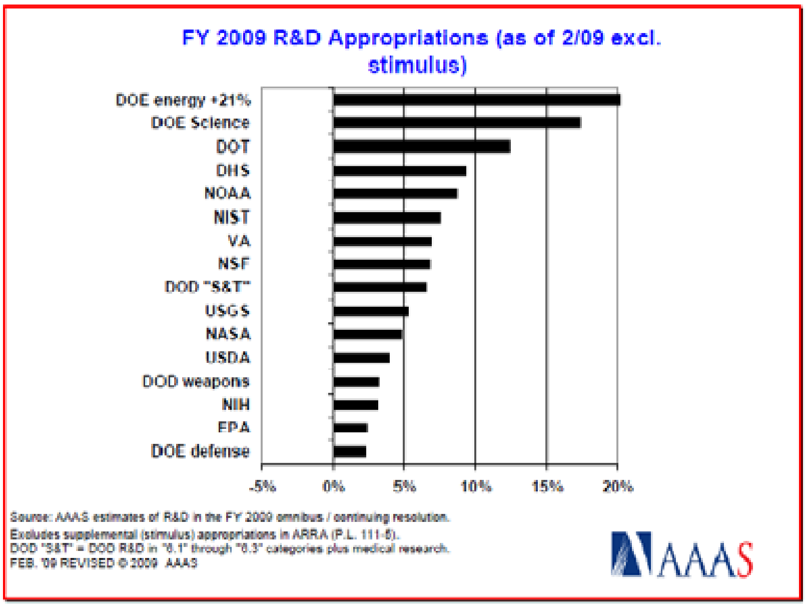
Source: American Association for the Advancement of Science (AAAS, 2008)

In his American Competitiveness Initiative (ACI, 2006)[10][3,4], former President Bush suggested a doubling of the funding for federally funded R&D within the physical sciences. These include areas such as physics, chemistry, engineering, mathematics and computer science. ACI included strong support for energy research and also included educational and workforce initiatives. The ACI was to a large extent a response to the National Academy of Sciences (NAS) 2005 report ”Rising Above the Gathering Storm” [5] which indicated areas in which the U.S. position needs to be strengthened to maintain the nations competitive edge. Under the initiative funding for the three ACI agencies; the National Science Foundation (NSF); the National Institute for Standards and Technology (NIST) and the Department of Energy, Office of Science (DOE-OS) would be doubled over a period of five years. Both parties in the Congress were generally supportive of the proposal although discussions and adjustments were made. The Congress then passed a bill called the America COMPETES Act in 2007[11]. However, in the budget negotiations for 2008, Congress did not set aside enough funds for the initiative which therefore was severely underfunded. President Bush’s budget proposal for 2009 again contained strong R&D budget increases for NSF, NIST and DOE-OS. DOE-OS would receive a budget increase of 20.7 % (to 4.3 billion USD), NIST would receive 447 million USD (+16.1%) while NSF would get a budget boost to 5.2 billion USD (+15.5%). The R&D budget decisions for FY 2009 (fig 7) were finally approved in March 2009[12] and the three agencies received funding levels approximately in accordance with the America COMPETES Act and President Bush’s proposal (NSF: 4.8 billion USD (+6.8%); DOE-OS: 4.3 billion USD (+17.3%); NIST 561 million USD (+7.5%); all figures exclude ARRA funds).

Defense R&D is presently at very high levels and will be 86.2 billion USD in 2009[13] (+3.8%). Basic research within the DOD will reach 1.8 billion USD while funding for applied research will be 5.1 billion USD[14]. The special Medical research program appropriated in the Defense Health Program is funded with 903 million USD.

[10] http://en.wikipedia.org/wiki/American_Competitiveness_Initiative
[11] http://science.house.gov/legislation/leg_highlights_detail.aspx?NewsID=1938
[12] http://www.aaas.org/spp/rd/omnibus09.htm
[13] http://www.aaas.org/spp/rd/omnibus09.htm
[14] http://www.aaas.org/spp/rd/dod09c.htm#tb

Figure 7 Changes in R&D funding for federal agencies in the final appropriations bill for 2009

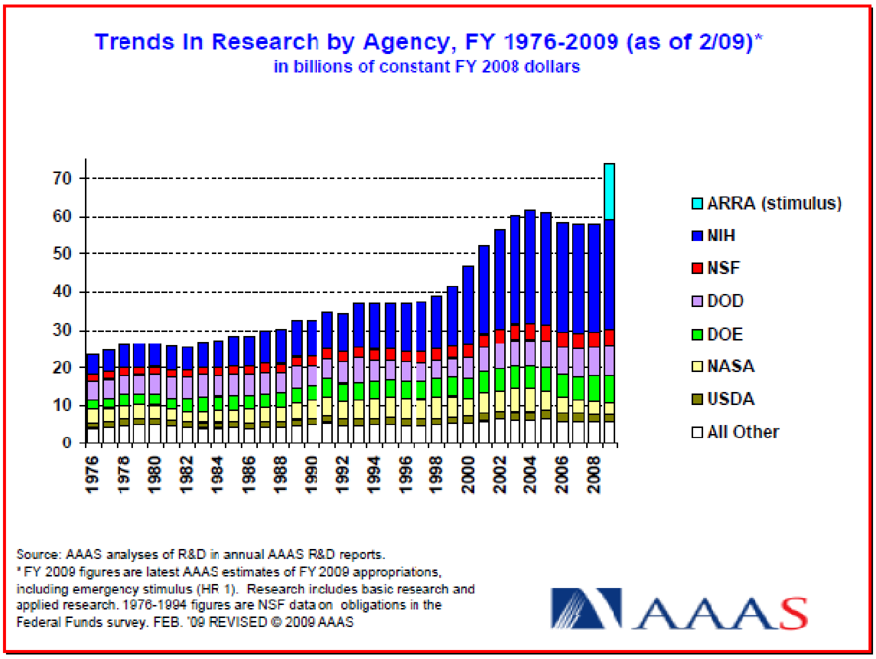


Source: American Association for the Advancement of Science (AAAS)

Life science research and development is funded and performed at a number of different agencies under the Department of Health and Human Services (HHS). However, some life science R&D is also performed and funded within other departments such as the Department of Defense and the Department of Veterans Affairs (VA). NIH, which may be the world's largest civilian public R&D funder and performer, would, in the original request from President Bush receive the same level of funding as during 2008 (29.5 billion USD). However, in the final decision from Congress, funding for NIH has been increased by 3.2% to a total of 30.5 billion USD (fig 7).

The funding levels of the most prominent federal agencies can be seen in fig 8. For more information on NIH and NIH funding, see chapter 7.

Figure 8 R&D funding for the most important federal agencies over time



Source: American Association for the Advancement of Science (AAAS). Please observe the ARRA funding which is described in chapter 5.1.2

5.1.1 What will Barack Obama do?

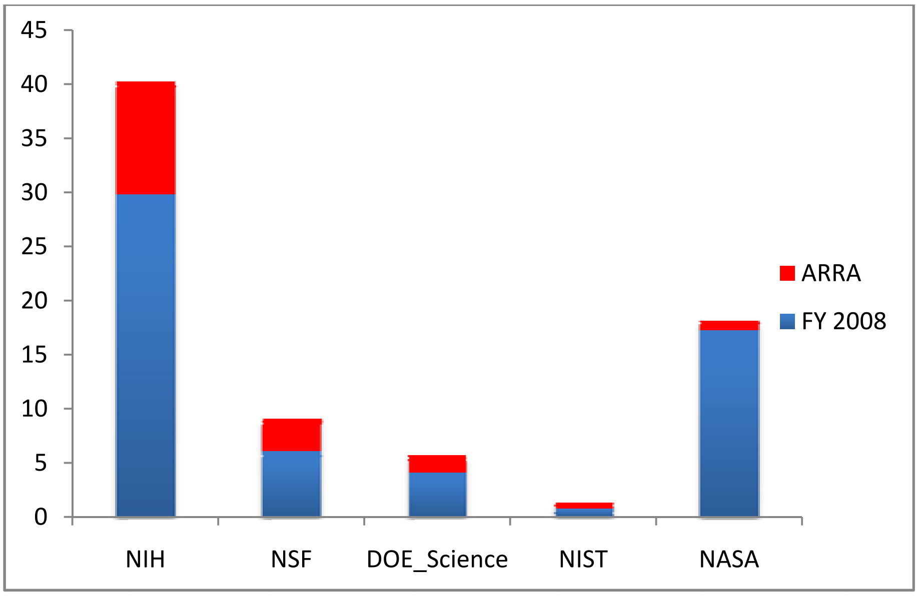
What priorities will President Obama give to Science and Engineering? It is difficult to assess how the new President will act and what areas he will prioritize. This is also dependent on the turbulent economy. However, during the election campaign [7,8] and also during the first months of his term, the President has clearly indicated that he plans to strengthen the federal research funding and there are even unconfirmed rumors that he may suggest a new ”doubling” of the NIH budget over a number of years. From the appropriations for 2009 that, in most cases, were approved in March 2009, it is clear that many federal R&D agencies (including NIH) will enjoy increased funding. Funding for the ACI agencies (NSF, NIST and DOE-OS) are in line with the America COMPETES Act and one area that is high up on the agenda is energy R&D. Furthermore, the new President may chose to strengthen initiatives to improve education in science, technology, engineering and mathematics (STEM) in schools[15]. President Obama has also said that he wants to strengthen the role of the Presidents Science Advisor, Professor John Holdren[16].

[15] http://www.barackobama.com/pdf/issues/FactSheetScience.pdf
[16] http://www.msnbc.msn.com/id/29795769/

5.1.2 The American Recovery and Reinvestment Act (ARRA)

The American Recovery and Reinvestment Act (ARRA) of 2009 includes investments of approximately 21.5 billion USD in research and development. Out of these, approximately 18 billion USD will be used for performance of R&D and 3.5 billion USD for infrastructure and large-scale equipment. The total federal investments earmarked for infrastructure were 4.5 billion USD in 2008. A special challenge for the federal funding agencies is that the ARRA funds are a one-time investment. Furthermore, they have to be spent within two years and can only be used for investments in the U.S.

Figure 9 The likely effects on R&D funding at some federal agencies based on the American Recovery and Reinvestment Act (ARRA) and FY 2008 funding



Source: American Association for the Advancement of Science (AAAS)

NIH received 10.4 billion USD in the stimulus package which constitutes the single largest investment that any federal R&D-investing agency receives. However, substantial investments are also made through for instance the NSF, NIST or Department of Energy (fig. 9). ARRA funding together with the normal annual funding results in that the total NIH budget is likely to reach near 41 billion USD during 2009. The normal appropriations were finalized on March 11th (2009) and resulted in strong funding increases for many federal agencies including the NIH. The estimated total R&D funding levels in fig 9 are therefore lower than the actual figures. The federal agencies that receive funding from ARRA are requested to perform a detailed reporting of how they will use the funds during the program. Continuous information concerning ARRA can be found at www.recovery.gov. Interestingly, the NSF has started a research program[17] on the ARRA.

5.2 Funding of research and development by non-profit organizations and individuals

Foundations, voluntary health organizations and other non-profit organizations (npo's) as well as private individuals are important funders of research and development. In 2006, 5-7%[18][2] of the funding for academic R&D came from such organizations and individuals. No specific data has been found for the life sciences, however, such funding can be expected to be in particular important for health-related research. One of the most important npo's is the Howard Hughes Medical Institute[19] (HHMI), founded in 1953, that has invested more than 8.3 billion USD in R&D during the last 20 years. The Institute commits almost 700 million USD per year for R&D and distributes more than 80 million USD in support for science education. HHMI funds talented researchers within the biomedical fields - at present 355 investigators selected through national competitions including 13 Nobel Prize Winners and 124 members of the National Academy of Sciences. Hughes laboratories are located at 71 U.S. universities, research institutes, medical schools, and affiliated hospitals. The Institute also has its own research establishment, Janelia Farm, in Virginia outside Washington D.C. Research at Janelia Farm is currently focused on the identification of the general principles that control how information is processed by neuronal circuits as well as the development of imaging technologies and computational methods for image analysis.

The American tradition, that a person who has made a fortune should give donations back to the society has resulted in many interesting initiatives. One example is the Broad Institute[20] in Cambridge, Massachusetts that is connected to both Harvard University and the Massachusetts Institute of Technology (MIT). The aim of the Broad Institute is *to pioneer a "new model" of collaborative science that would transform medicine with the power of genomics.* The Institute was founded in 2003/04 on a gift of 100 million USD from Eli and Edythe Broad. The Broad's founding gift was later increased to 200 million USD and they also made a subsequent gift of 400 million USD in 2008. At this time the total gift from the Broad's has therefore reached 600 million USD.

[17] http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf09034
[18] http://www.nsf.gov/statistics/seind08/c5/c5s1.htm
[19] http://www.hhmi.org/
[20] http://www.broad.mit.edu/

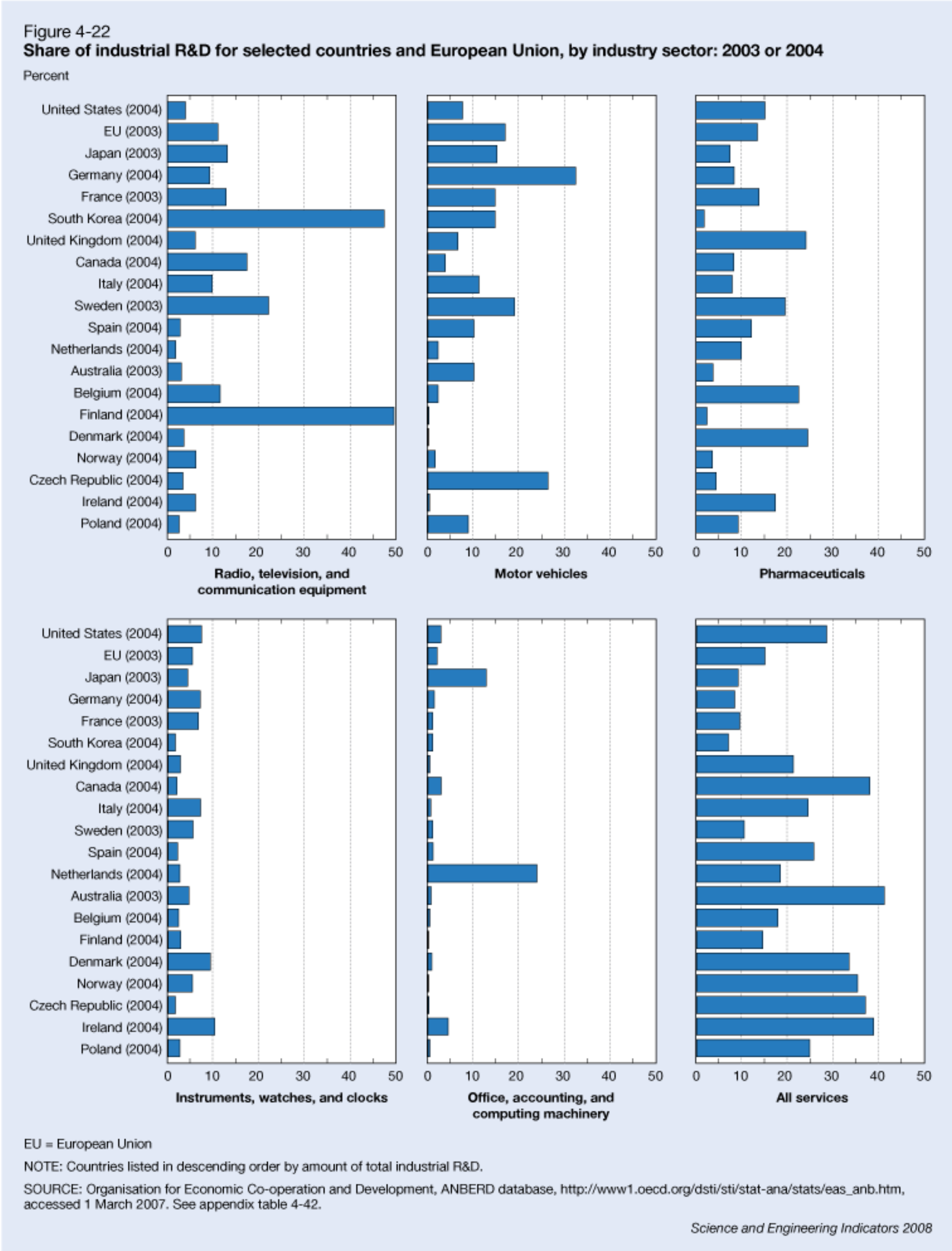
5.3 Industry R&D

In 2005, the private sector was responsible for R&D performance amounting to 226 billion USD of which 22 billion (9.7%) was funded by federal sources [2]. Four manufacturing and two services industries account for 75% of company-funded business R&D and 95% of federally funded business R&D. The sectors are computers & electronics products, chemicals, computer-related services, aerospace and defense manufacturing, R&D services, and automotive manufacturing. The chemical industry sector performed R&D worth 43 billion USD in 2005 and received little federal support. The largest industry in this sector was the pharmaceutical/medical industry which invested 34.8 billion USD (2005) or 81% of the nonfederal R&D in the sector. According to the Pharmaceutical Research and Manufacturers of America (PhRMA)[21], its members domestic R&D investments support R&D in projects that originated in their own laboratories although 25% supports R&D on products licensed from other companies (e.g. biotechnology companies), universities, or the government [8]. A large fraction of the biotechnology companies are classified as belonging to the R&D services group. The R&D performed by companies in this sector and funded by company or other nonfederal sources amounted to 11.9 billion in 2005. Companies in the sector also performed federally funded R&D amounting to 5.1 billion USD.

The shares of all industry R&D performed by different industrial sectors in various countries can be seen in fig 10. It is interesting to note that the pharmaceutical industry is responsible for around 20% or more of all business R&D in Denmark, the UK and Sweden. Among the top 20 corporate spenders on R&D globally are three U.S.-based multinational pharmaceutical corporations. These are Pfizer corporation that invested 6.6 billion USD in R&D during 2004 (rank 4), the Johnson & Johnson corporation which invested 5.2 billion USD (rank 10) and the Merck corporation (3.9 billion USD, rank 20). As a comparison, Merck corporation invested 0.1 billion USD more than the UK-based AstraZeneca corporation.

[21] http://www.phrma.org/

Figure 10 Industrial R&D broken down by sector and country



Source: OECD ANBERD database

5.4 The States

The top 10 R&D performing states account for more than 60% of all R&D expenditures in the U.S. In table 1 is depicted state rankings for total R&D, industry R&D, R&D performed by universities and colleges as well as state research intensity.

Table 1 State rankings of sector R&D

Top 10 states in R&D performance, by sector and intensity: 2004

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Industry	U&C	Federal intramural and FFRDC[b]	State	R&D/GDP (%)	GDP (current $billions)
1	California	59 607	California	California	Maryland	New Mexico	8,01	63,9
2	Michigan	16 722	Michigan	New York	California	Maryland	6,26	229,2
3	Massachusetts	15 987	Massachusetts	Texas	New Mexico	Massachusetts	5,17	309,5
4	Maryland	14 341	New Jersey	Maryland	Virginia	Michigan	4,6	363,4
5	Texas	14 266	Texas	Pennsylvania	District of Columbia	Rhode Island	4,38	42,2
6	New York	13 113	Washington	Massachusetts	Massachusetts	Washington	4,33	252,4
7	New Jersey	12 460	New York	Illinois	Illinois	Connecticut	4,28	183,9
8	Illinois	11 300	Illinois	North Carolina	Washington	California	3,93	1 515,50
9	Washington	10 936	Pennsylvania	Michigan	Alabama	New Hampshire	3,22	51,7
10	Pennsylvania	10 813	Connecticut	Ohio	Tennessee	District of Columbia	3,06	77,8

FFRDC = federally funded research and development center; GDP = gross domestic product; U&C = universities and colleges

[a]Includes in-state total R&D performance of industry, universities, federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b]Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTE: Rankings do not account for margin of error of estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Bureau of Economic Analysis, Gross Domestic Product by State (2006), http://www.bea.gov/regional/gsp, accessed 25 August 2007.

Science and Engineering Indicators 2008

Source: National Science Foundation (NSF), Science & Engineering indicators (2008)

Chemical industry R&D is particularly prominent in New Jersey (56% of all state R&D), Pennsylvania (54%) and Connecticut (50%) while R&D performed by the R&D services industry is strong in Massachusetts, California and Pennsylvania (table 2.).

Table 2 Industry R&D performance broken down by sector

Top 10 states in industry R&D performance and share of R&D, by selected industry: 2005
(Percent)

State	Industry-performed R&D (current $millions)	Chemicals	Computer and electronic products	Computer-related services	R&D services	Motor vehicles
All states	226 159	19,0	19.2 L	13,5	7,5	7.1 L
California	50 683	11,2	33,2	15,0	10,7	D
Michigan	16 752	9,5	2,3	D	1,5	74,3
Massachusetts	13 342	13,2	41,1	D	11,1	D
New Jersey	13 214	65,7	5,7	3,5	5,6	0,2
Texas	12 438	4,7	37,4	18,3	6,3	0,5
Washington	9 736	5,5	5,6	D	6,3	0,7
Illinois	9 712	18,9	37,4	5,1	1,7	2,4
New York	9 474	28,4	6,6	18,8	3,7	D
Pennsylvania	8 846	54,2	6,9	6,0	8,3	0,4
Connecticut	7 885	50,3	3,5	2,4	4,0	0,1

L = lower-bound estimate; D = suppressed to avoid disclosure of confidential information

NOTES: Rankings do not account for margin of error of estimates from sample surveys. Detail does not add to total because not all industries shown.

Source: National Science Foundation (NSF), Science & Engineering indicators (2008)

6 The Department of Health and Human Services

Of the world's medical R&D, 70% is carried out in the United States[22]. Medical R&D in the U.S. is carried out by private industry, universities, private and public research centers, government agencies etc. The federal government and in particular the Department of Health and Human Services (HHS) plays an important role in financing biomedical R&D primarily through its large support of the National Institutes of Health (NIH) and other agencies. The federal government, though its agencies, is the largest funder of R&D at universities and colleges.

The HHS is the largest federal department with a 2007 fiscal year budget of 698 billion USD[23], representing approximately a quarter of all federal expenditures and staffed with approximately 67,000 individuals. It should however be noted that the budget includes the Medicaid (health-care insurance for low-income individuals) and Medicare (care program for those over 65, for disabled or who suffer from end-stage renal disease) programs.

The HHS mission is to enhance the health and well-being of U.S. citizens by providing efficient and high quality human services and by promoting advances in the sciences underlying medicine, public health and social services. Biomedical R&D on the federal level is primarily supported by the department.

The former Secretary of Health, Mr. Leavitt developed a number of *core principles* (headings) for HHS. These are:

- National standards, neighborhood solutions
- Collaboration, not polarization
- Solutions that transcend political boundaries
- Markets before mandates
- Protect privacy
- Science for facts, process for priorities
- Reward results, not programs
- Change a heart, change a nation
- Value life

---

[22] Milken Institute (2006) Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization
[23] http://www.hhs.gov/

HHS runs over 300 different programs and initiatives of which many include biomedical research. Some of the objectives involving R&D are:

- Assuring the safety of foods and medical products
- Planning and preparing for public health emergencies including those that result from terrorism
- Conducting, supporting and overseeing scientific and biomedical R&D related to health and human services

HHS has identified four strategic goal areas that include health care, public health promotion and protection including disease prevention and emergency preparedness, human services and scientific research and development. Four broad objectives have been identified in the scientific R&D goal areas:

- Strengthen the pool of qualified health and behavioral science researchers
- Increase basic scientific knowledge to improve human health and development
- Conduct and oversee applied research to improve health and well-being
- Communicate and transfer research results into clinical, public health and human service practices

6.1 The Agencies of the Department of Health and Human Services

The HHS controls 12 agencies. These are:

- The National Institutes of Health (NIH)
- The Agency for Healthcare Research & Quality (AHRQ)
- The Center for Disease Control (CDC)
- The Food and Drug Administration (FDA)
- The Administration for Children and Families (ACF)
- The Administration on Aging (AoA)
- The Agency for Toxic Substances and Disease Registry (ATSDR)
- The Centers for Medicare and Medicaid Services (CMS)
- The Health Resources & Services Administration (HRSA)
- The Indian Health Services Administration (IHS)
- The Office of the Inspector General (OIG)
- The Substance Abuse and Mental Health Services Administration (SAMHSA)

The majority of the research efforts are made by the National Institutes of Health which consists of 27 different institutes centered on disease types or specific research areas. It is important to be aware that while NIH has a central administration, most of the individual institutes receive their budget directly from Congress and not through the Office of the Director. NIH as well as AHRQ, CDC and FDA are described in separate chapters.

6.1.1 The Biomedical Advanced Research and Development Authority (BARDA)

The Department of Health and Human Services contains a large number of research and research-related initiatives. One important initiative worth mentioning is the Biomedical Advanced Research and Development Authority (BARDA)[24]. BARDA is located within the Office of the Assistant Secretary for Preparedness and Response and its purpose is to provide an integrated, systematic approach to the development and acquirement of the necessary vaccines, drugs, therapies, and diagnostic tools for public health medical emergencies. BARDA manages Project "BioShield" which includes the procurement and advanced development of medical countermeasures for chemical, biological, radiological, and nuclear agents. In addition, BARDA coordinates much of the development and procurement of medical countermeasures for pandemic influenza and other emerging infectious diseases that fall outside the BioShield-project. BARDA manages the Public Health Emergency Medical Countermeasures Enterprise. In 2003, the President created a discretionary reserve of 5.6 billion USD to fund the program through FY2013.

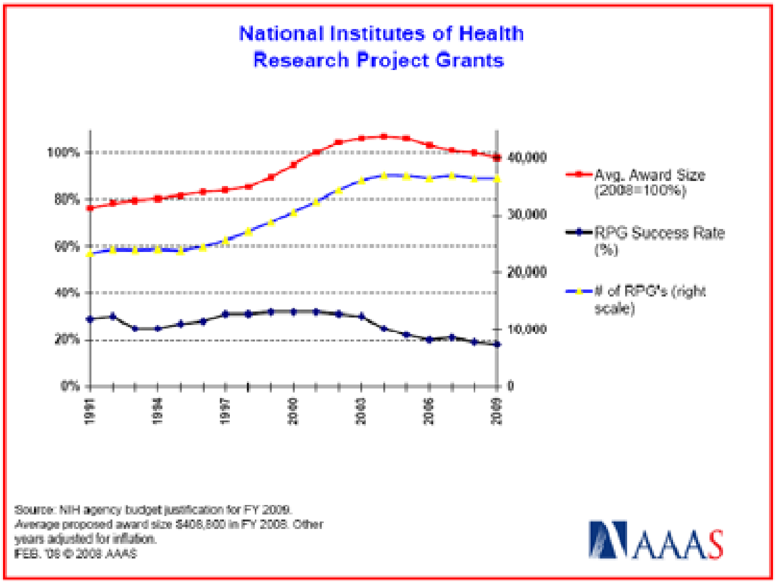
[24] http://www.hhs.gov/aspr/barda/

7 National Institutes of Health (NIH)

The NIH is an agency within the Department of Health and Human Services and the largest supporter of federal R&D, after the Department of Defense. NIH's mission is "science in pursuit of fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to extend healthy life and reduce the burdens of illness and disability"[25]. After a doubling of the agency budget from 1998 to 2003, the NIH has had a slow declining budget until this year. President Bush's budget for FY 2009 suggested that funding for biomedical research would be flat. However, Congress increased the NIH budget with approximately 1 billion USD to 30.5 billion USD (+3.2%). Added to this are one-time ARRA funds resulting in a total budget of around 41 billion USD for 2009.

The declining NIH budget since 2003 has lowered the success rate for research project grant applications and caused the average grant size to be reduced (fig 11). This may now change.

Figure 11 Development of research program grants over time



Source: American Association for the Advancement of Science (AAAS)

As mentioned earlier, NIH consists of 27 institutes and centers (IC's) of which 24 are grant-making institutes. Some of the institutes are focused on a disease-area while others may be focusing on a certain life stage, organ

[25] NIH (2008) www.nih.gov

system or cause. Each institute or center has its own mission, its own budget and sets its own research priorities after advice from many sources. The IC's support extramural research and training (approximately 80% of NIH-funded research are carried out by extramural investigators in the U.S. and globally) [9]. Most IC's also conduct intramural research and training in laboratories on the NIH campus in Bethesda, Maryland. In Appendix 1 can be seen the grant levels for individual states as well as the U.S. universities that receive most funds from NIH.

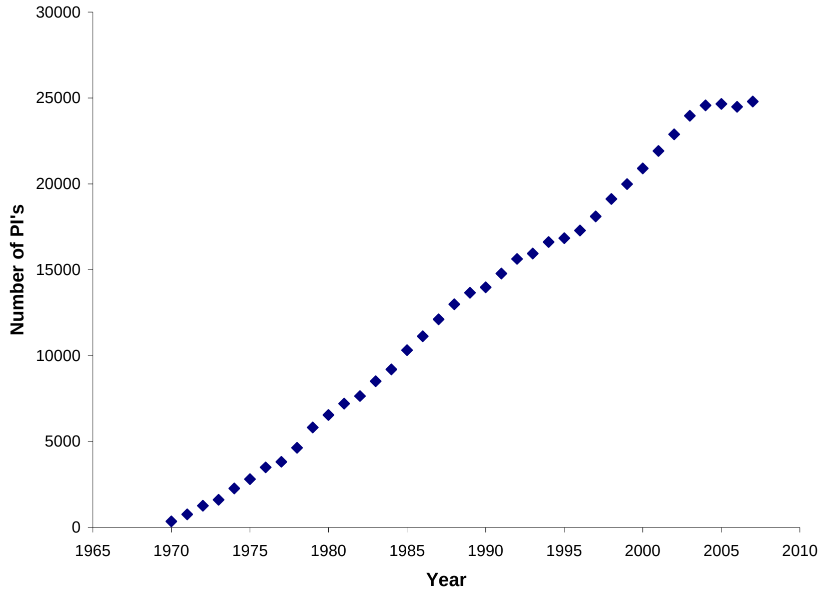
NIH's strategies are formulated in different ways. Firstly, the U.S. Congress sets IC funding levels, establishes the missions for some IC's and directs NIH attention to certain areas of interest. In addition, the administration sets its health priorities for the nation. Many of these must be addressed by NIH. The Healthy People 2010 program (a comprehensive set of disease prevention and health promotion objectives to be reached by 2010) is one such example of priorities made by the administration are involving NIH[26]. Furthermore, the HHS strategic plan is the overarching framework for NIH's goals and priorities[27]. Most strategic plans for NIH are set by the IC's but there are also numerous trans-NIH strategic plans. The IC's strategic plans give an outsider investigator and potential grant applicant an idea of what is on the agenda and therefore guides them in proposed research directions and methods. It also guides the IC's in their planning, handling of applications and selection of projects. Meetings, workshops, conferences, program announcements, research framework programs and more are ways to carry out the strategic plans. It is not uncommon that there are specific disease-related or program-specific plans within overarching IC strategic plans. One of the many trans-NIH strategic plans is the Roadmap – a strategic plan that involves NIH as a whole (See separate chapter).

7.1 NIH researchers

The total number of NIH-funded Principal Investigators (PI's) increased more or less linearly over a long time (fig 12). However, the increase in the number of PI's accelerated somewhat in 1998 when the doubling of the NIH was initiated and leveled out around 2004-2005 when the process was complete.

[26] The Healthy People 2010 program www.healthypeople.gov
[27] HHS Strategic Plan Goals and Objectives – FY 2007-2012, www.hhs.gov/strategic_plan/

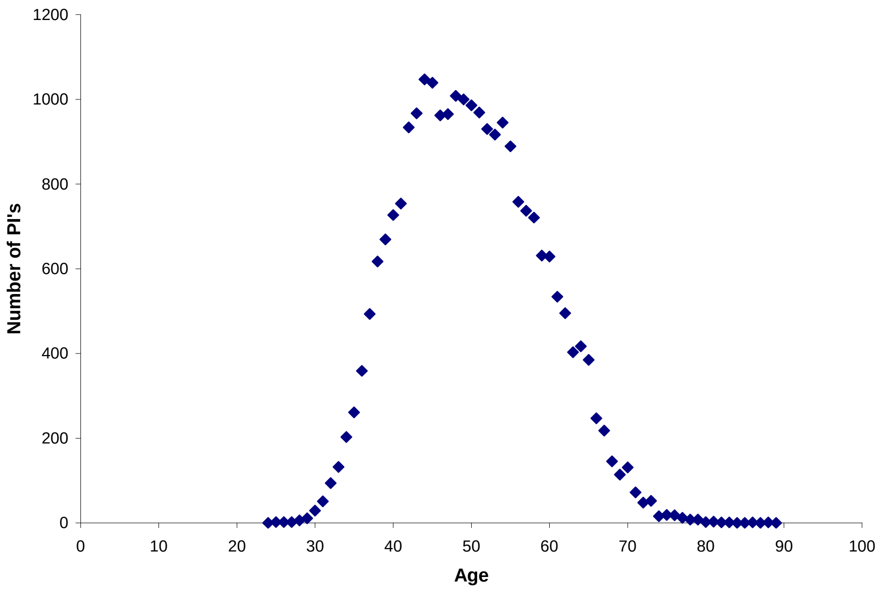
Figure 12 The total number of NIH Principal Investigators over time



Source: The National Institutes of Health

In the U.S. system it is normally illegal to force a researcher into retirement. There are however relatively few principal investigators funded by the NIH that are over the age of 70 (Fig. 13).

Figure 13 Age distribution of NIH Principal Investigators (2007)



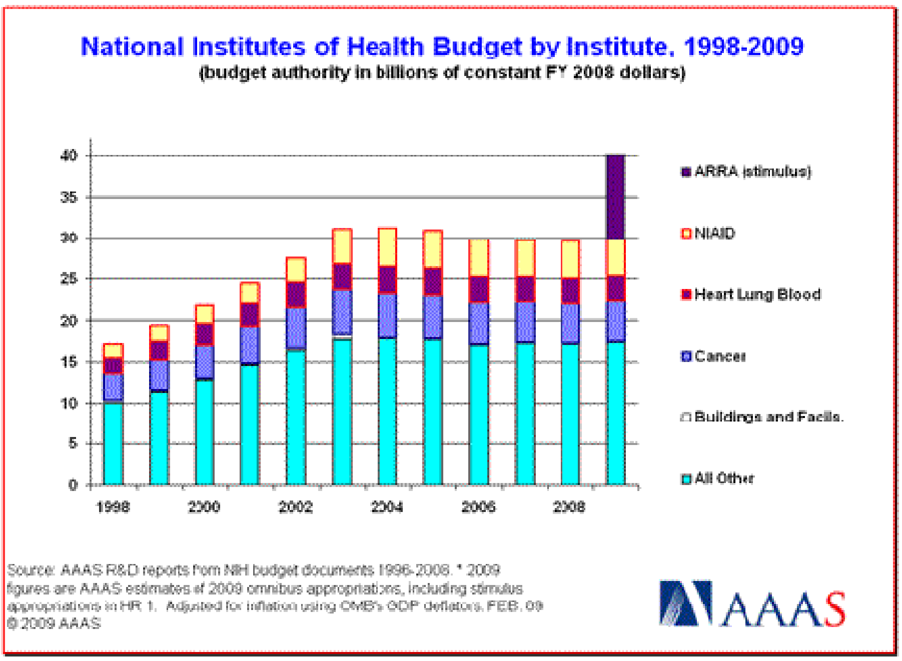
Source: The National Institutes of Health

7.2 Individual institutes

In all, twenty institutes, four centers, the Office of the Director (OD) and the Buildings and Facilities account have separate budgets. These entities receive their budget directly from the Congress in 26 budget decisions and both funding increases and decreases can therefore normally be seen on the institute level. The largest individual institutes in terms of federal funding are the National Cancer Institute (NCI), the National Institute of Allergy and Infectious Disease (NIAID) and the Heart, Lung and Blood Institute. Neuroscience research is divided on a number of institutes such as the National Institute for Metal Health (NIMH), the National Institute of Neurological Disorders and Stroke (NINDS) and others.

In President Bush's budget proposal[28] for 2009 none of the 20 institutes would have received a funding increase higher than 0.5%. 16 of the institutes would have received less funds in 2009 than in 2005 even before inflation is factored in. After Congress actions, the overall NIH budget was increased by 3.2% compared to 2008 and the research-oriented IC's received 2.4-2.9% increases. The OD that handles trans-NIH strategic initiatives including the NIH Roadmap received an increase of 5.6% while the Buildings and Facilities account was increased by 12.2% compared to 2008. The overall funding for the largest institutes can be seen below (fig 14).

Figure 14 Budget authority for the largest NIH institutes



Source: American Association for the Advancement of Science (AAAS)

[28] http://www.aaas.org

In table 3 is shown the final Congress bill for all NIH institutes as well as the funding level for 2008.

Table 3 Budget authority for individual NIH institutes for 2008 and 2009 and President Bush's request for 2009

Table 1. National Institutes of Health
Congressional Action on R&D in the FY 2009 Budget (excluding stimulus)
(budget authority in millions of dollars)

				Action by Congress			
	FY 2008 Estimate	FY 2009 Request	**FY 2009 Congress**	Chg. from Request Amount	Chg. from Request Percent	Chg. from FY 2008 Amount	Chg. from FY 2008 Percent
Cancer	4,831	4,810	**4,969**	159	3.3%	138	2.9%
Allergy and Infectious Diseases 1/	4,583	4,569	**4,703**	134	2.9%	119	2.6%
Heart, Lung and Blood	2,938	2,925	**3,016**	91	3.1%	78	2.7%
General Medical Sciences	1,946	1,938	**1,998**	60	3.1%	52	2.7%
Diabetes, Digestive and Kidney 2/	1,866	1,858	**1,911**	53	2.8%	46	2.4%
Neurological Disorders	1,552	1,545	**1,593**	48	3.1%	41	2.7%
Mental Health	1,413	1,407	**1,450**	44	3.1%	38	2.7%
Child Health & Human Dev.	1,261	1,256	**1,295**	39	3.1%	34	2.7%
Research Resources	1,156	1,160	**1,226**	66	5.7%	71	6.1%
Office of the Director 4/	1,112	1,057	**1,247**	190	18.0%	135	12.2%
Aging	1,053	1,048	**1,081**	33	3.1%	28	2.7%
Drug Abuse	1,006	1,002	**1,033**	31	3.1%	27	2.7%
Environmental Health Sciences 3/	723	720	**741**	20	2.8%	18	2.4%
Eye	671	668	**688**	21	3.1%	18	2.7%
Arthritis /musculoskeletal	511	509	**525**	16	3.1%	14	2.7%
Human Genome	489	488	**502**	14	3.0%	13	2.7%
Alcohol Abuse and Alcoholism	439	437	**450**	14	3.1%	12	2.7%
Deafness and Communication	396	395	**407**	12	3.1%	11	2.8%
Dental Research	392	391	**403**	12	3.1%	10	2.7%
National Library of Medicine	322	323	**331**	8	2.4%	9	2.7%
Biomed/Bioengineering	300	300	**308**	8	2.6%	8	2.7%
Minority Health / Disparities	201	200	**206**	6	3.1%	5	2.7%
Nursing Research	138	138	**142**	4	3.1%	4	2.7%
Buildings and Facilities	119	126	**126**	0	0.0%	7	5.6%
Complementary and Alt	122	122	**125**	4	3.1%	3	2.7%
Fogarty International Center	67	67	**69**	2	3.1%	2	2.7%
Total NIH Budget	29,607	29,457	**30,545**	1,088	3.7%	938	3.2%
subtract:							
- Training and Overhead	*781*	*791*	***806***	*15*	*1.9%*	*25*	*3.2%*
Total NIH R&D	28,826	28,666	**29,739**	1,073	3.7%	913	3.2%
[NIH Roadmap for Medical Res.]	*496*	*534*	***541***	*7*	*1.3%*	*45*	*9.1%*

AAAS estimates based on FY 2009 appropriations bills. Includes conduct of R&D and R&D facilities.
FY 2008 and FY 2009 request figures based on OMB R&D data and supplemental agency budget data.
Figures are rounded to the nearest million. Changes calculated from unrounded figures.
FY 2008 figures include funds enacted in FY 2008 supplemental (Public Law 110-252).
1/ Includes transfers to the Global Fund for HIV/AIDS ($295 mil. '08; $300 mil. '09).
2/ Includes $150 million each year in mandatory diabetes funds.
3/ Includes separate appropriations for Superfund-related activities.
4/ Trans-NIH initiatives (Roadmap) are consolidated in OD.

FY 2009 Congress figures exclude estimates for supplemental appropriations in Public Law 111-5 (ARRA).
February 24, 2009 - AAAS estimates of FY 2009 omnibus appropriations.
These figures exclude supplemental (stimulus) appropriations in P.L. 111-5.

Sources: The Office for the Management of the Budget (OMB) and the American Association for the Advancement of Science (AAAS)

7.3 The Common Fund and the NIH Roadmap

The NIH Director at the time, Dr. Elias A. Zerhouni initiated the NIH Roadmap for Medical Research in 2002[29]. The initiative was taken to "identify and prioritize the most pressing problems (roadblocks) facing medical research that could be uniquely addressed by NIH as a whole."[9]. The basic idea was to enable NIH to "quickly respond to new ideas, challenges, gaps, and advances in biomedical research". The NIH roadmap was launched in 2003 with three broad themes including over 30 initiatives[30]. The original themes were "New Pathways to Discovery", "Research Teams of the Future", and "Re-engineering the Clinical Research Enterprise". The themes remain the same today although the Roadmap is continuously updated and expanded. The Roadmap was institutionalized in 2006 when NIH created the Office of Portfolio Analysis and Strategic Initiatives (OPASI). The purpose of OPASI is to:

- Provide NIH and the IC's with the methods and information necessary to manage their large and complex scientific portfolios
- Lead trans-NIH efforts in identifying new and shifting public health challenges and important areas of emerging scientific opportunity
- Assist in accelerating trans-NIH investments in these areas, focusing on those involving multiples IC's

OPASI evaluates initiatives taken within the framework of the Roadmap. Each initiative goes through a thorough screening with outcome tracking, an annual review of progress, and a review no later than four years into the funding. OPASI solicitates ideas for coming initiatives by talking to various stakeholders such as the scientific community, patient advocates and the general public.

The next generation of research initiatives within the framework of the Roadmap[31] is named Roadmap 1.5 and was funded for the first time in FY 2008. The first set of initiatives funded in 2004 is set to graduate in 2014 and NIH needed to add new strategic initiatives to the Roadmap. The development of new initiatives started in 2006 and generated over 300 topics from NIH staff and scientists, extramural researchers, the stakeholder community and the general public. The topics were evaluated and emphasis was given to topics that "addressed gaps in knowledge or that would lead to the development of tools that would allow researchers to overcome barriers in basic, translational, or clinical research". This open process is to be made every year. However, the periods may in the future become longer.

[29] http://nihroadmap.nih.gov/overview.asp
[30] See ITPS report Medical Research in the United States (2004)
[31] http://nihroadmap.nih.gov/

Trans-NIH working groups then developed proposals within 13 broad areas that the IC directors had selected based on the earlier work by OPASI. The proposals were reviewed by the IC directors and the NIH Director and resulted in two main topics, the Human Microbiome Project and Epigenetics (see below), that were implemented immediately as 5-year Roadmap initiatives with a combined investment of 32 million USD the first year (2008).[32] Other projects became pilot studies (Genetic Connectivity Map and Transient Molecular Complexes), coordination areas, or strategic planning areas. Some of the areas selected were Protein Capture Tools/Proteome Tools, Phenotyping Services and Tools, and Inflammation as a common mechanism of disease (see below). Lastly, Roadmap coordination groups will continue to investigate the areas of Regenerative Medicine, Pharmacogenomics, and Bioinformatics as potential future trans-NIH initiatives. For future years, the recently formed NIH Council of Councils consisting of representatives from the IC's advisory councils will take part in the prioritization of the Roadmap. See below (box 1) for current initiatives within the Roadmap.

Box 1 NIH Roadmap initiatives

Common Fund/Roadmap by Initiative

- New Pathways of Discovery
  - Molecular Libraries and Imaging
  - Building Blocks, Biological Pathways and Networks
  - Structural Biology
  - Bioinformatics and Computational Biology
  - Nanomedicine
  - Human Microbiome Project (new for 2008)
  - Epigenomics (new for 2008)
  - Genotype-tissue expression (new for 2008)
- Research Teams of the Future
  - Interdisciplinary Research
  - High-risk Research
    - NIH Director´s Pioneer Award
    - NIH Director´s New Innovator Award
    - Transformative R01 Program
  - Public-Private Partnership
- Re-engineering the Clinical Research Enterprise
  - Clinical Research Networks and NECTAR
  - Clinical Outcomes Assessment
  - Clinical Research Training
  - Clinical Research Policy Analysis and Coordination
  - Analysis

Source: National Institutes of Health (2008)

Roadmap initiatives were initially funded by the different IC's and the Office of the Director (OD) but has, since FY 2007, its own funding through

[32] For details regarding the NIH Human Microbiome Project (HMP) and the NIH Epigenomics Program see http://nihroadmap.nih.gov/

the NIH Common Fund (created in 2004 and into law by the NIH Reform Act of 2006). In order to receive funding from the Common Fund, initiatives have to be trans-NIH, fill a gap in the knowledge base and be transformative. Funding is formally time-limited to 5-10 years. After that time, the initiatives either continue within an IC or are concluded. This has however, according to the NIH, been difficult to implement in an effective way.

The Common Fund is now part of the budget of the NIH Office of the Director. Approximately 1% of the NIH budget has been distributed to fund Roadmap projects since the Common Fund was started. This percentage increases to 1.8% in President Bush's budget for FY 2009. However, Congress finally approved a large funding increase to the OD (+12.2%, See table 3) of which large parts are likely to be used for the Common Fund. The majority of the Common Fund funding goes to research grants and research centers. According to the original proposal, the area "New Pathways to Discovery" (see above) receives the largest percentage of the three areas - approximately 50% in the FY 2009 budget. Increases are planned in the following areas: Sequencing a Reference Set of Genomes; Human Microbiome Demonstration Projects, and Epigenomics in Human Health and Disease. Decreases may occur in Technology Development, Interdisciplinary Research Training Initiative, Clinical Research Training and Clinical and Translational Science Awards. Within the Roadmap, two investigator awards are given; the Director's Pioneer Award and the Director's New Innovator Awards.

7.3.1 Brief descriptions of a number of Roadmap Initiatives

New Pathways to discovery

Building blocks, biological pathways and networks

An important part of this initiative is to develop new proteomic technologies to make it possible for researchers to improve the understanding of biological pathways, the ultimate goal being to understand diseases involving such pathways. Another critical part of the initiative is to provide researchers with new analytical tools to better understand the metabolic components and networks within the cell (the metabolome). In order to develop highly sensitive tools to quantify, measure the activity, translocation and interactions of intracellular protein molecules, the National Technology Centers for Networks and Pathways will cooperate in an effort to develop new technologies within the Proteomics field.

The Metabolomics field seeks to understand small molecules found in cells and tissues. The Metabolomics technology development initiative aims to encourage the development of new and innovative tools to identify and quantify cellular metabolites.

Molecular Libraries and Molecular Imaging

The initiative will provide public sector biomedical researchers with access to small organic molecules to be used as chemical probes in order to study the function of genes, cells and biochemical pathways in health and disease.

Molecular imaging is an emerging research field that aims to elucidate the biochemical and physiological abnormalities that underlie disease. The initiative will enhance the discovery and availability of technologies and reagents for the imaging of molecules and molecular events in single cells and organisms. The main aim of the initiative is to provide a detailed molecular understanding of cell and tissue function in healthy and pathological states.

The initiative involves a number of efforts involving a Molecular Libraries Small Molecule Repository, a network of Molecular Libraries Screening Centers, high-throughput Molecular Screening Assay development, innovation to improve Molecular Imaging Probes, development of high-resolution probes for cellular imaging and the development of innovative instrumentation that can be integrated into High-Throughput Screening (HTS) systems to identify small molecules and biological mechanisms in living cells.

More information concerning this and similar efforts can be found in the report “Chemical Biology in the USA” [10].

Structural biology

The initiative is an effort to create a “picture gallery of the molecular shapes of human proteins and to enhance the understanding of how proteins and their components function in the body”. The initiative also involves investments into centers with the goal of developing new methods to produce significant amounts of proteins for subsequent structural studies.

Bioinformatics and Computational Biology

Modern life science R&D generates huge amounts of data and information management is therefore becoming increasingly important. The initiative will create a networked computational infrastructure for the needs of biomedical computing and storage.

Nanomedicine

The initiative is the first step in a new process to develop a network of Nanomedicine Development Centers. The centers will focus on developing methods to define the physical characteristics of structures inside cells at the molecular level. Teams of scientists from many disciplines will work together to develop new technologies enabling them to better understand the molecular interactions within cells and the physical and chemical properties of nanoscale molecular structures. Nanomedicine efforts will be described in greater detail in a separate report.

The Human Microbiome Project

Microbial cells are estimated to outnumber human cells by a factor of ten to one in the body and are largely unstudied. The Human Microbiome Project (HMP) aims to generate resources enabling comprehensive characterization of the human microbiota and analysis of its role in human health and disease.

By using metagenomic and traditional approach to genomic DNA sequencing, the Human Microbiome Project will lay the foundation for further studies of human-associated microbial communities. The project has the following main goals:

- Determining whether individuals share a core human microbiome
- Understanding whether changes in the human microbiome can be correlated with changes in human health
- Developing new technological and bioinformatics tools needed to support these goals
- Addressing the ethical, legal and social implications raised by human microbiome research.

Epigenomics

Epigenetics involves the study of changes in regulation of gene activity and expression that are not dependent on gene sequence. While epigenetics refers to the study of single or sets of genes, epigenomics concerns the more global analyses of epigenetic changes across the entire genome. The Roadmap Epigenomics Program will: (1) create an international committee; (2) develop standardized platforms, procedures, and reagents for epigenomics research; (3) conduct demonstration projects to evaluate how epigenomes change; (4) develop new technologies for single cell epigenomic analysis and *in vivo* imaging of epigenetic activity; and (5) create a public database to accelerate the application of epigenomic approaches.

Genotype expression (GTex)

Genome-wide association studies are used to identify genetic changes associated with common human diseases, such as heart disease, cancer, diabetes, asthma, and stroke. A large majority of these genetic changes lies outside of the protein-coding regions of genes and often even outside of the genes themselves, making it difficult to conclude what genes are affected and by what mechanism. The Genotype-Tissue Expression (GTEx) project aims to provide a resource with which to study human gene expression and regulation as well as its relationship to genetic variation. The project will collect and analyze multiple human tissues from donors who are densely genotyped to assess genetic variation within their genomes.

Research Teams of the Future

Modern science demands that researchers become more multidisciplinary and that new models to perform science are tried. NIH wants scientists to try a variety of models for conducting research.

High-risk research

A number of initiatives to stimulate high risk, high reward R&D has been put into place by NIH. Within the Roadmap the following grant types exist:

- The NIH Director’s Pioneer Award Program
- The program aims to support individual scientists with pioneering ideas and approaches. The award will give the recipient the time (5 years) and resources to develop and test ideas and hopefully make groundbreaking discoveries.
- The NIH Director´s New Innovators Award
- The Award is intended to support unusually creative new investigators with highly innovative research ideas at an early stage of their career when they may lack the preliminary data required for a standard “R01” grant. The emphasis is on innovation, creativity and potential impact.
- Transformative RO1 grants (T-RO1)
- The newly announced Transformative RO1 Program within NIH will support “out-of-the-box” projects. The program “is designed to stimulate disruption of paradigms or creation of paradigms where none exists” and is intended to stimulate high-risk high-reward R&D and cutting edge projects. Among areas that have been identified for the program are:
    - Understanding and incenting behavior change
    - 3-D tissue models
    - Functional variation in mitochondria
    - Transition from acute to chronic pain
    - Formulation of novel protein capture reagents
    - Evidence for pharmacogenomics clinical studies

The program is a demonstration project and funding opportunities were first announced during the summer of 2008. The initiative has budget of 25 million USD per year for 5 years.

Interdisciplinary research

Modern biomedical R&D requires interdisciplinary approaches. Through the Roadmap, NIH has introduced a number of planning centers to better integrate different disciplines. The planning centers combine aspects from individual disciplines to provide new ways of thinking about and addressing complex scientific problems. Examples of specific efforts include:

- Interdisciplinary Research Training: Behavior, Environment and Biology
- Training for a New Interdisciplinary Research Workforce
- Curriculum Development Award in Interdisciplinary Research
- Short programs for interdisciplinary research training
- Supplements for methodological innovations in the behavioral and social sciences
- Meetings and networks for methodological development in interdisciplinary research

Re-engineering the Clinical Research Enterprise

The Roadmap initiatives within the area aim to improve and accelerate clinical research by adopting a more systematic infrastructure. The issues are complex and NIH works together with other agencies to address them.

Clinical Research Networks and NECTAR

By improving the efficiency of clinical research networks through informatics and other technologies, it will be easier for researchers to broaden the scope of their research. Reduced duplication of studies will leave more resources to address new research questions.

The Clinical Research Networks part of the initiative was designed to promote and expand clinical research networks to enable rapid high-quality clinical studies addressing multiple research questions. An inventory of existing clinical research networks explored existing informatics and training infrastructure in order to identify characteristics that promoted or inhibited successful network interactivity, productivity and expansion. Feasibility studies aimed at enhancing the clinical research infrastructure by increasing the scope of research activities, increasing participation, and facilitating communication and cooperation among networks, were performed. The results of the inventory and the feasibility studies are used in the development of a National Electronics Clinical Trials and Research (NECTAR) network. NECTAR is intended to work as an informatics infrastructure to interconnect research networks.

Clinical Outcomes Assessment

The initiative "Dynamic Assessment of Patient-Reported Chronic Disease Outcomes" supports researchers who will develop and implement a publicly available information system and computerized adaptive tests. As members of a network, the Patient-Reported Outcomes Measurement Information System (PROMIS), scientists are developing a computerized system to measure patient-reported outcomes more efficiently in study participants with a wide range of chronic diseases and demographic characteristics.

Clinical Research Training

Through the Roadmap, NIH is working to expand and diversify the clinical research workforce. A number of initiatives have been taken such as a Multidisciplinary Clinical Research Career Development Program, the National Clinical Research Associates program and the NIH Clinical Research Training Program.

Clinical Research Policy Analysis and Coordination

NIH has established working groups together with other agencies to make progress in highly prioritized areas. One of the goals is to develop clear, effective and coordinated rules for clinical research, maximize human protection, sharing of data and overall enhancement of the quality and productivity of clinical research activities.

Translational Research

To lower the barriers between clinical and basic science the Clinical and Translational Science Awards (CTSA) consortium was launched in 2006. The consortium started out with 12 academic health centers and another 52 institutions have received planning grants to join the consortium. The purpose of the CTSA is largely to assist institutions investing in clinical and translational science with resources to create well-trained multidisciplinary teams of investigators, to create incubators for innovative research tools and information technologies and to create synergies to catalyze the application of new knowledge and techniques in clinical practice.

Translational Research Core Services

NIH is making efforts to make resources available for the development of small molecule therapeutic agents.

7.4 The Fogarty International Center

The Fogarty International Center (FIC)[33] is one of the NIH centers and works for the overall NIH mission; by supporting and facilitating global

[33] http://www.fic.nih.gov

health R&D conducted by U.S. and international investigators, by building partnerships between health research institutions in the U.S. and abroad, and by training new scientists to address global health needs[34]. Training of foreign health scientists, extending research support to foreign researchers, and building alliances and partnership with international partners all support the idea of extending the NIH mission globally. In the new strategic plan for the center, the focus is on global health and infectious diseases, in particular in low- and middle-income countries (LMIC's). FIC funds approximately 400 projects at both foreign and U.S. institutions. Of these, around 20% are awarded to research institutions in LMIC's. FIC was founded in 1968 and then had a budget of 500,000 USD. Today (2008), the center's budget is around 69 million USD and the center funds 5000 scientists worldwide and is active in over 100 countries.

Other IC's also funds international research which increased from 50 million USD in 1997 to 500 million dollars in 2005. FIC plays an important role in coordinating international collaboration at NIH. For example, its Division of International Relations explores opportunities worldwide for potential collaboration with foreign research institutions and funding agencies. Statistics for 2006-2008 show that Swedish universities are competing for research grants. Researchers at Karolinska Institutet receive the largest number of awards, although researchers at Gothenburg University, Lund University, Stockholm University, Umeå University and Uppsala University also are among the recipients. In 2006, a total of 16 grants were given to researchers at Swedish universities at an average of 443,000 USD[35]. Two much smaller grants were given to Karolinska Institutet university-wide (not included in the average). The largest grant of 1,885,350 USD was given to Uppsala University. The grants cover a wide range of research areas.

An example of an international program within FIC is the Fogarty International Collaborative Trauma and Injury Research Training Program (ICTIRT). The program was first initiated with awards in FY 2005 and involves collaboration of researchers from the U.S. and developing country institutions. Another example is Fogarty's FIRCA Awards (Fogarty International Research Collaboration Award). These awards are intended to foster international research partnerships between NIH-supported scientists and their collaborators in countries of the developing world. Each award values 150,000 USD over three years and with few exceptions all areas of biomedical and behavioral research at NIH are eligible as research topics.

[34] http://www.fic.nih.gov/about/plan/strategicplan_08-12.htm
[35] http://report.nih.gov/award/state/state.cfm

7.5 Examples of federally prioritized disease areas

7.5.1 Obesity

Overweight and obesity has increased dramatically in the United States over the last 20 years. According to the Center for disease Control (CDC), two thirds of non-institutionalized adults over 20 years of age are overweight or obese. Of these approximately one third are obese. The problem is not isolated to adults and the number of overweight young people has doubled over the last 20 years.

The importance of the obesity epidemic as a public health problem as well as its relevance to the mission of many of the NIH institutes and centers resulted in that the previous NIH Director Dr. Elias Zerhouni established the NIH Obesity Research Task[36] Force in 2003. The task force is an effort to accelerate progress in obesity research across the NIH and is co-chaired by the Director of the National Institute of Diabetes and Digestive and Kidney Diseases and by the Director of the National Heart, Lung, and Blood Institute. The members of the Task Force are representatives from across the NIH institutes and other entities. A key element of the NIH Director's charge to the task force is the development of a strategic plan for NIH obesity research. The following NIH components are represented on the Task Force (table 4):

[36] http://www.obesityresearch.nih.gov/about/about.htm

Table 4 Representatives on the NIH Task Force for Obesity

National Institute of Diabetes & Digestive & Kidney Diseases (NIDDK)	National Heart, Lung, and Blood Institute (NHLBI)
National Cancer Institute (NCI)	National Human Genome Research Institute (NHGRI)
National Institute on Aging (NIA)	National Institute on Alcohol Abuse and Alcoholism (NIAAA)
National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)	National Institute of Biomedical Imaging and Bioengineering (NIBIB)
Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD)	National Institute of Dental and Craniofacial Research (NIDCR)
National Institute on Drug Abuse (NIDA)	National Institute of Environmental Health Sciences (NIEHS)
National Institute of Mental Health (NIMH)	National Institute of Neurological Disorders and Stroke (NINDS)
National Institute of Nursing Research (NINR)	National Center for Complementary and Alternative Medicine (NCCAM)
National Center on Minority Health and Health Disparities (NCMHD)	National Center for Research Resources (NCRR)
NIH Division of Nutrition Research Coordination (DNRC)	NIH Fogarty International Center (FIC)
Office of Behavioral and Social Sciences Research (OBSSR)	Office of Dietary Supplements (ODS)
Office of Disease Prevention (ODP)	Office of Research on Women's Health (ORWH)
Center for Scientific Review (CSR)	

Source: The National Institutes of Health

7.5.2 Cancer

Cancer is the second most common cause for death in the U.S. and the costs are approximated to be around 210 billion USD annually. CDC through its National Comprehensive Cancer Control Program[37] funds states, territories and tribes to asses the burden of cancer and to develop cancer control programs. The programs include among other areas early detection, improvement of cancer treatments and enhancement of quality of life for cancer patients. The National Program of Cancer Registries[38] collects data on the occurrence of cancer through state and territorial registries. CDC's National Breast and Cervical Cancer Early Detection program[39] as well as the Prostate Cancer Initiative[40] are other examples of important programs.

[37] http://www.cdc.gov/cancer/ncccp/
[38] http://www.cdc.gov/cancer/npcr/
[39] http://www.cdc.gov/cancer/nbccedp/
[40] http://www.americanprostate.org/

The FDA is also involved in cancer prevention through the development and licensure of cancer prevention vaccines.

The National Cancer Institute[41] (NCI) is by far the largest NIH institute with a budget of USD 4,792 billion USD (2007). 44% of the funds were allocated to 5,472 research project grants. Intramural research comprised 15% of the total NCI budget. 278 grants, a total of 94 million USD, were funded as Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards. 10% of the total NCI budget was allocated for Cancer Prevention & Control.

7.5.3 Heart Disease and Stroke

Heart disease and stroke are the most common cardiovascular diseases[42] and the first and third cause for death in the United States. Even though these diseases are more common among the elderly, they are increasing in frequency among the younger population. HHS works to educate health practitioners and the public about prevention, signs and symptoms. Among important programs is the National Heart, Lung and Blood Institute (NHLBI)[43] collaboration with other actors in a national campaign called the “Heart Truth”[44] that aims to raise woman’s awareness about the risk of heart disease. CDC has a special Heart Disease and Stroke Prevention program[45] in which they work together with the states to control individual’s high blood pressure and blood cholesterol. The total budget for NHLBI was approximately 2.9 billion USD (FY 2007). Research grants constituted approximately 68% of this including 73.5 million USD for Small Business Innovation Research (SBIR) and Small Business Technology Transfer Grants (STTR)[46].

Other prioritized areas include Diabetes, Oral health, Substance abuse and more.

[41] http://www.cancer.gov
[42] http://www.nlm.nih.gov/medlineplus/heartdiseases.html
[43] http://www.nhlbi.nih.gov/
[44] http://www.nhlbi.nih.gov/educational/hearttruth/
[45] http://www.cdc.gov/DHDSP/
[46] http://www.nhlbi.nih.gov/about/factbook/FactBookFinal.pdf

8 The Food and Drug Administration

The Food and Drug Administrations[47] (FDA) main objective is to safeguard the health of the public by monitoring product (including foods) safety and to work with manufacturers to develop new and safe drugs and medical devices. According to the FDA, the products they monitor correspond to approximately 25% of every consumer dollar. Simply stated the FDA mission is:

- To promote and protect public health by helping safe and effective products to reach the market
- To monitor products for continued safety after they have been used
- To help the public acquire accurate, science-based information needed to improve health

The FDA website states that:

> *"The FDA is responsible for protecting the public health by assuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation. The FDA is also responsible for advancing the public health by helping to speed innovations that make medicines and foods more effective, safer, and more affordable; and helping the public get the accurate, science-based information they need to use medicines and foods to improve their health."*

FDA consists of nine centers and offices:

- Center for Biologics Evaluation and Research (CBER)
- Center for Devices and Radiological Health (CDRH)
- Center for Drug Evaluation and Research (CDER)
- Center for Food Safety and Applied Nutrition (CFSAN)
- Center for Veterinary Medicine (CVM)
- National Center for Toxicological Research (NCTR)
- Office of Chief Counsel
- Office of the Commissioner (OC)
- Office of Regulatory Affairs (ORA)

[47] http://www.fda.gov/

In addition, there are two affiliated organizations:

- Joint Institute for Food Safety and Applied Nutrition
- National Center for Food Safety and Technology

8.1 The Critical Path

In 2004, a white paper entitled "Innovation/Stagnation: Challenge and Opportunity on the Critical Path to New Medical Products"[48] that diagnosed scientific reasons for the decrease in the number of innovative medical products submitted for approval in recent years, was released by the FDA. The report called for national concerted efforts to modernize scientific tools such as *in vitro* tests, computer models, qualified biomarkers, and innovative study designs, as well as efforts to harness the potential of bioinformatics to evaluate and predict safety, effectiveness, and manufacturability. In addition, the report highlighted the need for national efforts to identify specific activities that would improve the situation.

Later, in 2006, a list of "Critical Path" opportunities was published[49]. The list described a number of areas for improvement within product development, and provided 76 cases of how new discoveries in fields such as genomics, proteomics, imaging, and bioinformatics could be applied to improve the accuracy of tests used to predict the safety and efficacy of medical products.

8.2 Research activities

R&D is an integral part of the FDA's work and many of the units listed above are involved in research. According to the FDA, research is important both to have a scientific basis for regulatory decisions and to provide new tools to identify and assess risks. Research is important for standard settings and to evaluate new products as well as to keep track of scientific breakthroughs. A number of units and their activities are listed below.

The mission of the **Center for Biologics Evaluation and Research (CBER)** mission is to protect and enhance public health through the regulation of biologicals and related products including blood, vaccines, allergenics, tissues as well as cellular and gene therapies. Biologics, in contrast to drugs that are chemically synthesized, are derived from living sources and are not easily identified or characterized. Many are manufactured using biotechnology. The products often represent cutting-edge biomedical research and may, in the long-term, offer the most effective

[48] http://www.fda.gov/oc/initiatives/criticalpath/whitepaper.html
[49] http://www.fda.gov/oc/initiatives/criticalpath/reports/opp_list.pdf

means to treat a variety of medical illnesses and conditions that presently have few or no treatment options.

To provide effective regulatory review of biological products, CBER conducts active mission-oriented research programs. The research expands the knowledge of relevant fundamental biological processes and is intended to provide a strong scientific base for regulatory review. A variety of technical and scientific issues related to the safety, potency, and efficacy of biological products requires knowledge of new developments and concepts of basic research in relevant biological disciplines. CBER offices and divisions that are involved in biomedical research include:

- The Office of Biostatistics and Epidemiology
- The Office of Blood Research and Review
  - Division of Hematology
  - Division of Emerging and Transfusion Transmitted Diseases
- The Office of Cellular, Tissue, and Gene Therapies
  - Division of Cellular and Gene Therapies
- The Office of Vaccines Research and Review
  - Division of Bacterial, Parasitic, and Allergenic Products
  - Division of Viral Products

CDER, the Center for Drug Evaluation and Research is heavily involved in research, not least to develop new tests and paradigms and to follow scientific breakthroughs.

The Research at the **National Center for Toxicological Research (NCTR)** is targeted at achieving the following strategic research goals in support of FDA’s public-health mission:

- Advance scientific approaches and tools to promote personalized nutrition and medicine for the (American) public
- Develop science-based best-practice standards and tools to incorporate translational and applied toxicological advancements into the regulatory decision-making process
- Conduct research to strengthen the understanding of food safety and food defense
- Modernize science management and infrastructure, and promote management expertise to effectively and efficiently support FDA/HHS goals
- Enhance technical expertise and provide expert technical advice and training to assure the availability of well-trained personnel to address scientific issues relevant to the agency

The NCTR research involves areas such as:

- Food safety
- Bioterrorism
- Biotechnology
- Information Technology
- Fundamental and applied research
- Premarket activities
- Antimicrobial resistance
- HIV-AIDS

8.3 Budget

The FDA budget request for 2009 was 2.4 billion USD[50] which is a 5.7% or 129.7 million USD increase from 2008. Of this, 1.77 billion USD is a budget authority while 628 USD consists of industrial user fees. To strengthen food protections, modernize drug safety and speed up the approval of drugs and devices a number of key budget increments have been suggested. These include an increase of the “Protect the American Food Supply” program with 42.2 million USD to a total of 662.4 million USD. The program aims to safeguard the food supply and the American homeland. The “Medical Product Safety and Devices” program has been suggested to enjoy a budget increase with 17.4 million USD in budget authority and 79 million USD in user fees to a total of 887 million USD. The program aims to improve the safety of products and to help manufacturers develop new products to treat certain diseases. An overview of some likely FY 2009 initiatives and adjustments can be seen in table 5.

[50] http://www.fda.gov/bbs/topics/NEWS/2008/NEW01789.html

Table 5 Some likely changes in FDA programs

Initiative	Amount	Synopsis
Budget Authority		
Protecting America's Food	+$42,232,000	This initiative supports the FDA's shift to a comprehensive, preventative, and risk-based approach to safeguard the food supply and the American homeland. The investment allows the FDA to implement major components of the Food Protection Plan, Import Safety Action Plan, the December 2007 agreements with China, and a possible FDA office in China. Includes a pay increase for agency personnel to sustain current services and conduct the FDA mission.
Medical Product Safety and Development	+$17,395,000	This initiative provides targeted resources to improve the safety of human and animal drugs, blood, human tissues, and medical devices. The investment will strengthen the FDA's ability to effectively monitor the safety of medical products, including imported products. The FDA will also assist medical product manufacturers to develop new products to treat life-threatening diseases and conditions. Includes a pay increase for agency personnel to sustain current services and conduct the FDA mission.
Administrative Savings and Management Efficiencies	- $8,918,000	In FY 2009 the FDA will redirect savings and management efficiencies to high priority activities.
Current Law & Proposed User Fees		
Current Law User Fees	+$57,534,000	The budget request includes inflationary increases for FDA user fee programs as well as other increases authorized by law under the prescription drug and medical device user fee programs. Three FDA user fee programs facilitate premarket review for human and animal drugs and human devices. Three other user fee programs support the mammography facilities inspection program and provide certification services for color additives and for drug and device products exported from the United States.

Initiative	Amount	Synopsis
Current Law & Proposed User Fees		
Proposed Generic Drug User Fee	+$16,628,000	The proposed user fee for Generic Drug Review will provide additional resources to improve the generic drug review process and to respond to the growing number of Abbreviated New Drug Applications.
Proposed Animal Generic Drug User Fee	+$4,831,000	The proposed user fee for Animal Generic Drug Review will provide additional resources to improve the animal generic drug review process and to respond to the growing number of Abbreviated New Animal Drug Applications.
Total Program Level Increase over FY 2008	***+ $129,702,000***	
Proposed Mandatory User Fees (Non-Add)		
Reinspection User Fee	+$23,276,000 (Non-Add)	Re-proposed new user fees to reimburse for reinspection of FDA-regulated facilities.
Food and Animal Feed Export Certification User Fee	+$3,741,000 (Non-Add)	Re-proposed new user fees to reimburse for issuing food and feed export certificates.
Mandatory User Fees	***+$27,017,000***	

Source: Food and Drug Administration (FDA)

9 The Center for Disease Control (CDC)

The CDC[51] is an important, mission oriented and research-intensive agency belonging to the HHS. The top organizational components include the Office of the Director (OD), six Coordinating Centers and Offices as well as the National Institute for Occupational Safety and Health (NIOSH). The OD manages the activities for disease control and prevention and provides overall direction to and coordination of the scientific and medical programs. The OD also provides leadership and coordination of the administrative management. The CDC has five main offices:

- CDC Washington
- Office of Chief of Public Health Practice
- Office of Health and Safety
- Office of Strategy and Innovation
- Office of the Chief Science Officer

CDC's Coordinating Centers and Offices are intended to make the agency responsive and effective when dealing with public health issues. Each coordinating office/center implements CDC's actions within its own field of responsibility and also provides intra-agency support and resources for cross-cutting issues. The centers and offices are briefly discussed below.

9.1 The Coordinating Center for Environmental Health and Injury Prevention (CCEHIP)

The mission of the CCEHIP is to plan, direct, and coordinate national and international public health research programs and laboratory sciences that improve health and counteract illness, disability and death caused by injuries or the environment. Two important program centers within CCEHIP are:

- The **National Center for Environmental Health** (NCEH-ATSDR) that works to prevent and control diseases and death resulting from the interactions between people and their environment. The Agency for Toxic Substances and Disease Registry (ATSDR) is actually a sister agency of CDC under HHS for which CDC performs many of the administrative functions. The Director of CDC also serves as the Administrator of ATSDR.

[51] http://www.cdc.gov/

- The **National Center for Injury Prevention and Control** (NCIPC) that works to prevent death and disability from non-occupational injuries including those that are unintentional and those that result from violence.

9.2 The Coordinating Center for Health Information and Service (CCHIS)

The CCHIS provides leadership and promotes innovation in public health informatics, health statistics, health marketing, and scientific communications. CCHIS includes the following centers:

- The **National Center for Health Statistics** (NCHS) that provides statistical information intended to improve health
- The **National Center for Public Health Informatics** (NCPHI) that works with the application of information technology (IT) in the pursuit of public health
- **The National Center for Health Marketing** (NCHM) that provides leadership in health marketing science and its applications to improve public health

9.3 The Coordinating Center for Health Promotion (CCHP)

The mission of the CCHP is to plan, direct and coordinate the national programs for the prevention of premature births, mortality, morbidity and disability due to chronic diseases, genomics, disabilities (physical and developmental), birth defects, reproductive outcomes and adverse consequences of hereditary conditions including blood disorders. It is made up of the following programs:

- The National Center on Birth Defects and Developmental Disabilities (NCBDDD) which is intended to prevent birth defects and developmental disabilities as well as to improve the health and wellness of people with disabilities
- The National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP) that works to prevent premature deaths and disability from chronic diseases, and to promote a healthy personal life style
- The Office of Genomics and Disease Prevention that provides leadership in fostering an understanding of human genomic discoveries and how they can be used to improve health and prevent disease

9.4 Coordinating Center for Infectious Diseases (CCID)

The mission of the CCID is to protect health and enhance the potential for healthy life by actions counteracting infectious diseases. CCID has recently been restructured and now includes the following elements:

- The **National Center for Immunization and Respiratory Diseases (NCIRD)** is an interdisciplinary immunization program bringing together vaccine-preventable disease R&D with immunization program activities
- The **National Center for Zoonotic, Vector-Borne, and Enteric Diseases (NCZVED)** that provides national and international scientific and programmatic leadership addressing zoonotic, vector-borne, foodborne, waterborne, mycotic, and related infections to identify, investigate, diagnose, treat, and prevent related diseases
- The **National Center for HIV/AIDS, Viral Hepatitis, Sexually transmitted diseases, and Tuberculosis prevention (NCHHSTP)** that integrates epidemiology, laboratory science and prevention measures for a broad range of diseases, to develop and implement collaborative public health interventions
- The **National Center for Preparedness, Detection, and Control of Infectious Diseases (NCPDCID)** that focuses on preparedness and response capacity for new and complex infectious disease outbreaks. The center manages and coordinates actions on emerging infectious diseases, integrates laboratory groups and works for increased quality and capacity in clinical laboratories

9.5 Coordinating Office for Global Health (COGH)

The office provides leadership, coordination, and support for CDC's global health activities. COGH's main mission is to work with partners around the world to increase life expectancy and years of quality life, in particular among those at highest risk for premature death such as vulnerable children and women, and to increase the global preparedness to prevent and control naturally-occurring and man-made threats to health. COGH is divided into:

- The International Experience and Technical Assistance Program (IETA)
- The Division of Epidemiology and Surveillance Capacity Development (DESCD)
- The Sustainable Management Development Program (SMDP)

9.6 The Coordinating Office for Terrorism Preparedness and Emergency Response (COTPER)

The mission of COTPER is to assist, prepare for and respond to urgent public health threats by providing strategic direction, coordination, and support for all of CDC's terrorism preparedness and emergency response activities. COTPER consists of the following departments:

- The **Division of Emergency Operations (DEO)** is responsible for overall coordination of CDC's preparedness, assessments, responses, recovery, and evaluations prior to and during public health emergencies. DEO is also responsible for the CDC Director's Emergency Operations Center, which maintains situational awareness of potential health threats at all times.
- The **Division of Select Agents and Toxins (DSAT)** regulates the possession, use, and transfer of biological agents and toxins that may pose as potential threats to public health and safety.
- The **Division of State and Local Readiness (DSLR)** that deals with the Public Health Emergency Preparedness (PHEP) Cooperative Agreement that supports nationwide preparedness at state, local, tribal, and territorial public health department levels. Furthermore, DSLR administers a cooperative agreement for the Centers for Public Health Preparedness (CPHP) program. The CPHP program is a national network of colleges and universities that collaborates with state and local public health departments and other local partners to provide preparedness education and training resources to the public health workforce, healthcare providers, students, and others.
- The **Division of the Strategic National Stockpile (DSNS)** has the mission to deliver critical medical assets to sites in a national emergency. DSNS manages the Strategic National Stockpile (SNS), a repository of antibiotics, chemical antidotes, antitoxins, antivirals, life-support medications, and other medical supplies.

9.7 Office of Strategy and Innovation (OSI)

The OSI leads efforts to develop, measure, and advance the health protection goals and supports CDC's participation in the Healthiest Nation Alliance. The Office of Women's Health is located within OSI and works to promote and improve the health, safety, and quality of life for women.

9.8 The National Institute for Occupational Safety and Health (NIOSH)

The NIOSH is responsible for conducting research and making recommendations for the prevention of work-related injury and illness. The institute was created in 1970 to ensure safe and healthful working conditions for working men and women by providing research, information, education, and training in the field of occupational safety and health. The institute:

- develops recommendations for occupational safety and health standards
- conducts research on worker safety and health
- conducts training and employee education
- develops information on safe levels of exposure to toxic materials and harmful physical agents and substances
- conducts research on new safety and health problems
- conducts health hazard evaluations to determine the toxicity of materials used in workplaces
- funds research by other agencies or private organizations through grants, contracts, and other arrangements

Furthermore, NIOSH provides leadership to prevent work-related illness, injury, disability, and death by gathering information, conducting scientific research and translating the knowledge gained into products and services. NIOSH also participates in international collaborations and cooperations.

10 The Agency for Healthcare Research and Quality (AHRQ)

AHRQ[52] that also belongs to HHS supports health services R&D initiatives that aim to improve the quality of health care in America. The mission[53] is to improve the quality, safety, efficiency, and effectiveness of health care for all. The agency works to fulfill the mission by conducting and supporting research, both within AHRQ as well as at academic institutions, hospitals, physicians' offices and others. The agency has a relatively broad research portfolio that concerns many aspects of health care. AHRQ-supported research includes:

- Clinical practices
- Outcomes of care and effectiveness
- Evidence-based medicine
- Primary care and care for priority populations
- Health care quality
- Patient safety and medical errors
- Organization and delivery of care and use of health care resources
- Health care costs and financing
- Health care system and public health preparedness
- Health information technology

In addition to the Office of the Director (OD), AHRQ consists of a number of offices and centers including:

- The Office of Financing, Access and Cost trends that conducts and supports studies of the cost and financing of health care, the availability of health care services and related trends. In addition, the center works to develop data sets to support policy making, analyses and research.
- The Center for Outcomes and Evidence that conducts and supports research and assessment of health care practices, technologies, processes and systems.
- The Center for primary Care, Prevention and Clinical Partnerships that works to expand the knowledge base for clinical providers and patients as well as to assure the translation of new knowledge and systems improvements into primary care practice.

[52] http://www.ahrq.gov
[53] http://www.ahrq.gov/about/strateix.htm

- The Center for Quality Improvement and Patient Safety that works to improve the quality and safety of the health care system through research and implementation of evidence-based results.
- The Office of Extramural Research, Education and Priority Populations that directs review processes for grants and contracts and that manages the agency's research training programs. The office also supports and conducts health services research on priority populations.

Originally, the estimated federal budget (FY 2009) for research within the healthcare research and quality area was 353 million USD which would have constituted a decrease compared to 2008. However, after congressional action[54], research expenditures are expected to be on the same level as for 2008 (362 million USD). Furthermore, ARRA provided 300 million USD for AHRQ healthcare research. The agency has three budget activities namely Research on Health Care Costs, Quality and Outcomes (HCQO), the Medical Expenditure Panel Survey (MEPS) and Program Support (PS). HCQO consist of six research portfolios:

- Comparative effectiveness
- Prevention/Care management
- Value research (FY 2009 original estimate 9.7 million USD). The suggested budget includes a 6 million USD increase from 2008 due to a new initiative, the health Insurance Decision Tool. The initiative is intended to facilitate the development of state-based affordable health plans for low income individuals and to provide state decision makers with the tools and information they need to design effective programs to reduce the number of Americans without health insurance.
- Health information technology
- Patient safety (FY 2009 estimate 32 million USD). This program includes the research programs; Patent Safety Threats and Medical Errors and Patient Safety Organizations.
- Other quality, effectiveness and efficiency research (FY 2009 estimate 142 million USD). Reductions within this account may occur for research contracts, research and training grants and in contract-based activities to fight Methicillin-resistant staphylococcus aureus (MRSA) and related infections.

MEPS is the only national data source for how Americans use and pay for medical care.

[54] http://www.aaas.org/spp/rd/upd209t1.pdf

11 The National Science Foundation (NSF)

The NSF[55] is one of the largest non-defense federal research funder and, in contrast to most other agencies, does not belong to any specific department but instead reports directly to Congress. The mission of the NSF is to finance research, development and innovation in areas such as chemistry, biology, physics, mathematics, information technology (IT) and the social sciences. The work of the agency is very much driven by the scientists' own ideas and proposition (bottom-up approach). With few exceptions, NSF does not finance the same type of R&D as NIH. There are however overlaps primarily within the biology, physical sciences, mathematics and IT areas.

The budget for NSF was approximately 6.1 billion USD (2008) of which research and related efforts stood for 4.8 billion USD. Appropriations for 2009 as well as one-time ARRA funding, results in large funding increases for NSF.

The Biological Sciences directorate budget was 633 million USD (2008) while chemistry research which is financed in the Mathematics and Physical Sciences directorate received 210.5 million USD. Some life science-related research areas and funding levels (2008) are:

- Molecular and cellular bioscience[56] 116.4 million USD
- Biological infrastructure[57] 96.1 million USD
- Emerging frontiers[58] 99.2 million USD

NSF supports efforts within bioinformatics and for instance funds the U.S. participation in the International Neurocomputing Coordinating Facility[59] (INCF) whose secretariat is located at the Karolinska Institute in Stockholm.

The Biological Sciences Directorate (BIO) is about to augment its funding to support emerging areas of interdisciplinary research, many of which lie at the intersection of the life and physical sciences. Priority will be given to projects that address fundamental questions about life in transition such as how the living world has and is adapting to and transforming the Earth's climate, the diverse strategies by which living systems obtain and use

[55] http://www.nsf.gov/
[56] http://www.nsf.gov/div/index.jsp?div=MCB
[57] http://www.nsf.gov/div/index.jsp?div=DBI
[58] http://www.nsf.gov/div/index.jsp?div=EF
[59] http://www.incf.org/

energy, biodiversity and, life’s origins and indispensable properties. Effects brought about by the likely climate change are clearly seen as important.

Interestingly NSF’s Biological Sciences directorate will have a joint initiative with the British Engineering and Physical Sciences Research Council (EPSRC). The collaboration is a so called “Sandpit”[60] in which UK and U.S. scientists will get together for five days to identify crucial projects and issues in “Synthetic biology”. Synthetic biology aims to discover and apply the operational principles of biological systems through the design and construction of biologically inspired parts, devices and systems that do not exist in the natural world as well as to redesign existing natural biological systems for various purposes. The EPSRC and the NSF plan to allocate up to 5.5 million pounds to support novel and potentially transformative research resulting from the sandpit.

[60] http://www.epsrc.ac.uk/CMSWeb/Downloads/Calls/SynBioSandpit.pdf

12 The Department of Defense (DOD)

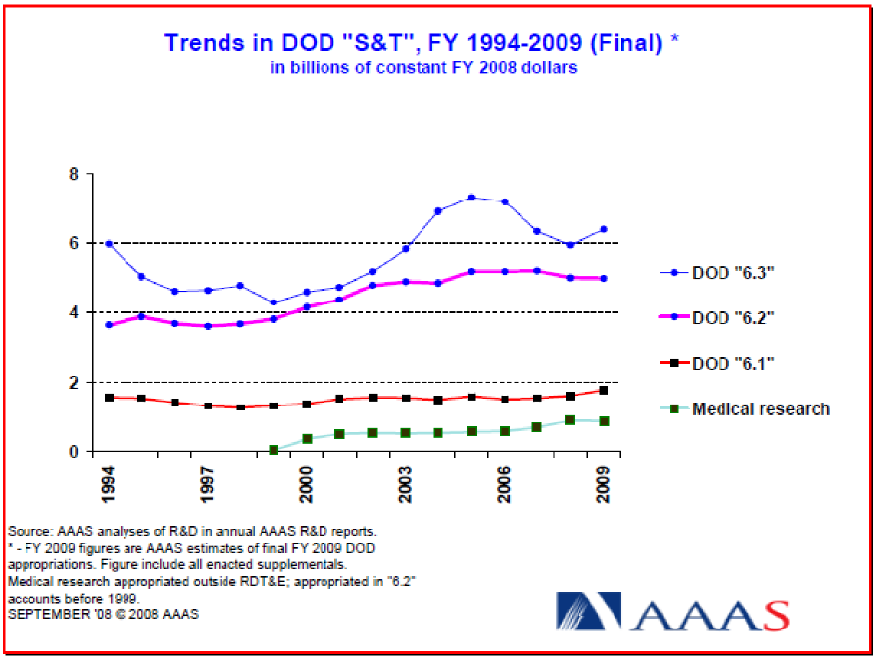
DOD is, by far, the largest federal funder of R&D (fig 15) and was, according to President Bush's original request, suggested to receive 80.7 billion USD[61] (+ 3.7% compared to 2008) for research and development investments in 2009. In the final appropriation[62], 82.4 billion USD was targeted for DOD R&D.

21% of DOD-financed basic and applied research is performed at universities making it the third-largest federal sponsor of academic research after the NIH and the NSF. Biomedical research takes place at a large number of military branches including the Army, Navy (including the Naval Medical Center[63]) and Air Force. Interestingly DOD requested a 4% increase to 1.7 billion USD for its basic research that mostly is performed at universities. DOD Science and Technology spending includes basic research, applied research including medical research, as well as technological development.

Large cuts for medical research in the Defense Health program were suggested in the Presidents budget request for 2009. The account was 893 million USD in 2008 including large investments into breast-, ovarian- and prostate-cancer research (228 million USD). In line with the pattern over the last years, Congress introduced earmarks resulting in funding of the medical program with 903 million USD for 2009. Congress allocated 250 million USD for the cancer research mentioned above. However, Congress also initiated several new research programs on lung cancer, orthopedics, spinal cord injuries, vision, and selected cancer topics. Furthermore, Congress continued funding for other medical research within DOD.

[61] http://www.aaas.org/spp/rd/09pch5.htm
[62] http://www.aaas.org/spp/rd/dod09c.htm
[63] http://www.bethesda.med.navy.mil/

Figure 15 Time series of funding levels for DOD-supported R&D. Note the development of the Medical research account. 6.1 =Basic research, 6.2= Applied research, 6.3= Development



Source: American Association for the Advancement of Science (AAAS)

12.1 Defense Advanced Research Project Agency (DARPA)

DARPA[64] is an agency belonging to (DOD and has a reputation for innovative and successful research and development. DARPA contributed to innovations such as the Internet and the Personal Computer, and is generally thought to be very successful. Although DARPA focuses on R&D of importance for the defense and the armed forces it funds relatively much basic science R&D and also funds research in other countries (including Sweden). To ensure that there is a continuous flow of ideas and projects, DARPA in its headquarters in Virginia does not allow project managers to stay in their position for more than five years. DARPA does not normally prevent researchers from publishing their results, in particular not when it concerns basic research where national defense issues are relatively far removed. Funding from DARPA may be extended to laboratories and universities in other countries. The administrative procedures become more complex if the receiving institution is a government body.

President Bush suggested that the DARPA budget for R&D be 3.29 billion USD fiscal year 2009. This was augmented by Congress to 3.13 billion

[64] http://www.darpa.gov/

USD. DARPA’s basic research budget increased 16% to 202 million USD while funding for applied research increased less (+3.3%). Congress has expressed dissatisfaction with DARPA’s ability to execute its full budget during previous years. Most life science-related research is funded through the Defense Sciences Office (DSO). Important examples of life science-related programs are the strategic thrusts within the Biology and Biological Warfare Defense Programs[65]. The programs include areas such as:

- Tactical biomedical technologies
  - Examples: Trauma, blood-related research
- Restorative biomedical technologies
  - Examples: Injury repair, prosthetics
- Maintaining human combat performance
  - Examples: Health prediction, disease prediction, human performance
- Biologically inspired platforms and systems
  - Example: Biologically inspired sensors
- Biological warfare defense
  - Examples: Protein design, Vaccine assessment
- Protection and detection
  - Example: Protein conformations

The Biology Warfare Defense program was originally estimated[66] to receive 66.3 million USD for 2009 (-8% compared to 2008) while the Materials and Biological technology program would receive 285.3 (-5.4%) million USD. Of these 94.4 million USD belongs to the area Biologically Based Materials and devices.

12.2 Other Defense research agencies

Examples of other defense agencies and initiatives involved in R&D are the Defense Threat Reduction Agency[67] (DTRA) and the Chemical and Biological Defense Program[68] (CBDP).

Related to the activity within the DOD, the **Department of Homeland Security**[69] (DHS) has some activities relating to life science research. The chemistry and biology programs within DHS are estimated to have used 208

[65] http://www.darpa.mil/dso/thrusts/bio/index.htm
[66] http://www.darpa.mil/Docs/DARPAPB09February2008.pdf
[67] http://www.dtra.mil/
[68]http://www.defenselink.mil/comptroller/defbudget/fy2009/budget_justification/pdfs/02_Procurement/Vol_2_SOCOM_CBDP/CBDP%20PDW%20PB09.pdf
[69] http://www.dhs.gov/

million USD in 2008. DHS is also an important department for project Bioshield (See Department for Health and Human Services).

13 The National Nanotechnology Initiative (NNI)

The NNI[70] is a federal program established in 2001 to coordinate federal nanotechnology R&D and is intended to provide a long-term vision for nanotechnology including Nanomedicine. The NNI works as a framework for nanotechnology R&D program by establishing shared goals, priorities, and strategies, and also provides ways for the 25 federal NNI member agencies to leverage the resources of all participating agencies. Thirteen of the participating agencies have R&D budgets that relate to nanotechnology, with the reported NNI budget representing the collective sum of these. The NNI as a program does not fund R&D. However, it informs and influences the federal budget and planning processes through its member agencies. The agencies with the largest investments in Nanoscience are the Department of Defense, the National Science Foundation, the Department of Energy and the National Institutes of Health. Nanomedicine will be the subject of a separate report.

[70] http://www.nano.gov/

14 The Network and Information Technology Research Development program (NITRD)

NITRD[71] is a coordinating program and office for federal agencies funding R&D in the IT-sector and in total coordinates R&D investments worth approximately 3 billion USD (2008) annually. There are 13 member agencies in the NITRD initiative. The five participants with most funding in the area are: the National Science Foundation, the National Institutes of Health, the Department of Defense (including DARPA) and the Department of Energy. NIH originally requested 509.7 million USD for NITRD-related Program Component Areas (PCA's) 2009. The two PCA's that NIH invests most heavily in are High-End Computing Infrastructure and Applications (request 159.4 million USD) and Human-Computer Interactions and Info Management (request 181.7 million USD). Other large areas for NIH are High-End Computing R&D (request 76.3 million USD) and Large-Scale Networking (request 68.0 million USD).

[71] http://www.nitrd.gov/

15 The Institute of Medicine of the National Academies

The Institute of Medicine[72] (IOM) was chartered in 1970 and is a part of the National Academies. The institute, which is influential, works outside government to provide scientific analysis and guidance. Its mission is to provide advice to the nation on issues concerning the improvement of health. According to IOM, it provides unbiased, evidence-based and authoritative information and advice concerning health and science policy to policy-makers, professionals and leaders in every sector of the society as well as to the public at large.

The work is conducted by committees of volunteer scientists from the U.S. as well as other countries. Committee reports can be on a large range of subjects such as the quality of health care, the organization of federal research organizations such as the NIH or how to safeguard the nation's food supply. The majority of the studies are requested and funded by the federal government although industry, foundations, states and local governments also initiate studies. The IOM also initiates studies itself.

IOM manages the Robert Wood Johnson Health Policy Fellowships Program. IOM is both an honorific membership organization and a policy research organization. Members can be American or from other countries and are selected on their professional achievements and other criteria.

[72] http://www.iom.edu/

16 Innovation, research and technology transfer

16.1 The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs

The SBIR programs[73] have been described in multiple texts [eg. 11] and are federal programs for small businesses in the U.S. to promote innovative R&D with the potential for commercialization and public benefit.

Federal agencies that have extramural R&D budgets over 100 million USD are required to have SBIR programs and to annually set aside 2.5% of the extramural R&D budget for this. At present, eleven federal departments/agencies participate in the SBIR program either directly or through the agencies that they control. These are the Departments of Health and Human Services, the Department of Agriculture, the Department of Commerce, the Department of Defense, the Department of Education, the Department of Energy, the Department of Homeland Security, the Department of Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation. In addition, federal agencies with extramural R&D budgets over 1 billion USD are required to run STTR programs by setting aside 0.3% of the R&D budget annually. Five federal agencies participate in the STTR program (DOD, DOE, HHS (NIH), NASA, NSF).

The objective of an SBIR program is to stimulate technological innovation and commercialization in small businesses, to strengthen and increase small businesses participation in federal R&D and to foster and encourage participation by socially and economically disadvantaged small businesses as well as women-owned businesses in the SBIR program. STTR and SBIR programs are similar. However, the unique feature of the STTR program is the requirement for the small business applying to formally collaborate with a research institution in two of the phases of the program (I and II). The STTR Program requires research partners at universities and other non-profit research institutions to have a formal collaborative relationship with the small business concern. The structure of the programs is described in box 2.

[73] http://www.sba.gov/aboutsba/sbaprograms/sbir/index.html

The SBIR program was created 1982 through the Small Business Innovation Act and the NIH funded SBIR grant and contract awards totaling over 572 million USD and STTR grant awards totaling over 68 million USD in fiscal year 2006[74]. When the program approached its 20th year in operation, congress requested that the National Research Council[75] (NRC) of the National Academies conducted an extensive review of how the program had stimulated technological innovation and used small businesses to meet federal research, development and innovation needs.

Box 2 The SBIR and STTR program structures

Structure of the SBIR and STTR Programs

Phase I. The objective of Phase I is to establish the technical merit and feasibility and potential for commercialization of the proposed R/R&D efforts and to determine the quality of performance of the small business awardee organization prior to providing further Federal support in Phase II. Support under Phase I normally may not exceed $100,000 for total costs (direct costs, F&A costs, and negotiated fee) for a period normally not to exceed six months for SBIR and one year for STTR.

Phase II. The objective of Phase II is to continue the R/R&D efforts initiated in Phase I. Funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II. Only Phase I awardees are eligible for a Phase II award. Support for SBIR and STTR Phase II awards normally may not exceed $750,000 total costs (direct costs, F&A costs, and negotiated fee) for a period normally not to exceed two years.

Deviations from the indicated Phase I/Phase II statutory award amount and project period guidelines are acceptable but must be well justified and should be discussed with appropriate NIH staff prior to submission of the application prior to submission of the application.

Phase III. The objective of Phase III, where appropriate, is for the small business concern to pursue with non-SBIR/STTR funds the commercialization objectives resulting from the Phase I/II R/R&D activities. In some Federal agencies, Phase III may involve follow-on non-SBIR/STTR funded R&D or production contracts for products, processes or services intended for use by the U.S. Government.

Source: The National Institutes of Health

The review[76] focused mostly on the NSF but most findings are relevant for other agencies as well. On a more general level, the NRC chose to assess the SBIR programs at five agencies that together are responsible for 96% of all SBIR expenditures. These are (in order of program size):

1 the Department of Defense
2 the National Institutes of Health
3 the National Aeronautics and Space Administration
4 the Department of Energy

[74] http://grants.nih.gov/grants/funding/sbirsttr_programs.htm
[75] http://sites.nationalacademies.org/nrc/index.htm
[76] An Assessment of the SBIR Program at the National Science Foundation, National Research Council (2007). http://www.nap.edu/catalog/11929.html

5 the National Science Foundation

A detailed description of the review is beyond the scope of this text. However, some of the highlights are listed below. Note that the text primarily concerns the SBIR program at NSF but, in most cases, can be extrapolated for other agencies such as the NIH.

The review was focused on a number of societal objectives such as; (1) stimulation of technological innovation, (2) increased private-sector commercialization of innovations, (3) the use of small businesses to meet federal R&D needs and (4) the encouragement of minorities and disadvantaged persons to participate in technological innovation. The study also dealt with the management of the SBIR programs including best practices that could be extended to other agencies.

In general, the study finds that the SBIR programs are sound and effective. They can however be improved. The programs are contributing to the nation's published scientific data and technological knowledge and many awardees say that their project would probably not or definitely not have been performed without SBIR support. Phase II awardees are involved in extensive licensing activities. There is also a large degree of networking between SBIR project participants and universities. The SBIR programs have also facilitated technology transfer out of universities. In addition, a significant fraction of SBIR-funded projects commercialize successfully although relatively few projects, seen individually, lead to immediate commercial success stories.

NSF's SBIR program is aligned with the agency's broader mission and is contributing broadly to federal R&D procurement needs. Success rates for woman- and minority-owned firms applying for Phase I awards was significantly lower compared to other firms. The participation by woman and minority-owned businesses is also lower than for other groups. The administration of the program is relatively effective and the NSF has, according to the report, made an impressive effort in developing a well-run program not least because of its strong management and talented program managers.

As a result of assessment, the NRC has made a number of recommendations. These include retaining and encouraging program flexibility, to conduct regular evaluations of the programs, to increase management and funding for SBIR programs and to ensure that the topic definition processes are bottom-up. The NRC also recommends that commercialization efforts support is stepped up. Efforts to increase the participation of woman- and minority-owned businesses need to be increased.

In addition to the evaluation described above, the NIH recently published a survey to evaluate its SBIR program[77]. Furthermore, an assessment of the SBIR-program performed at NIH was published recently[78] by the NRC. The evaluation was generally seen positive and points to that the NIH program is special in that is more decentralized than is usual and also in that the NIH mission is not geared towards procurement. The SBIR-awards are therefore often not intended to support the direct needs at the NIH. The evaluators emphasizes that the program is effective and that it is important that the program remains flexible. Among other recommendations they suggest that efforts should be made to improve evaluations and commercialization management.

The Technology Innovation Program[79] (TIP) is another program run by the National Institute for Standards and Technology (NIST) that is intended to support, promote, and accelerate innovation through high-risk, high-reward research in areas of critical national need. Some of the future TIP investments are likely to be within the life sciences.

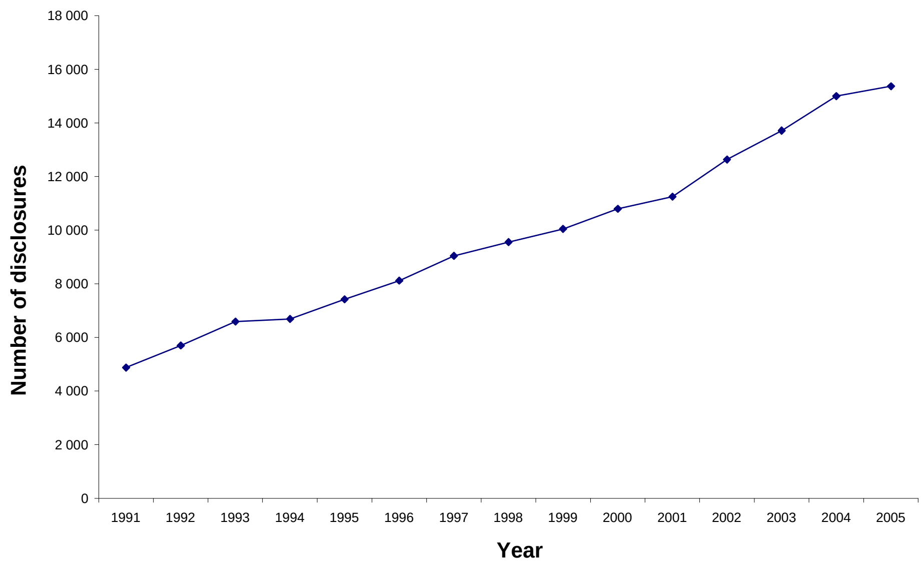
16.2 Overall technology transfer trends from academic institutions

In accordance with the Bayh-Dole Act[80] of 1980, U.S. universities normally own the research results produced at their institutions if the research was funded by public bodies. The same is true for much research funded by other sources. Because of this, it is in the interest of the universities to encourage commercialization and an increasing number of research institutions establish technology transfer offices. The number of invention disclosures in a survey[81] conducted by the Association of University Technology Managers (AUTM) increased to 15,400 in 2005 (fig. 16). As the AUTM does not include all institutions, the survey should not be regarded as representing all universities but rather as a trend. According to the U.S. Patent and Trademark Office[82] (USPTO), patent grants to universities increased from 1995 to 2002 when they reached 3,300 patents per year (fig 17)[83]. Three biomedical related utility classes dominated university patenting in the 1990s and together accounted for more than one-third of all utility patents awarded to U.S. academic institutions in 2005. The classes are; (1) drug, bio-affecting and body treating compositions

[77] http://www.grants.nih.gov/grants/funding/sbir_2008surveyreport.pdf
[78] http://books.nap.edu/openbook.php?record_id=11964&page=R1
[79] http://www.nist.gov/tip/
[80] http://en.wikipedia.org/wiki/Bayh-Dole_Act
[81] http://www.autm.net/AM/Template.cfm?Section=FY_2005_Licensing_Survey
[82] http://www.uspto.gov/
[83] http://www.nsf.gov/statistics/seind08/c5/c5s3.htm

(15.4%); (2) chemistry: molecular biology and microbiology (13.8%); and (3) organic compounds (5.6%).A decline in the number of patents from academic institutions could be observed for 2003 to 2005. This, however, contrasts with the number of invention disclosures to university technology transfer offices that increased from 13,700 in 2003 to 15,400 in 2005[84]. Furthermore patent applications also increased. The median net income per university relating to patenting activities can be seen in fig. 18. It is important to note that the incomes from patents arise from relatively few patents and universities.

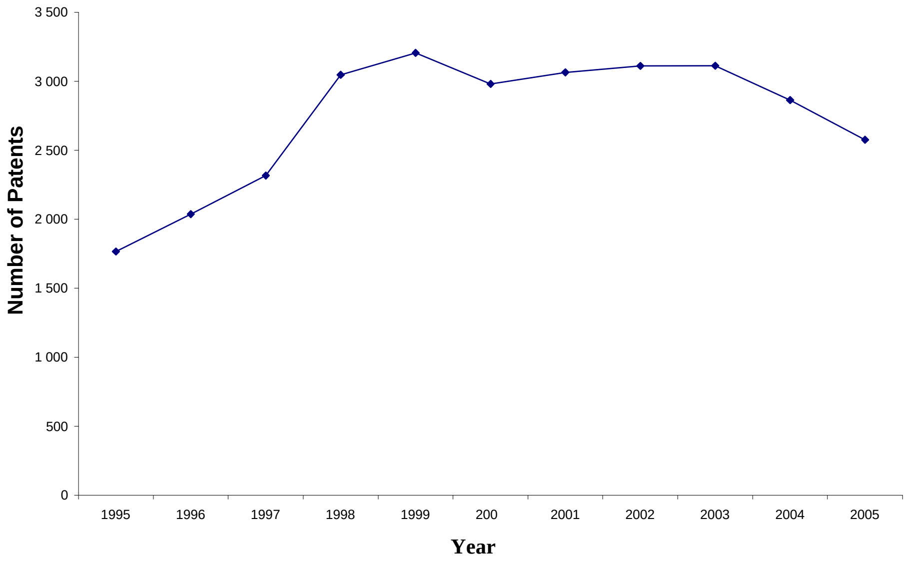
Figure 16 Invention disclosures reported by university technology transfer offices



Sources: Association of University Technology Managers and the National Science Foundation

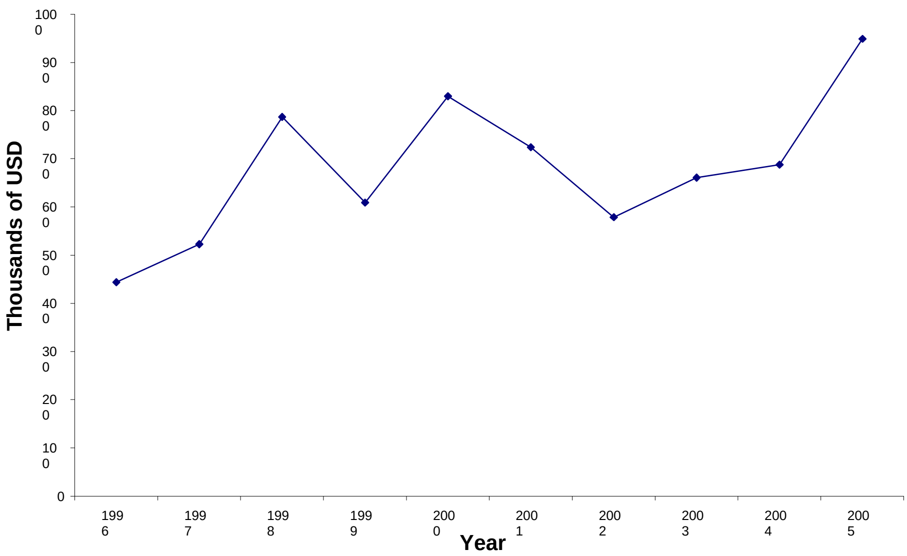
[84] The Association of University Technology Managers (www.autm.org)

Figure 17 Patents granted to U.S. universities and colleges



Sources: U.S. Patents and Trademark Office and the National Science Foundation

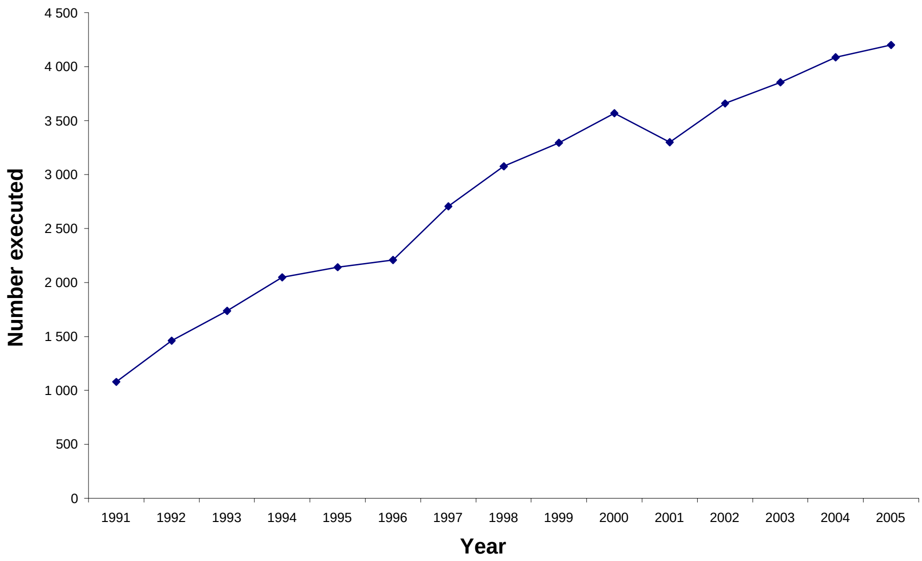
Figure 18 Net royalties from academic patenting per university



Sources: Association of University Technology Managers and the National Science Foundation

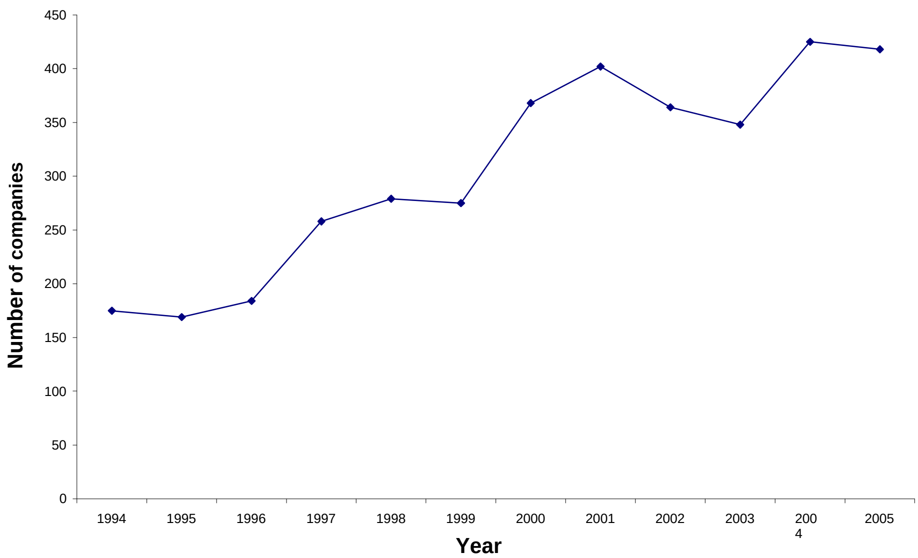
The number of new licenses and options executed from universities has been increasing for a long time and has reached more than 4,000 (fig 19). The data should be interpreted with some care as the wording in the survey questions has been changed over time. The number of revenue-generating licenses was approximately 10,200 in 2005 compared to 5,000 in 1996.

Figure 19 New licenses and options executed at U.S. universities



Sources: Association of University Technology Managers and the National Science Foundation

Figure 20 Startup companies formed at U.S. universities



Sources: Association of University Technology Managers and the National Science Foundation

Finally the number of start-up companies from the universities answering the survey was 418 in 2005 (fig. 20).

16.3 Biotechnology patents*

The U.S. share of biotechnology patent was 40.6% in 2005 according to the OECD[85]. Japan came in second with 17.0% while the EU stood for 25.1%. Sweden had only 1.3% of all biotechnology patents. The top 10 regions in the world (2003-2005) were:

1. San Jose-San Francisco-Oakland, USA (5.7%)
2. Boston-Worcester- Manchester, USA (5.1%)
3. New York-Newark-Bridgeport, USA (3.8%)
4. San Diego-Carlsbad-San Marco, USA (3.2%)
5. Tokyo, Japan (3.1%)
6. Washington-Baltimore, Northern Virginia, USA (2.9%)
7. Los Angeles-Long Beach-Riverside, USA (2.0%)
8. Philadelphia-Camden-Vineland, USA (1.9%)
9. Kanagawa, Japan (1.8%)
10. Denmark (1.7%)

*=Biotechnology is here used in a wide sense.

[85] http://www.oecd.org/dataoecd/5/19/37569377.pdf

17 International collaborations in the life sciences

The U.S. research and innovation system is extremely distributed and international collaborations occur on many levels. The most common collaborative form is most likely that between researchers and research groups although collaborations also take place between various public and private organizations including between government agencies as well as on the national and multilateral levels. At present, Sweden has a number of research agreements with the United States including a general collaborative research agreement[86] (umbrella agreement) that was signed on June 29th, 2006. In total, the U.S. has 37 agreements[87] of this kind with various countries including Norway and Finland. Another Swedish-U.S. research agreement concerns "Homeland security"[88] where the Department of Homeland Security is the primary U.S. counterpart. The Polar research agreement[89] was signed in 2007 by the National Science Foundation (NSF), the Swedish Research Council (VR) and the Swedish Polar Research Secretariat. An example of another type of collaboration is that between the NIH and the Karolinska Institute which concerns graduate studies in the neurosciences[90]. This program is seen as very successful but is at present relatively small.

Below are described some offices within the federal administration and its agencies that are of importance for international collaborations within the life sciences. NIH is in focus although we also touch upon the role of the NSF.

17.1 Office of Science and Technology Policy (OSTP)

OSTP[91] belongs to the White House administration and acts in an advisory capacity to the President in questions that concern how science, research and technology affects national and international questions including policy. The director of the OSTP is the Assistant to the President on science and

---

[86] http://www.newsdesk.se/view/pressrelease/39447
[87] http://www.state.gov/g/oes/rls/fs/2009/115031.htm
[88] http://www.dhs.gov/xlibrary/assets/agreement_us_sweden_sciencetech_cooperation_2007-04-13.pdf
[89] http://www.nsf.gov/about/contracting/rfqs/support_ant/docs/gen_management/swedish_polar_agreement.pdf
[90] http://www.uic.edu/depts/oaa/ssp/nih.htm
[91] http://www.ostp.gov/

technology questions (science advisor). President Obama has named Dr. James P. Holdren as his Science Advisor. Dr. Holdren is the Teresa and John Heinz Professor of Environmental Policy at Harvard's John F. Kennedy School of Government and director of the Science, Technology, and Public Policy program in the School's Belfer Center for Science and International Affairs. The previous OSTP director was Dr. John H. Marburger III.

The role of OSTP is primarily;

- to advise the President and others within the Administration on the effects mediated by science and technology on national and international matters
- to lead interagency efforts and initiatives for the development and implementation of sound policies and budget discipline for Science and Technology efforts
- to, together with the private sector ensure that federal investments in science and technology contribute to economic wellbeing, good environment and national security
- to build partnerships between federal and state departments and agencies, local authorities, the science community as well as with parties in other countries
- to evaluate the scale, quality and efficiency of federal investments in science and technology

17.1.1 Criteria for U.S. participation in international scientific collaborations

A few years ago a number of criteria for U.S. participation in international scientific collaboration, were formulated. According to the OSTP director at the time, Dr. Marburger, the U.S. (as a federal country) should not commit funds for collaborations unless at least one of the below criteria[92] is satisfied;

- To maintain and improve the quality of U.S. research by applying the highest standards globally (performing science to the highest standards)
- To ensure that all U.S. researchers have access to the newest and most important scientific questions, the latest research results and the best resources (access to the frontiers of science)
- To increase the productivity of U.S. research through collaborations between U.S. scientists and the best scientists in the world irrespectively of location (access to scientific talent)

[92] https://secure.wikileaks.org/leak/crs/RL34503.txt

- To strengthen U.S. research through visits, exchanges and immigration of leading scientists from other countries (augmentation of scientific human capital)
- To increase national security and economic prosperity in the U.S. by contribution to the improvement of conditions in other countries through technological development (security through technology-based equity)
- To accelerate scientific and technological results and breakthroughs through collaborations in a wider area than the U.S. wants or can do only with its own resources (leveraging on foreign science capabilities)
- To increase the understanding of American values and ways of acting in other countries (science diplomacy)
- To handle U.S. interests of global nature that the U.S. is unable to affect efficiently solely by itself (global support for global scientific issues)
- To perform obligations negotiated in connection with treaties (science as a tradable asset)
- To increase the prestige and influence of the U.S. in other nations (science for glory)

Located in the White House organization is also the Presidents Council of Advisors on Science and Technology[93] (PCAST) as well as the National Science and Technology Council[94] (NSTC). PCAST consists of members from industry, universities and authorities and acts in an advisory capacity to the President in scientific and technological matters. PCAST's member are listed at http://www.ostp.gov/cs/pcast/membership.

NSTC coordinates science and technology initiatives in between the many federal agencies and departments. The council is headed by the President and also includes the vice President, the head of OSTP, ministers, heads of agencies and civil servants of the White House. Organized under NSTC are four main committees and a large number of subcommittees. The main committees are:

- Committee of Environment and Natural Resources (CENR)
- Committee on Homeland and National Security (CHNS)
- Committee on Science (CoS)
- Committee on Technology (CoT)

[93] http://ostp.gov/cs/pcast
[94] http://ostp.gov/cs/nstc

17.2 Department of State

It is self evident that the Department of State[95] is of primary importance for bilateral and multilateral agreements and treaties. “State’s” **Bureau of Oceans, Environments and Science (OES)** works with international collaborations in different forms and for various purposes. Examples of topics concerned are infectious diseases, biodiversity, climate change, water and energy supply, oceans, handling of toxic substances, space research and other collaborations in science and technology. Offices involved in international research, development and education collaborations include the:

- Office of International Health and Biodefence.
- Office of Science and Technology Cooperation.
- Office of Space and Advanced Technologies.

The **Office of Science & Technology Cooperation (STC)** works on the policy level to promote the interests of the science community internationally. OES/STC also represents U.S. science and technology in multilateral international organizations such as UNESCO, APEC, OECD and others. Furthermore, OES/STC deals with binding bilateral and multilateral S&T agreements. Agreements may for instance concern global safety and security, sustainable development, the improvement of woman’s positions in S&T or evidence-based decision making. According to the State Department, the bilateral Science and Technology agreements facilitates collaborations between researchers in many ways by addressing for instance scientific exchanges, intellectual property rights (IPR), tax matters and access to national and international resources.

17.3 National Institutes of Health (NIH)

As may be expected, international collaborations among life science researchers are common and NIH takes a very positive attitude towards international collaborative research. NIH directly fund research projects in other countries. An example of this is that around 8% of the external grants to some departments at the Karolinska Institute came from NIH in 2007 [12]. NIH has a strong focus on “peer review” as a selection process and many of the program initiatives comes from the research community. Formal program collaborations relatively often take place with countries on low- or middle income levels and are often organized on the institute level. The Fogarty International Center has a special role in that it solely focuses on international issues and in particular global health issues (see below).

[95] http://www.state.gov/

NIH is directly or indirectly involved in global partnerships with for instance the World Health Organization (WHO), other UN-organizations, national governments and their agencies, foundations, non-profit organizations and actors from the private sector. “Critical Global Partnerships” have been formed in some areas such as for malaria, epidemiology (including influenza) and vaccine development. International collaborations are common in many areas including global health, malaria, epidemiology, HIV/AIDS, and injury prevention.

Collaborations such as those concerning infectious diseases and biological defense partly concerns exchange of information, the build-up of research and education capacity as well as infrastructure in developing countries. Examples of NIH’s international collaborations are:

- Drug addiction (e.g. with Malaysia, Kina)
- Influenza seasonal mortality (20 countries)
- Global HIV vaccine enterprise, Partnership for AIDS Vaccine Evaluation (PAVE)
- Global infectious disease research training (training of researchers in developing countries)
- HIV research training program (build-up of institutional, national and regional capacity for research in low- and middle income countries)
- Mechanisms of HIV neuropathogenesis (domestic & global issues, global patterns)
- HIV virus transmission from primates to humans
- International Research Scientist Development Award (IRSDA, support to U.S. researchers)
- Disease Control Priorities Project (DCPP, inform policy-makers in developing countries with the purpose of improving these countries healthcare systems; WHO, Gates foundation etc.)
- Population studies and reproductive biology
- International Collaborative Trauma and Injury Research Training Program (ICTIRT). This program which is about to be closed down may become replaced with a new program. The ICTIRT program concerns trauma and injuries in developing countries and is supporter by the Fogarty International Center, other NIH partners, the Center for Disease Control, the Pan-American Health Organization and the WHO. The program deals with injury preventions, emergency care, risk factors, survival factors, rehabilitation, and long-term injuries

17.3.1 Collaborations between Swedish actors and the NIH

Much collaboration between NIH and Swedish actors and researchers are ongoing, as mentioned above, the NIH and the Karolinska Institute have a program collaboration concerning graduate studies in Neuroscience. NIH also has graduate program collaborations with the universities in Oxford and Cambridge.

17.3.2 Fogarty International Center

The NIH institute that mostly works with international questions and in particular with global health issues is the Fogarty International Center (FIC). FIC is the “international arm” of the NIH and deals with many bilateral cooperation’s and collaborations. Note, however, that FIC, as all other NIH institutes, is focused on peer review as a selection process. FIC, which is a relatively small institute with a budget of approximately 69 million USD per year (2009), runs bilateral collaborations with countries including India and China and in particular deals with matters that concerns developing countries.

Present collaborations with India concern for instance low-cost diagnostics, vaccine development and, the environment and occupational health. There is also an interest in non-infectious diseases and nutrition problems (including obesity).

Among other areas, bilateral agreements with India concern:

- HIV/AIDS (Approximately 2 million USD/year and partner)
- Infectious diseases
- Mental health

Many collaborations concerns graduate studies and the education of researchers.

FIC is in general interested in new collaborations with other countries.

17.4 National Science Foundation (NSF)

NSF has via the researchers they fund a very large international collaboration, and many of programs are open for international applicants. As mentioned earlier, NSF normally has a “bottom-up” approach and expects that most ideas and initiatives come from the scientists themselves. The National Science Board[96] (NSB) which is the influential board for NSF has recently published ”International Science and Engineering Partnerships: A priority for U.S. Foreign Policy and Our Nation,s Innovation Enterprise[97]” in which the authors strongly encourages the Administration and other actors to facilitate international collaborations and exchanges. The importance of international partnerships with other countries and NSF’s role

[96] http://www.nsf.gov/nsb/
[97] http://www.nsf.gov/pubs/2008/nsb084/nsb084_2.pdf

in this are highlighted. The agency's formal international collaborations and collaborations are in particular within the following areas:

- U.S. collaborations in research networks and global projects
- Support for international resources
- Links to research programs in other countries (often intended to make it possible for U.S. researchers to collaborate with scientists in other countries)
- Support to, in particular, younger researchers for international research experiences
- Support for exchanges including conferences and educational efforts

The **Office of International Science and Engineering**[98]" (OISE) is NSF's international office and works:

- to support planning, visits and workshops that may lead to international collaborative projects
- to provide U.S. researchers and students with the possibility of international activities and experiences
- to support and establish international partnerships to expand global networks and to create links with other countries institutions as well as to use international investments

OISE has offices in Paris, Tokyo and Beijing. The offices have close contacts with foreign organizations and research councils. In Washington D.C. there is a close contact with the Science offices at many of the embassies (including the Science office at the Embassy of Sweden). NSF's Biology directorate has many international collaborations including a "sandpit" with the British Engineering and Physical Sciences Research Council to be held during the spring 2009 (See chapter 11).

17.5 Discussion

In general, federal research funders and performers have a positive view on international collaborations and are open for new ideas and ways to cooperate.

Collaborations can take many forms and have a large number of aims but NIH as well as NSF is focused on peer review for the selection of funded projects. FIC that primarily works with global health, works to a very large degree with developing countries and is open for discussion, for instance, concerning joint programs in research and education. Funding from

[98] http://www.nsf.gov/od/oise/about.jsp

Department of Defense sources is also, in some cases, open to international applicants.

18 The Universities

18.1 What U.S. universities are best in the life sciences?

The question is not easily answered as it may be interpreted in different ways. There are a number of different rankings that are based on, for instance, graduate school quality or research expenditures. Furthermore all rankings should be considered with care as the methodology and the quality of the methodology varies. In addition, it should be kept in mind that even if a university is not highly ranked, individual top scientists and groups may be located at the institution. Furthermore research in new scientific areas is sometimes published in journals with relatively low impact factors. Although a number of problems with rankings have been listed above, they still provide some information. Furthermore, when the results of many rankings are similar, they may serve as a relatively strong indication of overall quality. Rankings may also have an impact on for instance student choice on where to study or on where researchers would like to work. Two rankings are described below.

18.1.1 U.S. News and World report

The rankings made by the U.S. News and World Report[99] are very influential. In 2008 the journal ranked research and primary-care at the 125 best Medical schools in the United States based on a number of factors. The research score was measured by peer assessment (weight factor=0.20), assessment by residency directors (0.20), total research activity (0.20), average research activity per faculty member (0.10), student selectivity (0.20), the mean MCAT score (Mean College Admission Test, 0.13), the mean undergraduate GPA (grade-point average, 0.06), student acceptance rate (0.01) and faculty resources (0.10). While interpreting the results below it is important to be aware that biomedical research is also performed Science and Arts schools including universities without Medical schools. The top Medical schools in the U.S. based on research rank were:

1. Harvard University, Boston, MA (Score=100)
2. Johns Hopkins University, Baltimore, MD (82)
3. Washington University in St Louis, MO (80)
4. University of Pennsylvania, Philadelphia, PA (79)
5. University of California-San Francisco, CA (78)

[99] http://www.usnews.com/sections/rankings/index.html

6. Duke University, Durham, NC (77)

6. University of Washington, Seattle, WA (77)

8. Stanford University, Stanford, CA (76)

9. University of California-Los Angeles, CA (73)

9. Yale University, New Haven, CT (73)

11. Columbia University College of Physicians and Surgeons, New York, NY (72)

11. University of Michigan-Ann Arbor, MI (72)

13. Baylor College of Medicine, Houston, TX (71)

14. University of California-San Diego, La Jolla, CA (68)

14. University of Pittsburgh, Pittsburgh, PA (68)

16. University of Chicago (Pritzker), Chicago, IL (67)

16. Vanderbilt University, Nashville, TN (67)

18. Cornell University (Weill), New York, NY (65)

19. University of North Carolina-Chapel Hill, NC (62)

20. Emory University, Atlanta, GA (60)

20. Northwestern University (Feinberg), Chicago, IL (60)

22. University of Texas Southwestern Medical Center-Dallas, TX (59)

23. Case Western Reserve University, Cleveland, OH (58)

23. Mayo Medical School, Rochester, MN (58)

23. Mount Sinai School of Medicine, New York, NY (58)

---

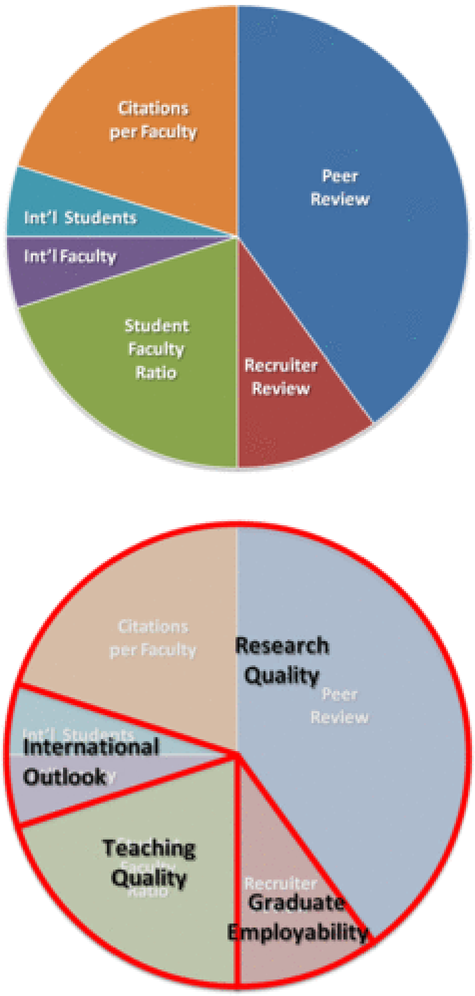
51. University of Massachusetts-Worcester, MA (44)

18.1.2 The Times rankings

The Times (London) ranks the worlds top universities in the life sciences and biomedicine. The weighted factors are illustrated in fig 21[100].

[100] www.topuniversities.com

Figure 21 Indicators and areas considered in the Times ranking of universities



Source: www.topuniversities.com

According to the ranking, the top universities in life sciences and biomedicine are (non-U.S. universities in italics):

1. Harvard University (Score=100)
2. University of Cambridge, UK (93.3)
3. University of Oxford, UK (87.1)
3. Johns Hopkins University (86.7)
4. University of California at Berkeley (85.4)
5. Stanford University (82.0)
6. IMPERIAL College London, UK (75.6)
7. Yale University (73.8)
8. Massachusetts Institute of Technology (73.5)
9. MC GILL University, Canada (70.8)
10. University of California-San Diego (66.9)

11. National University of Singapore (66.3)
12. University of TOKYO, Japan (65.2)
13. University of TORONTO, Canada (63.9)
14. University of California-Los Angeles (63.4)
15. Cornell University (62.8)
16. The University of Melbourne, Australia (61.1)
17. PEKING University, China (61.0)
18. DUKE University (60.0)
19. University of British Columbia, Canada (59.5)
20. California Institute of Technology (57.9)
21. MONASH University, Australia (57.8)
22. The University of Sydney, Australia (57.7)
23. COLUMBIA University (55.1)
24. University College London, UK (54.8)
25. KYOTO University, Japan (54.5)

18.2 The wealthiest U.S. universities

The possibilities for a university or college to be successful and autonomous is dependent on a large number of factors including the organizational form (private, public), the governance system, grant levels as well as its ability to attract students and qualified teachers and researchers. One important factor is the endowment level. Some U.S. universities are quite wealthy while others have constant problems with lack of funds. It is therefore interesting to see what universities that have the largest endowment levels. It should however be remarked that the endowment levels listed below[101] are from 2007 and that the current economic crisis has reduced the wealth of a least some universities significantly. In 2007 the U.S. universities with the largest endowments were:

University and State	**Endowment (2007, billions of USD)**
1. Harvard University, MA	34.6
2. Yale University, CT	22.5
3. Stanford University, CA	17.2
4. Princeton University, NJ	15.8
5. University of Texas System, TX	15.6
6. Massachusetts Institute of Technology, MA	10.0
7. Columbia University, NY	7.1
8. University of Michigan, MI	7.1

[101] http://en.wikipedia.org/wiki/List_of_U.S._colleges_and_universities_by_endowment

9. University of Pennsylvania, PA	6.6
10. Texas A&M University Sys.+ Foundations, TX	6.6
11. Northwestern University, IL	6.5
12. University of California System, CA	6.4
13. University of Chicago, IL	6.2
14. University of Notre Dame, IN	5.9
15. Duke University, NC	**5.9**
185. University of Massachusetts+ Foundations	**0.350**

Note: Endowment levels are listed for the whole university, not only for life science-related activities.

If the endowment levels instead are calculated per student, the picture becomes different:

University and State	Endowment/stud. (2006, millions of USD)
1. Princeton University, NJ	1.9
2. Bryn Athyn College, PA	1.8
3. Yale University, CT	1.8
4. Rice University, TX	1.6
5. Harvard University, MA	1.5

18.3 Descriptions of life science research and development at two universities

Two universities have been selected for a more detailed description, Duke University in North Carolina and University of Massachusetts. Duke University is a private university which is highly ranked within the life sciences. University of Massachusetts is a public (state) university which is highly regarded within the biomedical fields. As the University of Massachusetts is distributed to a number of different campuses, the campus of the Medical School at Worcester and the flagship campus at Amherst are described in greater detail. It should, as mentioned before, be remembered that, in the U.S. system much life science research is performed outside the Medical schools in for instance the Science and Arts faculties or Technology schools. Biomedical research is therefore also performed at universities without Medical schools.

18.3.1 Duke University (North Carolina)

The University[102] was created in 1924 by James Buchanan Duke as a tribute to his father, Washington Duke. The Duke family built a fortune and a worldwide empire largely based on tobacco products. Duke university origin stems from Trinity College in Randolph County that moved to Durham in 1892. In 1924, the Duke endowment[103] made it possible to expand Trinity College into Duke University.

Duke University is a private University with approximately 6,400 undergraduate students. Caucasian students (51%) constitute the largest group followed by Asian Americans (22%). 15% of the students are from North Carolina and only 6% are from other countries. University admission is competitive with less than 10% of the applicants admitted. Approximately 50% of the class of 2012 are woman.

The university campus has approximately 8,500 full-time or part-time employees while the Schools of Medicine and Nursing employ approximately 9,600 (table 6). The employment picture is shown below.

Table 6 Personnel situation at Duke University

EMPLOYEES (June 2008) (full-time and part-time)	
Campus	8,521
Schools of Medicine, Nursing *(includes **Duke** Clinical Research Institute and Private Diagnostic Clinic)*	9,861
DUHS Clinical Labs*	639
Duke University Hospital*	6,350
Durham Regional Hospital*	1,612
Duke Health Raleigh Hospital*	977
Duke HomeCare & Hospice*	213
Patient Revenue Management Org.*	1,309
Davis Ambulatory Surgical Center*	63
DUHS Corporate Services*	1,274
Duke University Affiliated Physicians*	503
Duke Non-Hospital Operations*	117
TOTAL	**31,439**
*(**Duke** University Health System)	

Source: Duke University

Assets, endowments, revenues and expenditures

The total fortune of Duke University is around 7.9 billion USD (2007). It is however likely to have been diminished during the current economic

[102] http://www.duke.edu/
[103] http://library.duke.edu/uarchives/history/histnotes/index.html

downturn. The endowment is to a large extent based on the original gift by James B. Duke in 1924 and had a market value of 6.1 billion USD at the end of the 2007/08 fiscal year. Approximately 5-15% of the endowment is tied to the School of Medicine. Duke University generated approximately 3.9 billion USD (2007/2008) in revenues of which 45% was generated by the Duke University Health System. Other major sources were governmental agencies (14%), investment income (11%), private grants (7%) and tuitions and fees (8%). During the year 2007/08, the university received nearly 300 million USD in gifts.

Health care services were responsible for 37% of the university's 3.7 billion USD operating expenditures, instruction and departmental research was responsible for 18%, and sponsored and budgeted research for 17%. The university is a very successful fundraiser.

Medicine

The School of Medicine was founded in 1930 and the School of Nursing in 1931. The School of Medicine has a faculty (2008) of 1,797 of which 878 are either tenured or on tenure-track [13]. The remaining 919 are a mixture of professors of the practice, research professors, lecturers, clinical professors and medical associates. The School of Nursing has a faculty of 47 of which 23 are tenured or on tenure-track. All faculty may achieve tenure and the requirements are dependent on the type of position considered. Team science is rewarded.

In 2008, the U.S. News and World report ranked Duke University School of Medicine among the top six programs in the United States[104] and the admittance frequency was less than 2%. In 2008 there were 404 students in the MD program and 488 students in basic science PhD programs.

The School of Medicine is research intensive with highly successful research in many areas of basic and clinical sciences. In 2007 the Duke University Medical Center attracted more than 600 million USD for sponsored research and it is ranked as one of the top five U.S. Medical schools in the U.S. with regard to funding from NIH[105]. While the largest share of the external income to the School of Medicine originates from the NIH (estimated to 300-450 million USD yearly), industry is the second largest funder (estimated to 150-200 million USD yearly). When funding originates from industry a thorough review of any special interests is performed and the right to publish openly is normally a requirement from

[104] http://grad-schools.usnews.rankingsandreviews.com/grad/med/search
[105] http://report.nih.gov/reports.aspx?section=NIHResearch&title=Funded%20Organizations

the university. Funds from industry may sometimes be refused due to the demands of the funder.

The overhead that the university and the School of Medicine charges on federal grants is between 50-60%. According to the university, the full cost is however closer to 70-75%. In some cases such as when grants originate from charities, the overhead may be lower than the federal rate.

The university has a large number of centers and initiatives that relate to the life sciences and it is not feasible to describe them all here. However some of the most important initiatives are discussed below.

An interesting initiative is the partnering between Duke University and the National University of Singapore (NUS) in the Duke-NUS Graduate Medical School[106] (GMS), Singapore (2005). The school will have a program based on that at the Duke University School of Medicine. Singapore has made significant investments in the project as a part of a national strategy.

Duke University Medical Center consists of clinical, training and research programs. Among those are a federally funded cancer center and an eye center. Duke hospital is the flagship hospital of the system although it also consists of community hospitals as well as of collaborations with other regional health care institutions. Duke University is also home to the Institute for Genomic Sciences and Policy, the Trent center for Bioethics, Humanities and History of Medicine the Sarah W. Stedman Nutrition and Metabolism Center, the Duke Center for the Study of Aging and Human Development, the Global health Institute, the Duke Human Vaccine Institute, the Duke Comprehensive Cancer Center, the Duke Heart Center, the Center for Chemical Biology as well as the Duke Translational Medicine Institute (see below). Duke University is also home to the Duke Clinical Research institute[107] (DCRI), which, according to the university, is the largest clinical research organization in the world. It performs clinical trials through phase I to IV, outcomes research as well as other types of research in many therapeutic areas. Furthermore, it is home to several professional society databases (e.g. in oncology and cardiovascular diseases). The DCRI is active in a large number of international studies.

The Duke Translational Medicine Institute (DTMI)

The DTMI[108] was established in 2006 with a 52.7 million USD grant from the NIH. The major objective is to expedite the translation of new scientific

[106] http://www.gms.edu.sg/
[107] http://www.dcri.duke.edu/
[108] http://www.dtmi.duke.edu/

discoveries into clinical practice and promote improvement in community health. Personalized medicine is a priority. The DTMI is Duke's academic "home" for the clinical and translational research community and is highlighted by the university leadership as one of the most interesting current initiatives. It is an integrated support structure that provides resources, training and facilitates for collaborative research in clinical and translational research and can assist investigators with many aspects of the research continuum, from preclinical research to clinical trials to community-based research. Through the DTMI, Duke Investigators can access resources in for instance:

- biostatistics and data management
- regulatory strategies and submissions
- core technology expertise in biobanking, genomics and proteomics, immune monitoring, cell and tissue therapies, and imaging
- research training and career development opportunities
- Funding opportunities
- early-phase clinical research projects in dedicated facilities with specialized staff, resources, and expertise

Within the DTMI are a number of new and old translational and clinical research initiatives. On of the new initiatives is the Duke Translational Research Initiative which focuses on streamlining the process of leading new scientific discoveries through development into applications that can be used to improve human health.

Technology transfer

As at all U.S. universities, most research results are owned by the university. If revenue is generated from a finding, it is shared by the university, the inventor and in some cases the research program. According to Duke University representatives, approximately three quarters of the revenues are generated from the School of Medicine and Glaxo Smith Kline has its headquarters in the same area as the university.

The university works to build relationships with Venture Capital firms and the Corporate & Venture Development (CVD) unit serves Duke University including its Medical Center. CVD is responsible for commercially-sponsored research, patents and licenses as well as new venture activity, corporate gifts, and corporate vending relationships. The Office of Licensing & Ventures (OLV) within the CVD is responsible for patents, technology licenses and new venture development for Duke University. Through interactions with faculty, small and large businesses, and venture investors the CVD aims to build strong relationships and strong agreements to translate academic discoveries into commercial products for society and public health. According to the University of Alberta[109], Duke University had 3.8 million USD per year in license income (average over tree years). A search in the US Patent and Trademark Office (USPTO) indicated that 37 patents were granted to Duke University in 2007 of which the vast majority were within the biomedical sciences. The university stresses that it gives credit for inventiveness.

18.3.2 University of Massachusetts

The University of Massachusetts[110] (UMass) System is not one single university in the classical sense but a system of semi-independent institutions similar to the famous University of California system. The UMass system consists of five main campuses located in Boston, Dartmouth, Worcester, Amherst and Lowell (fig 22). The Amherst campus is sometimes referred to as the UMass "flagship" campus and the Medical School is located in Worcester.

Figure 22 University of Massachusetts locations

Source: University of Massachusetts

The University of Massachusetts was established in 1863 as the Massachusetts Agricultural College located in Amherst[111]. In 1932, it was transformed to the Massachusetts State College and then, in 1947, became the University of Massachusetts. The Worcester and Boston campuses were established in 1962 and 1964 respectively. However the University of Lowell, now the Lowell campus, and Southeastern Massachusetts

[109] http://www.uofaweb.ualberta.ca/strategic/nav03.cfm?nav03=17173&nav02=17145&nav01=17121
[110] http://www.massachusetts.edu/index.html
[111] http://www.umass.edu/

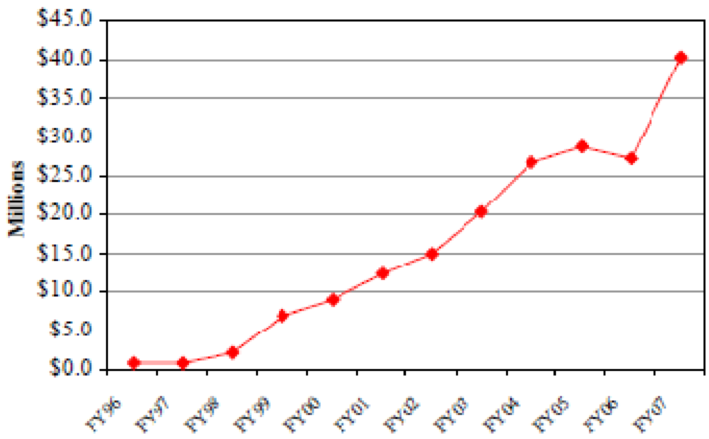
University (now the Dartmouth campus) were incorporated into the UMass system as late as 1991.

The UMass system, which is a public (state-owned) university, is governed by a 22-member board of trustees, the President of the university, and the Chancellors at the five campuses.

The total UMass endowment was approximately 350 million USD in 2007 which is significantly less than at Duke University. Funding to UMass comes from a large number of sources including the annual state appropriation from the Commonwealth of Massachusetts, student tuitions and fees, and funding from federal and private sources. In 2008, the university operations budget for the entire university was 2.4 billion USD and the appropriation from the Commonwealth of Massachusetts 492 million USD. The university raised 91 million USD in gifts during fiscal year 2007.

The university generates revenue in a variety of ways including through its commercial venture and intellectual property division. In 2007, 174 inventions were disclosed and 78 licenses completed. The university received 41.4 million USD in license incomes. In fig 23, can be seen the development in recent years. The university is ranked as one of the top-20 universities with regard to license incomes. A search in the U.S. Patent and Trademark Office database indicate that 22 patents were granted to UMass in 2007. Around 50% of the patents were within the life science field.

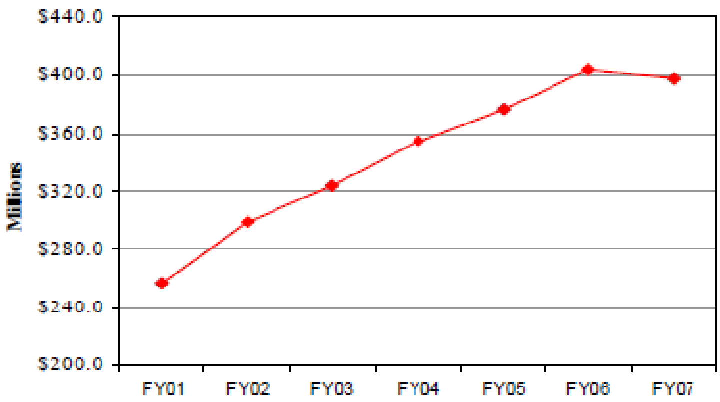
Figure 23 UMass license income



Source: University of Massachusetts

In 2007, R&D expenditures reached a total of 397 million USD for UMass of which Worcester spent 157 and Amherst 146. R&D expenditures have increased strongly in recent years (fig 24).

Figure 24 University of Massachusetts research expenditures



Source: University of Massachusetts

UMass had 46,928 undergraduate students and 14,106 graduate students in 2007. At Worcester, there were a total of 1,013 graduate students (medical) while Amherst, the flagship campus, had 20,114 undergraduate students and 5,759 graduate students. As is normal for state universities, tuition and mandatory fees are strongly reduced for in-state students (from Massachusetts) compared to out-of-state students (e.g. at Amherst 9,921 USD for in-state students and 20,499 USD for out-state students). 84% of the undergraduate students are from Massachusetts. 23% of undergraduates belong to one of the minorities; black, Asian, Hispanic or Native American.

Amherst

Out of the Amherst campus R&D expenditures of 146 million USD (2007), 142 were spent in science and engineering. As mentioned before, it is important to remember that a large proportion of biomedical research is being performed within the Arts and Sciences faculties. Amherst has a tradition of research in agricultural biotechnology. The total faculty consisted of 1,242 full-time equivalents (FTE) of which 972 were either tenured or on tenure-track [cf 13].

Worcester

The Worcester campus consists, as mentioned above, of the UMass Medical School and is ranked as number 51 for research in the U.S. News and World Report ranking[112].

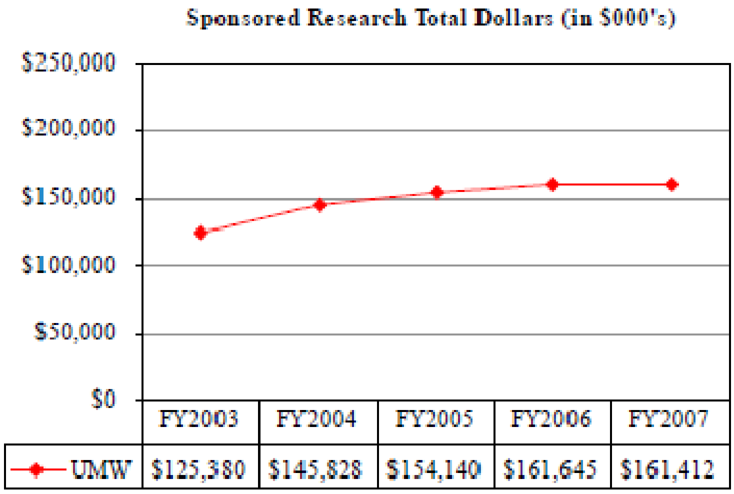
The Medical School has a very ambitious and expansive agenda and Dr. Craig Mello[113] received the Nobel Prize in Medicine or Physiology in 2006. The Medical School has and endowment of 94.5 million USD (2007) and

[112] http://gradschools.usnews.rankingsandreviews.com/grad/med/search/title+University%20of%20Massachusetts

[113] http://www.hhmi.org/research/investigators/mello.html

raised 7.9 million USD in private donations. The campus attracted 161 million USD (fig 25) for sponsored research. Funds from NIH reached 119 million USD.

Figure 25 Income to the University of Massachusetts Medical School for sponsored research



Source: University of Massachusetts

In 2007, 58 patent applications were filed and the schools license revenues reached 40.7 million USD. The vast majority of UMass license income originates from the Medical School.

The UMass Medical School educational system[114] consists of the School of Medicine, the School of Nursing and the Graduate School of the Biomedical Sciences. The educational programs will not be described in detail here. The Medical School has a relatively large number of research initiatives and departments and the translation of research results “from bench to bedside” is largely in focus. The university works to:

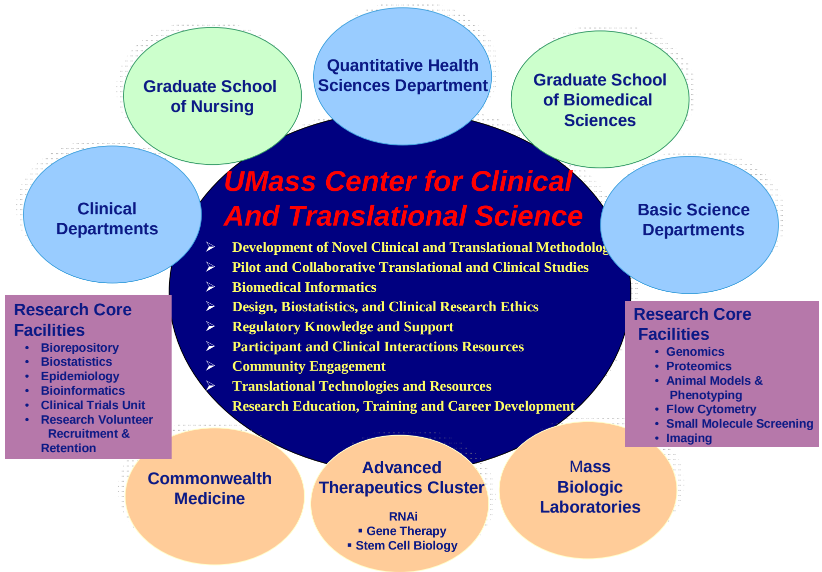
- recruit and retain outstanding leaders in clinical and translational research
- build capabilities in the Department of Quantitative Health Sciences
- develop research in emerging diagnostics and therapeutics through development of a Bioinformatics program and an Advance Therapeutic Cluster
- create a University-wide Center for Clinical and Translational Science including training programs, databases and a biorepository
- make sure that the UMass Medical School continues to be competitive in basic sciences

[114] http://www.umassmed.edu/Education/index.aspx?linkidentifier=id&itemid=4508

- develop new methods to ensure delivery of high quality healthcare

A graphic representation of the clinical and translational science efforts can bee seen in fig 26.

Figure 26 Organization of the University of Massachusetts clinical and translational science efforts



Source: University of Massachusetts

The UMass Medical School has earmarked 371.5 million USD (table 7) for the initiative during the period 2008-2013. This includes major recruitments to the RNAi Therapeutics Institute, the Stem Cell Biology Program, the Gene Therapy Program, the Quantitative Health Sciences and many other areas (e.g. Bioinformatics, Clinical Cancer and Neuroscience research, Heart and Vascular diseases etc.).

Table 7 University of Massachusetts Medical School earmarks

Institutional Commitment to the UMCCTS/CTSA 2008 - 2013	
Program Function	**Funds Committed Over 5 Years**
Space	$315 million
Faculty Recruitment	$29 million
Dean's Challenge Program	$5 million
Education and Training	$3.5 million
Pilot Grant Program	$5.0 million
Conquering Diseases Core	$4.0 million
Other Core Support and Information Technology Infrastructure	$5.0 million
Clinical Research Infrastructure	5.0 million
Total	**$371.5 million**

The initiatives also aim to streamline processes for inventors to achieve rapid bench to bedside assessment and to stimulate advancement of new medical devices and therapeutics. Furthermore, core technologies are to be available to faculty at all campuses. Collaborations with the other UMass campuses in their fields of expertise are important and special grants will be made available to facilitate this.

The efforts are connected to the UMass-wide "Life Science Task Force[115]" (LSTF) initiative for life sciences that was initiated in 2007/08. It is also connected to the 2008 Massachusetts Life Sciences Law[116] (state law). The legislation, a 10-year, 1-billion USD investment in the industry is intended to secure and expand Massachusetts' life science supercluster. The UMass LSTF is intended to foster university initiatives in the life sciences, increase collaboration and leverage and optimize the use of resources. The LSTF is organized in six working groups responsible for different thematic areas that are considered as "pillars". These are:

- Shared infrastructure and additional R&D
- Advanced therapeutics
- Nanotechnology
- Technology innovation centers
- Workforce and policy initiatives
- Health, disease and behavior

Each of the working groups makes situation analyses of campus and university-wide research within the areas and makes recommendations. According to LSTF, a new collaborative structure is needed within UMass that helps to make the system more efficient, brings together faculty from different disciplines and provides them with opportunities to engage in collaborations. The university position should also be strengthened to be an even more attractive institution to invest in for industry, philanthropists and federal agencies. Some of the LSTF recommendations are listed below:

1. Attract and retain graduate university students in STEM degree programs and prepare them to become the coming life science talents
2. Focus on existing university R&D strengths in the life sciences
3. Develop a network of university-led or supported regional innovation centers across the commonwealth (of Massachusetts)
4. Continue university-wide support of life science collaborative efforts

[115] http://www.umassd.edu/provost/lifesciencestaskforce.cfm
[116] http://www.boston.com/news/local/massachusetts/articles/2008/06/19/biotech_law_holds_local_aid/

5. Establish the University of Massachusetts center for clinical and translational science
6. Establish life sciences-specific seed funding
7. Establish the University of Massachusetts core facilities steering committee to develop new models for inter-campus sharing of core facilities
8. Develop organized and funded programs of inter-campus retreats, Symposia, seminars and visiting professorships
9. Undertake a systematic review of administrative, regulatory and statutory barriers that inhibit inter-campus collaboration and prevent the university from acting in an entrepreneurial manner
10. Pursue capital and operating funding to enhance university life sciences infrastructure and research initiatives

The creation of regional innovation centers may be of special interest. The centers are intended to provide regional infrastructure and services to support growth in the life science sector and will, according to the university, enable UMass to better link its research and teaching capabilities with the needs of industry in the state. The centers should be organized as a state-wide network.

A 1 million per year Life Science Moment Fund has been created intended for multi-investigator pilot projects that largely should be oriented towards clinical and translational research. The goal is also to develop technologies that will interest industry partners. Removing barriers between the UMass campuses is seen as crucial.

The UMass Medical School Office of Technology Management (OTM)

The mission of the office is to facilitate the commercial development of intellectual property arising at the medical school. The development of innovations and commercially viable products is thought to benefit the inventor, the university as well as the state. The OTM personnel have a scientific, technical, legal or business background to provide services related to the commercialization of intellectual property. When relevant, researchers are expected to submit invention disclosure forms to the OTM.

18.4 Private or public

It is interesting to note that there are relatively few public universities among those that normally are ranked among the 20 best in the United States. The University of California is more often than not the highest ranked among public universities. Representatives for Duke University and the University of Massachusetts were asked if there was a significant advantage in being a private or public university. Both universities stated that one major difference lies in that private universities are less bound to public obligations and political decisions in the state and may therefore pursue more independent agendas and enjoy a higher degree of autonomy. This is however also dependent on the internal funds of the university. A ”poor” university is much more dependent on external financiers than a wealthy one. According to representatives from Duke University (private), the decision process may be faster and more nimble at a private university. Furthermore, legislation has a, relatively seen, smaller impact at private universities and they can therefore be more independent. The private university has to survive in its own right which may be seen as a “Darwinian-style” selection process.

It is however worth noting that many private universities interact extensively with the area in which it is located in and take an active role in various social initiatives. However, a private university is for instance not obligated to charge different tuition fees for in-state and out-of-state students. It is interesting to note that a relatively small proportion of the total funds are provided by the State at many public universities. State funding for public universities is often quite small and even these institutions are heavily dependent on endowments, gifts, contracts and grants.

19 Discussion and Conclusion

The United States R&D system consists of a very large number of actors including academia, industry, nonprofit organizations (npo's), the federal government and its agencies, as well as state and local governments. The system is complex partly due to the large number of actors and the 50 states with different legislations and that often have different types of agendas and resources. The U.S. is responsible for approximately one third of the world R&D investments and, similar to many other countries including Sweden, industry is responsible for around two thirds of the investments. Industry is however largely investing into development while the federal government is the largest funder of research at universities and colleges. In all, the country makes R&D investments worth around 340 billion USD annually (2008) and is responsible for more than 50% of the total R&D investments by the G-7 countries.

As mentioned above, there is a large heterogenity in between the states and the R&D intensity expressed as fraction of state GDP is in particular high in for instance New Mexico, Maryland, Massachusetts, Michigan and California. Other states have much lower R&D investments. The U.S. pharmacological/medical industry invested around 35 billion USD in R&D in 2005. Chemical industry is in particular prominent in New Jersey, Pennsylvania and Connecticut while the R&D service industry is strong in Massachusetts, California and Pennsylvania.

The federal government invested approximately 140 billion USD in R&D in 2008 of which around 60% was defense-related. Former President Bush and later Congress decided on large funding increases for federal R&D in the physical sciences through the American Competitiveness Initiative and the America COMPETES Act. However, these initiatives were never fully funded. Furthermore, during the last 8 years, there has often been a tension between Congress and the President with regard to research funding. In many cases, Congress has augmented the Presidents original request strongly. For 2009, Congress has decided to fund many initiatives contained in the original COMPETES act and has also decided on budget increases in other areas including for biomedical research at the National Institutes of Health (NIH). Together with the American Recovery and Investment Act (ARRA) which, in total, provides more than 21 billion USD in a one-time investment into R&D in addition to the normal budget, the NIH has a 2009 budget approaching 41 billion USD. The extra funds will be used both for R&D performance and for investments into infrastructure. The ARRA invests only in civil R&D. In general, the new President has demonstrated an interest for and commitment to R&D.

In addition to federal investments, there are many other funding sources such as public funding from states and local governments as well as funding from industry, npo's and private individuals. In the U.S., it is not uncommon with large private donations to research institutions.

The Department for Health and Human Services (HHS) is responsible for most of federally funded biomedical R&D through the department's agencies. NIH is, by far, the largest agency for life science R&D, and performs and funds research both intramurally and extramurally. NIH consists of 27 institutes and centers focusing on specific diseases and/or research areas. Most institutes and centers receive their funding directly from Congress. The largest institute is the National Cancer Institute while the smallest institute, the Fogarty International Center focuses on international issues and global health. In addition to R&D at the different institutes, the NIH Roadmap and the Common Fund makes strategic investments of particular importance for life science research development and education. The Roadmap contains a number of strategic initiatives that are continuously updated. In addition to the NIH, other federal agencies involved in biomedical R&D include the Food and Drug Administration (FDA), the Center for Disease Control (CDC), the National Science Foundation (NSF), the Defense Advanced Research Project Agency (DARPA) and others.

In general, an individual federal agency funds R&D from basic research to innovation within a specific area. The federal agencies stimulate research, development and innovation in small businesses through a number of programs including the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs. These programs are often highlighted as successful initiatives. The U.S. share of the world's biotechnology patents is around 40% and the most "patent productive" regions are located in California, Massachusetts and New York.

The U.S. universities are a heterogeneous group of institutions with varying focus areas, organizational forms, fortunes and fame. Examples of universities famed for their life science research include Harvard University, Columbia University Johns Hopkins University. Washington University in St Louis, University of California, Stanford University, Duke University and others.

There are relatively few public universities among those that are top-ranked. Representatives from universities point to the fact that private institutions often are more independent from public control and obligations, and may therefore be more flexible to develop their own profiles compared to their public counterparts. It is interesting to note that some public universities receive a relatively small part of their operating budget from the state government. The two universities studied here, the public University of Massachusetts (UMass) and the private Duke University, both have a number of highly interesting initiatives within the life sciences, not least with regard to translational and clinical medicine. The UMass investments are impressive given the university's endowment is small compared to many private universities.

In the U.S. system, the university normally owns the R&D results produced at the institution. Most universities therefore have technology transfer offices and researchers are expected to disclose findings that are of potential commercial interest to the office. In all cases studied, there is a strong economic incentive for the researcher to do so as he/she will receive a large proportion of any revenue generated. It should however be noted that there are relatively few universities that have large incomes from patents and that, when this is the case, it is usually based on relatively few inventions.

In all, the U.S. continues to be world leading in life science R&D with many of the worlds best research institutions. According to some estimates, 70% of the worlds medical R&D is carried out in the country. Many of the strongest life science business regions are located in the U.S. and it has a comparatively strong innovation culture. Although there is relatively much venture capital, access to it varies in different parts of the country. U.S. institutions, from the federal level to individual universities are usually positive to international collaboration and cooperation. One interesting, although not officially confirmed, observation is that the number of European students and postdocs active at U.S. institutions is smaller than previously. This should be investigated further and, if found to be correct, should lead to further investigations into the underlying reasons.

Appendix 1

The Universities with the largest funding (2007, preliminary data, adjustments may occur) from NIH[117] are:

California

UNIVERSITY OF CALIFORNIA DAVIS
$158,443,967
UNIVERSITY OF CALIFORNIA BERKELEY
$103,591,053
UNIVERSITY OF CALIFORNIA SAN FRANCISCO
$438,999,174
UNIVERSITY OF CALIFORNIA LOS ANGELES
$373,202,174
STANFORD UNIVERSITY
$304,732,407
UNIVERSITY OF SOUTHERN CALIFORNIA
$166,536,420
UNIVERSITY OF CALIFORNIA IRVINE
$121,608,539
SCRIPPS RESEARCH INSTITUTE
$198,162,313
UNIVERSITY OF CALIFORNIA SAN DIEGO
$316,260,010

Oregon

OREGON HEALTH & SCIENCE UNIVERSITY
$174,268,401

Washington

FRED HUTCHINSON CANCER RESEARCH CENTER
$219,263,139
UNIVERSITY OF WASHINGTON
$427,118,180

Utah

UNIVERSITY OF UTAH
$116,496,070

Arizona

UNIVERSITY OF ARIZONA
$101,224,912

[117] http://report.nih.gov/

Texas

BAYLOR COLLEGE OF MEDICINE
$211,774,568
UNIVERSITY OF TEXAS MD ANDERSON CAN CTR
$152,367,991
UNIVERSITY OF TEXAS MEDICAL BR GALVESTON
$99,915,612
UNIVERSITY OF TEXAS SW MED CTR/DALLAS
$171,750,816

Missouri

WASHINGTON UNIVERSITY
$374,060,779

Iowa

UNIVERSITY OF IOWA
$169,489,549

Minnesota

MAYO CLINIC COLL OF MEDICINE, ROCHESTER
$173,248,828
UNIVERSITY OF MINNESOTA TWIN CITIES
$247,220,478

Wisconsin

UNIVERSITY OF WISCONSIN MADISON
$241,080,242

Illinois

UNIVERSITY OF CHICAGO
$205,386,589
NORTHWESTERN UNIVERSITY
$149,169,474
UNIVERSITY OF ILLINOIS AT CHICAGO
$130,726,954

Alabama

UNIVERSITY OF ALABAMA AT BIRMINGHAM
$193,223,812

Georgia

EMORY UNIVERSITY
$226,318,754

Florida

UNIVERSITY OF FLORIDA
$100,535,674

North Carolina

DUKE UNIVERSITY
$385,692,132
UNIVERSITY OF NORTH CAROLINA CHAPEL HILL
$305,104,214

Tennessee

VANDERBILT UNIVERSITY
$298,531,343

Virginia

UNIVERSITY OF VIRGINIA CHARLOTTESVILLE
$158,821,400

Maryland

JOHNS HOPKINS UNIVERSITY
$581,979,420
UNIVERSITY OF MARYLAND BALTIMORE
$142,357,237

Pennsylvania

UNIVERSITY OF PENNSYLVANIA
$451,453,875
UNIVERSITY OF PITTSBURGH AT PITTSBURGH
$386,162,428

New York

NEW YORK UNIVERSITY SCHOOL OF MEDICINE
$121,835,760
SLOAN-KETTERING INSTITUTE FOR CANCER RES
$110,782,087
WEILL MEDICAL COLLEGE OF CORNELL UNIV
$114,541,521
COLUMBIA UNIV NEW YORK MORNINGSIDE
$44,881,607
COLUMBIA UNIVERSITY HEALTH SCIENCES
$292,260,228
COLUMBIA UNIVERSITY TEACHERS COLLEGE
$3,014,075
YESHIVA UNIVERSITY
$132,454,345
UNIVERSITY OF ROCHESTER
$169,889,867
MOUNT SINAI SCHOOL OF MEDICINE OF NYU
$175,748,201

Connecticut

YALE UNIVERSITY
$360,560,965

Massachusetts

UNIV OF MASSACHUSETTS MED SCH WORCESTER
$118,856,210
BETH ISRAEL DEACONESS MEDICAL CENTER
$113,451,201
BRIGHAM AND WOMEN'S HOSPITAL
$259,702,673
CHILDREN'S HOSPITAL BOSTON
$100,659,143
DANA-FARBER CANCER INSTITUTE
$132,810,698
HARVARD UNIVERSITY
$46,467,161
HARVARD UNIVERSITY (MEDICAL SCHOOL)
$172,136,524
HARVARD UNIVERSITY (SCH OF PUBLIC HLTH)
$110,350,806
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
$196,422,417
MASSACHUSETTS GENERAL HOSPITAL
$303,267,017

Appendix 2

NIH funding (2007, preliminary data, adjustments may occur) by State[118]:

State	Amount	N grants
ALABAMA	$233,576,930	590
ALASKA	$10,810,273	13
AMERICAN SAMOA	$340,759	1
ARIZONA	$170,898,328	483
ARKANSAS	$59,539,029	160
CALIFORNIA	$3,163,252,176	7357
COLORADO	$316,628,101	917
CONNECTICUT	$469,206,694	1200
DELAWARE	$28,868,589	73
DIST OF COL	$195,737,381	392
FLORIDA	$339,607,753	984
GEORGIA	$365,703,745	1027
GUAM	$949,688	3
HAWAII	$65,801,461	111
IDAHO	$9,557,462	18
ILLINOIS	$723,645,370	1985
INDIANA	$207,951,807	642
IOWA	$194,631,513	498
KANSAS	$87,059,958	238
KENTUCKY	$139,724,999	423
LOUISIANA	$137,123,345	309
MAINE	$67,055,452	127
MARYLAND	$976,541,042	2248
MASSACHUSETTS	$2,236,110,071	5013
MICHIGAN	$552,932,019	1440
MINNESOTA	$443,523,672	1031
MISSISSIPPI	$27,914,278	70
MISSOURI	$473,057,974	1161
MONTANA	$34,707,148	82
NEBRASKA	$73,692,219	218
NEVADA	$22,003,916	52
NEW HAMPSHIRE	$90,044,131	233
NEW JERSEY	$253,653,664	672
NEW MEXICO	$104,008,061	228
NEW YORK	$1,935,399,273	4792

[118] http://report.nih.gov/

NORTH CAROLINA	$931,189,101	2111
NORTH DAKOTA	$16,992,305	34
OHIO	$628,293,858	1762
OKLAHOMA	$76,922,835	185
OREGON	$277,731,593	748
PENNSYLVANIA	$1,399,307,660	3497
PUERTO RICO	$59,856,470	62
RHODE ISLAND	$143,434,997	480
SOUTH CAROLINA	$127,836,238	382
SOUTH DAKOTA	$15,647,765	29
TENNESSEE	$434,819,317	1084
TEXAS	$1,083,464,922	2756
UTAH	$132,537,079	404
VERMONT	$66,558,404	161
VIRGIN ISLANDS	$1,819,748	3
VIRGINIA	$271,271,192	817
WASHINGTON	$785,736,150	1610
WEST VIRGINIA	$24,690,635	70
WISCONSIN	$370,395,477	999
WYOMING	$7,365,267	16
Yearly Total	**$21,067,129,294**	**52001**

References

Articles

[1] RESEARCH AND DEVELOPMENT, FY 2009, American Association for the Advancement of Science (AAAS), REPORT XXXIII (2008).

[2] National Science Foundation, Science and Engineering Indicators (2008).

[3] American Competitiveness Initiative, Leading the World in Innovation, Office of Science and Technology Policy, the White House (2006).

[4] White House news release: ”State of the Union: American Competitiveness Initiative”, January 31, (2006).

[5] National Academies Rising Above the Gathering Storm, The National Academies Press, Washington D.C., (2007).

[6] Witze, A., Obama outlines science spending boost. Nature News (25 Sep 2008), doi: 10.1038/news.2008.1135 (2008).

[7] Obama versus McCain on science and education. Editorial Nature Structural & Molecular Biology 15, 999 - 1000 (01 Oct 2008), doi: 10.1038/nsmb 1008-999 (2008).

[8] Pharmaceutical Research and Manufacturers of America (PhRMA). 2006b. 2005 Industry Profile.

http://www.phrma.org/2005_industry_profile/6.

[9] National Institutes of Health, Biennial report 2006-2007

[10] Wikström, M. Chemical Biology in the USA, ITPS PM 2008:04

[11] Breidne, M., Hunnius Ohlin, E., Jonsson, S., Schwaag Serger, S., Wikström, M., Zhang, J. Forskning och innovationspolitik i Kanada, USA, Kina, Indien, Korea och Singapore, ITPS PM 2007:02

[12] Wikström, M.A. The Departments of Neuroscience at the Karolinska Institute and Columbia University - A limited Comparative Study ITPS PM 2008:003

[13] Wikström, M.A. Karriärstrukturer vid universitet och högskolor i USA. ITPS arbetsrapport R2008:002

Interviews

Dr. Lana Skirboll, Director, Office of Science Policy, National Institutes of Health

Dr. Stefano Bertuzzi, Office of the Director, National Institutes of Health

Dr. James Herrington, Director for International Relations, Fogarty International Center, National Institutes of Health

Dr Elizabeth L. Wilder, Director of the Division of Strategic Coordination in the Office of Portfolio Analysis and Strategic Initiatives (OPASI), National Institutes of Health

Dr. Bonnie Thompson, Office of International Science & Engineering (OISE), National Science Foundation

Dr. Tony F. Chan, Assistant Director, Directorate for Mathematical and Physical Sciences, National Science Foundation

Dr. James P. Collins, Assistant Director, Directorate for Biological Sciences, National Science Foundation

Dr. R. “Sandy” Williams, Dean of Duke University School of Medicine, Duke University

Dr. Paul Kostecki, Vice Chancellor for Research and Engagement, University of Massachusetts (Amherst)

Dr. Craig Mello, University of Massachusetts Medical School (Worcester)

Dr. John Sullivan, Vice Provost for Research, University of Massachusetts Medical School (Worcester)

VINNOVA´s publications

June 2009

See www.VINNOVA.se for more information

VINNOVA Analysis

VA 2009:

01 Svenska tekniker 1620 - 1920

02 Effekter av statligt stöd till fordonsforskning - Betydelsen av forskning och förnyelse för den svenska fordonsindustrins konkurrenskraft. *For brief version in Swedish and English see VA 2009:11 and VA 2009:12*

03 Evaluation of SIBED. Sweden - Israei test bed program for IT applications. *Only available as PDF*

04 Swedish possibilities within Tissue Engineering and Regenerative Medicine

05 Sverige och FP7 - Rapportering av det svenska deltagandet i EUs sjunde ramprogram för forskning och teknisk utveckling. *Only available as PDF*

06 Hetast på marknaden - Solenergi kan bli en av världens största industrier

07 Var ligger horisonten? - Stor potential men stora utmaningar för vågkraften

08 Vindkraften tar fart - En strukturell revolution?

09 Mer raffinerade produkter - Vedbaserade bioraffinaderier höjer kilovärdet på trädet

10 Förnybara energikällor - Hela elmarknaden i förändring

11 Sammanfattning - Effekter av statligt stöd till fordonsforskning. *Brief version of VA 2009:02, for brief version in English see VA 2009:12*

12 Summary - Impact of Government Support to Automotive Research. *Brief version in English of VA 2009:02, for brief version in Swedish see VA 2009:11*

13 Singapore - Aiming to create the Biopolis of Asia

14 Fight the Crisis with Research and Innovation? Additional public investment in research and innovation for sustainable recovery from the crisis.

15 Life Science Research and Development in the United States of America - An overview from the federal perspective. *Only available as PDF*

VA 2008:

01 VINNOVAs Focus on Impact - A Joint Approach for Impact Logic Assessment, Monitoring, Evaluation and Impact Analysis

02 Svenskt deltagande i EU:s sjätte ramprogram för forskning och teknisk utveckling. *Only available as PDF*

03 Nanotechnology in Sweden - an Innovation System Approach to an Emerging Area. *For Swedish version see VA 2007:01*

04 The GSM Story - Effects of Research on Swedish Mobile Telephone Developments. *For brief version in Swedish or English see VA 2008:07 or VA 2008:06*

05 Effektanalys av ”offentlig såddfinansiering” 1994 - 2004

06 Summary - The GSM Story - Effects of Research on Swedish Mobile Telephone Developments. *Brief version of VA 2008:04, for brief version in Swedeish see VA 2008:07.*

07 Sammanfattning - Historien om GSM - Effekter av forskning i svensk mobiltelefoniutveckling. *Brief version of VA 2008:04, for brief version in English see VA 2008:06*

08 Statlig och offentlig FoU-finansiering i Norden

09 Why is Danish life science thriving? A case study of the life science industry in Denmark

10 National and regional cluster profiles - Companies in biotechnology, pharmaceuticals and medical technology in Denmark in comparison with Sweden

11 Impacts of the Framework Programme in Sweden

12 A benchmarking study of the Swedish and British life science innovation systems. Comparison of policies and funding. *Only available as PDF*

13 Looking over the Shoulders of Giants - A study of the geography of big pharma R&D and manufacturing operations. *Only available as PDF*

14 Utvärdering av MERA-programmet

VINNOVA Information

VI 2009:

02 Forskning om chefskap. Presentation av projekten inom utlysningen Chefskap; förutsättningar, former och resultat. *For English version see VI 2009:03*

03 Research on the managerial tasks: condition, ways of working and results. *Finns endast som PDF. For Swedish version see VI 2009:02*

04 Högskolan utmaningar som motor för innovation och tillväxt - 24-25 september 2008

05 VINNOVA news

06 Årsredovisning 2008

07 Innovationer för hållbar tillväxt. *For English version see VI 2009:08*

08 Innovations for sustainable Growth. *For Swedish version see VI 2009:07*

09 Forska&Väx.

10 Ungdomar utan utbildning - Tillväxtseminarium i Stockholm 4 mars 2009

VI 2008:

01 Upptäck det innovativa Sverige.

02 Forskningsprogrammet Framtidens personresor - Projektbeskrivningar

03 Passenger Transport in the Future - Project Descriptions

04 Vehicle ICT - Project Descriptions

06 Årsredovisning 2007

07 Innovationer och ledande forskning - VINNOVA 2007. *For English version see VI 2008:08*

08 Innovations and leading research - VINNOVA 2007. *For Swedish version see VI 2008:07*

09 Forskning och innovation för hållbar tillväxt

10 Swedish Competence Research Centres - within the Transport Sector and funded by VINNOVA

11 E-tjänster i offentlig verksamhet. *For English version see VI 2006:18*

12 VINN Excellence Center - Investing in competitive research milieus

13 Relationships between R&D Investments, Innovation and Economic Growth - A Conference Summary

14 Arbetslivsutveckling för global konkurrenskraft

15 Innovationspolitik och tillväxt -

En seminarierapport från Svenskt Näringsliv, IF Metall och VINNOVA

16 Den kompetenta arbetsplatsen - Forskning om kompetems i arbetsplatsens relationer. Programkatal

17 Nya möjligheter för små och medelstora företag - Rapport från VINNOVAs seminarium för småföretag 3 september 2008

18 ”No wrong door” alla ingångar leder dig rätt! - Erbjudande från nationella aktörer till små och medelstora företag

19 Forskning om kvinnors företagande - Presentation av projekten. *For English version see VI 2008:23*

20 MERA-programmet - Projektkatalog 2008

21 The MERA-program - Project Catalogue 2008

22 VINNVÄXT - A programme to get Sweden moving! Regional growth through dynamic innovation systems

23 Research on Women´s Entrepreneurship - A presentation of the ten projects funded by the programme. *For Swedish version see VI 2008:19*

24 Mobilitet, mobil kommunikation och bredband - Branschforskningsprogram för IT & telekom

25 The Future in clean Transport - Stockholm 2009

VINNOVA Policy VP 2009:

01 TRANSAMS uppföljning av ”Nationell strategi för transportrelaterad FUD” åren 2005 - 2007. Två uppföljningar - en för 2005 och en för 2006 - 2007. *Only available as PDF*

02 VINNOVAs internationella strategi - att främja hållbar tillväxt i Sverige genom internationellt forsknings- och innovationssamarbete

VP 2008:

01 Forskning och innovation för hållbar tillväxt - VINNOVAs förslag till forsknings- & innovationsstrategi 2009-2012

02 Offentlig upphandling som drivkraft för innovation och förnyelse. *Only available as PDF. For English version see VP 2007:03*

VINNOVA Report VR 2009:

01 Affärsutveckling inom trämaufaktur och möbler - hur skapas effektivare värdekedjor? *Only available as PDF*

02 Användarna och datorerna - en historik 1960 - 1985

03 First Evaluation of the Berzelii Centra Programme and its centres EXSELENT, UCFB, Uppsala Berzelii & SBI Berzelii

04 Evaluation of SAFER – Vehicle and Traffic Safety Centre at Chalmers - a Centre of Excellence with financing from VINNOVA. *Only available as PDF*

05 Utvärdering av forskningsprogrammet SkeWood. *Only available as PDF*

06 Managing and Organizing for Innovation in Service Firms - A literature review with annotated bibliography. *Only available as PDF*

07 Den tjänstedominanta logiken - Innebörd och implikationer för policy.

08 Tjänster och relaterade begrepp - Innebörd och implikationer för policy.

09 Underlag för VINNOVAs satsningar inom transportsäkerhetsområdet. *Only available as PDF*

10 Utmaningar och kunskapsbehov - Om innovation, ledning och organisering i nio olika tjänsteföretag. *Only available as PDF*

11 De två kulturerna på Internet - En utmaning för företag, myndigheter och organisationer. Huvudrapport

12 Uppföljning av VINN NU-företag

VR 2008:

01 Mot bättre vetande - nya vägar till kunskap på arbetsplatsen

02 Managing Open Innovation - Present Findings and Future Directions

03 Framtiden är öppen! Om problem och möjligheter med öppen källkod och öppet innehåll

04 First Evaluation of the Institute Excellence Centres Programme

05 Utvärdering av det Nationella Flygtekniska forskningsprogrammet - NFFP. Evaluation of the Swedish National Aeronautics Research Programme - NFFP

06 Utvärdering av Vehicle - Information and Communication Technology programmet - V-ICT

07 Kartläggning av ett halvt sekels jämställdhetsinsatser i Sverige

08 Politiken, offentlig verksamhet - en av tre parter i samverkan

09 Forsknings- och innovationspolitik i USA - Näringslivets fem roller

10 ”Born to be wild” - 55+... eller hur förvandla en global demografisk förändring till ett svenskt styrke- och tillväxtområde?

11 DYNAMO 2 i halvtid - Rapport från VINNOVAs konferens på Ulfsunda slott 10 - 11 april 2008

12 VINNVÄXT II - Generalist and Specialist Evaluation of process and knowledge development 2004 - 2007

13 Svensk makrologistik - Sammansättning och kostnadsutveckling 1997 - 2005

14 Leading Companies in a Global Age - Managing the Swedish Way

15 Chefskapets former och resultat. Två kunskapsöversikter om arbetsplatsens ledarskap

16 NRA Security - Swedish industry proposal for a National Research Agenda for security

17 University strategies for knowledge transfer and commercialisation - An overview based on peer reviews at 24 Swedish universities 2006

18 Vårda idéerna! - Trots många framgångsrika projekt inom vård och omsorg skapas inte varaktiga effekter. Varför förvaltas och utnyttjas inte idéerna?

19 Growth through Research and Development - what does the research literature say?

20 Sesam öppna dig! Forskarperspektiv på kvinnors företagande

Production: VINNOVA´s Communication Division
June 2009

VINNOVA´s mission is to promote sustainable growth
by funding needs-driven research
and developing effective innovation systems

VERKET FÖR INNOVATIONSSYSTEM – SWEDISH GOVERNMENTAL AGENCY FOR INNOVATION SYSTEMS

VINNOVA, SE-101 58 Stockholm, Sweden   Besök/Office: Mäster Samuelsgatan 56
Tel: +46 (0)8 473 3000   Fax: +46 (0)8 473 3005
VINNOVA@VINNOVA.se   www.VINNOVA.se