Milken Institute

Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization

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by Ross DeVol and Armen Bedroussian

Anna Babayan, Meggy Frye, Daniela Murphy,

Tomas J. Philipson, Lorna Wallace,

Perry Wong and Benjamin Yeo

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I. Executive Summary

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Three decades have passed since researchers from Stanford and UC San Francisco began to develop the commercial applications for their work on recombinant DNA and launched the birth of the biotech industry. The result is a flourishing global landscape of spin-offs, startups and collaborations between biotechnology firms, financiers and academia. Those linkages were fortified in the United States with the 1980 passage of the Bayh-Dole Act, granting to universities the right to own, license and market the fruits of their faculty research. Nations worldwide quickly followed suit.

Research and innovation are increasingly shifting away from the corporate lab and back to where they began: the university campus. And as the global economy grows increasingly dependent on the generation and dissemination of knowledge, universities are seen as natural partners for both business and government. With government sources of R&D funding often mandating in-kind private-sector investments, the university-industry relationship is growing more complex and entwined. For this reason, it is crucial to examine the process of university technology transfer for its strengths and vulnerabilities in order to facilitate the commercialization process and ensure the greatest possible returns on public investment.

Key Findings:

- Harvard ranks first in terms of biotech research, as measured by papers and citations, followed by the University of Tokyo and University of London. U.S. universities hold eight of the top 10, and 28 of the top 40 positions. California universities hold five of the top 25 rankings; the UK and Japan hold three each.

- The University of Texas system scores first on our Biotech Patent Composite Index, followed by UC San Francisco — which is likely first among individual campuses since the University of Texas doesn't report data on individual campuses — and Johns Hopkins. Nine of the top 10 patent holders are U.S. universities. The University of London ranks first among foreign universities (10^{th} overall). (U.S.-issued university biotech patents grew from a cumulative total of 433 through 1995 to 11,430 in 2004.)

- Our University Technology Transfer and Commercialization Index shows MIT first on outcome measures, which include such factors as licensing income and startups. The University of California system ranks second (led by UC San Francisco), with Caltech third, Stanford fourth and Florida fifth. The University of British Columbia was the highest-ranked Canadian institution, coming in eighth overall.

- Among U.S., Canadian and European universities, the United States leads in invention disclosures, patents filed and granted, licenses executed and licensing income. However, European universities surpass their U.S. counterparts in startups established.

- Research activity has a high rate of return. Each 10-point increase in our Research Papers score contributes an additional $1.7 million in annual licensing income.

- Investments into OTTs also offer high returns. For every $1 invested in OTT staff, the university receives a little more than $6 of licensing income.

- In terms of job creation, the Amgens and Genentechs most differentiate the economic impact of U.S. university-based biotech commercialization from that originating in universities in other nations.

Technology transfer reflects the delicate balance of a university's wider culture and is an important byproduct of its mission.

University research tends to be oriented toward basic research that addresses long-term, fundamental scientific discovery and knowledge. An increasing share of the funding — from government, industry, nonprofit donor and other sources — is going into biotechnology and the life sciences, as evidenced by the dramatic increase since 1995 in university patenting.

The core mission of the world's leading research universities is education, discovery research and the dissemination of knowledge. It is also understood that the commercialization of research and knowledge is controversial to some audiences. Many academic researchers are conflicted by the greater focus on commercialization, feeling that it might impede research in areas with a lower probability of direct-market applicability but which could nevertheless lead to advances in fundamental scientific knowledge. We maintain that technology transfer reflects the delicate balance of a university's wider culture and is, in fact, an important byproduct of its mission.

In this study, we examine the biotech transfer process taking place at universities, from knowledge creation to technology transfer and early-stage commercialization. A key focus of our investigation is the role played by technology transfer professionals. Research is essential for commercial outcome, but the technology transfer professional is crucial in the successful conversion of knowledge to the private sector.

The University Innovation Pipeline

The phrase "university innovation pipeline" refers to the support and process infrastructures that enable a university to convert its research and creativity into commercially viable intellectual property. A rich innovation pipeline plays a pivotal role in a university's ability to commercialize its research.

We developed indexes that allow a systematic comparison and rank individual universities among their peers.

For this study, we analyzed national and international university biotechnology and overall innovation pipelines, using three measures of comparison: publication rankings, patenting activity and office of technology transfer (OTT) outcome measures, or how universities perform in the overall innovation pipeline. We developed indexes that allow a systematic comparison and rank individual universities among their peers. Any ranking system presents challenges and requires some subjective weighting of the components. For example, when examining research quantity and quality by analyzing biotechnology publications, one must decide the importance of the number of publications per university versus the citations of those papers by others. Nonetheless, we believe that our approach will contribute to informed discourse on best practices.

Publication Rankings: Global Data Analysis

Publication and citation counts are important output measures of scientific research. Thus, comparing and evaluating the scientific strength (research output) of universities around the world, as measured by the quantity and quality of published research, is the first sequence in the process. We used statistical data for the period 1998–2002, using databases from Thomson Scientific, Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and the Swiss Center for Science and Technology Studies (CEST).

We used 683 universities in the analysis of all academic fields, including: 217 in the United States (32 percent); 303 in Europe (44 percent, of which Eastern European universities represent 6 percent); 56 in Japan; 30 in Canada; and 11 in China. Within the field of biotechnology, we evaluated eight subfields represented in 492 universities, including: 161 in the United States (33 percent); 222 in Europe (45 percent, including 5 percent for Eastern Europe); 44 in Japan; 23 in Canada; 9 in Australia; 5 in China; and 17 in the rest of Asia.

We based our evaluation on assessments of three performance indicators — the Number of Publications, Activity and Impact — at the aggregate level of biotechnology, after having assigned a unique weight, based on its relative importance to the overall biotechnology category, to each of the eight subfields.

1. **Number of Publications:** A size indicator that reflects the absolute number of university publications.
2. **Activity:** A concentration indicator, measured by the number of publications in specific subfields as a percentage of a university's total publications, divided by the world's publications in that subfield, as a share of the world's total publications.
3. **Impact:** A quality indicator that reflects the number of citations of a university in a specific subfield as a percentage of the number of the university's total publications in that field, divided by the total citations of the world in the specific field, as a share of the world's total publications in that field.

We also assigned weights to the three indicators: Number of Publications (40 percent); Activity (20 percent); and Impact (40 percent). A lower weight was accorded for Activity because a university's concentration in biotechnology, relative to overall research papers, cannot be considered as important as the Number of Publications and Impact. In each measure, the universities are benchmarked to the best-performing university, which earned a score of 100.

U.S. universities dominate the top 50 rankings worldwide across the three performance indicators. The list is topped by Harvard University, followed by the University of Tokyo; the University of London; the University of California, San Francisco; and the University of Pennsylvania. Positions 6 through 10 are all from the United States: the University of California, San Diego; Johns Hopkins University; Washington University; the University of Washington; and the University of California, Los Angeles.

The dominance of U.S. universities is highlighted by several findings: they hold eight of the top 10 positions; 14 of the top 20 positions; and 28 of the top 40 positions. The top 10 U.S. universities account for 11.8 percent of world publications. And within the United States, California universities play a dominant role: three University of California campuses rank among the top 10; Stanford ranks 12th; and the University of California, Berkeley, ranks 25th. California universities hold five of the top 25 positions. Britain and Japan each have three universities among the top 25.

The United States accounts for 46 percent of the worldwide scientific biotech publications in the period 1998–2002, while European universities account for 35 percent, Japan 9 percent and Canada 5 percent. But it would be shortsighted to reduce differences between U.S. universities and European universities to such mass effects as publication counts. Research quality is affected by national policies, funding, industry clustering and other factors. Our analysis of publications is complemented by other indicators (Impact and Activity), and relatively small but specialized institutions can score as well as large research universities.

The following table summarizes our University Biotechnology Publication Ranking. Harvard, with a Publications score of 100, is credited with 11,098 biotech publications over the period 1998–2002. The university has an Activity score of 74.8 and Impact of 63.3. The University of Tokyo, at third (and second overall, with a score of 83.3), recorded 9,418 publications, from 1998 to 2002, heavily concentrated within biochemistry and biophysics — more than 43 percent of the total. In contrast, the University of London, second with 9,633 total publications (and third overall, scoring 83.1), has a higher concentration within molecular biology and genetics.[1]

Rockefeller University has the highest Activity in total biotech research. The University of Dundee in Scotland has the second-highest research focus in biotechnology, scoring 85.9 out of 100. The State University of New York (SUNY) at Stony Brook is a very close third, scoring 85.8. The University of Wales, Aberystwyth, excels in the Impact indicator, with a score of 100. But this remarkable performance stems from its high Impact within the subfield microbiology, where its research efforts are focused. Still, among the overall top 50 performers, Rockefeller, at second, is 33 index points behind the University of Wales.

Milken Institute University Biotechnology Publication Ranking

Top 50, 1998-2002

Rank	University	Country	Biotech Publ. by Univ. Score	Activity Score	Impact Score	Overall Score
1	Harvard University, Cambridge	USA	100.0	74.8	63.3	100.0
2	University of Tokyo	Japan	84.9	77.5	43.5	83.3
3	University of London	UK	86.8	60.0	50.0	83.1
4	University of California, San Francisco	USA	54.5	83.0	63.8	79.6
5	University of Pennsylvania, Philadelphia	USA	51.8	77.2	55.9	72.9
6	University of California, San Diego	USA	42.0	72.8	64.5	71.2
7	Johns Hopkins University, Baltimore	USA	47.5	70.8	59.1	70.8
8	Washington University, St. Louis	USA	37.9	85.4	58.6	69.4
9	University of Washington, Seattle	USA	47.1	69.7	55.4	68.4
10	University of California, Los Angeles	USA	47.0	66.2	54.3	67.0
11	Yale University, New Haven	USA	37.5	74.5	59.0	66.7
12	Stanford University	USA	37.9	68.3	59.8	65.7
13	Rockefeller University, New York	USA	14.1	100.0	67.0	65.3
14	University of Wisconsin at Madison	USA	36.9	76.6	53.3	64.0
15	University of Cambridge	UK	34.6	67.4	58.3	63.1
16	Baylor College of Medicine, Houston	USA	30.5	80.9	55.3	62.9
17	University of Oxford	UK	31.8	72.6	58.1	62.9
18	Duke University, Durham	USA	31.5	72.4	55.8	61.5
19	Osaka University	Japan	43.4	69.2	45.2	61.4
20	Kyoto University	Japan	41.7	71.1	45.7	61.2
21	Massachusetts Institute of Technology (MIT), Cambridge	USA	27.4	60.2	64.2	60.6
22	University of Texas at Dallas	USA	25.8	77.5	56.8	60.5
23	Universités de Paris (I - XIII)	France	48.4	59.3	41.7	59.7
24	Columbia University, New York	USA	32.0	58.3	58.3	59.5
25	University of California, Berkeley	USA	32.4	54.1	59.8	59.4
26	Case Western Reserve University, Cleveland	USA	25.7	82.5	52.0	59.3
27	Cornell University, Ithaca	USA	32.2	68.3	52.4	59.2
28	University of North Carolina at Chapel Hill	USA	27.9	71.6	54.8	59.1
29	Yeshiva University	USA	20.7	85.8	54.5	58.8
30	University of Toronto	Canada	40.9	57.3	48.4	58.7
31	McGill University, Montreal	Canada	30.2	73.4	51.0	58.7
32	University of Michigan, Ann Arbor	USA	36.5	61.3	50.0	58.4
33	Vanderbilt University, Nashville	USA	25.9	82.5	49.7	58.2
34	University of Iowa, Iowa City	USA	24.4	78.7	51.9	57.7
35	Karolinska Institutet, Stockholm	Sweden	30.7	73.5	48.0	57.5
36	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	26.4	73.4	51.7	57.2
37	University of Alabama at Birmingham	USA	23.1	85.5	47.6	56.5
38	State University of New York (SUNY) at Stony Brook	USA	15.4	76.5	58.5	55.9
39	Université de Genève	Switzerland	12.7	66.4	65.8	55.7
40	University of Wales, Aberystwyth	UK	0.5	22.5	100.0	55.7
41	New York University (NYU)	USA	21.1	68.0	56.2	55.5
42	University of Utah, Salt Lake City	USA	19.6	72.1	55.0	55.1
43	Universität Basel	Switzerland	10.4	75.0	60.9	54.2
44	University of Chicago	USA	23.1	61.4	54.3	53.9
45	University of Massachusetts at Amherst	USA	16.1	70.6	56.0	53.5
46	University of Dundee	UK	10.1	85.9	54.2	53.4
47	Oregon Health & Sciences University, Portland	USA	12.3	80.6	53.9	53.1
48	University of Edinburgh	UK	17.3	73.1	51.9	52.7
49	Universités de Strasbourg (I - III)	France	13.4	69.8	56.4	52.1
50	Universität Zürich	Switzerland	17.4	73.1	50.7	52.1

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

Among universities with a large research base, UC San Diego scores 64.5, ranking third. UCSD has consistently high Impact scores but stands out for its exemplary performance within the subfield cell and developmental biology, where it receives a 67 percent higher Citation rate than the university average in the sample.

Further research will be helpful to determine whether recent changes in publication patterns alter these rankings in a meaningful way. Chinese universities seem most likely to improve their publication scores as the result of increased emphasis by the government on biotechnology research, higher funding and improvement in the number of publications in recent years.

Global University Biotech: Patents Issued in the United States

Since we are interested primarily in capturing university patents stemming from the biotech research, we used patent data compiled through ipIQ, which specializes in intellectual property analysis within the technology sector. Biotech patents issued in the United States to universities have increased dramatically. Between 2000 and 2004, the cumulative number of U.S.-issued university biotech patents increased by 77 percent, for a compound annual growth rate of 17.4 percent.

The ipIQ data concentrate on the productivity or quality associated within a university's biotech patents, and allow an assessment of a university's biotech research quality. The data incorporate U.S. and international patent codes, and examine all Type 1 (utility)[2] patents issued to universities within biotechnology. In cases where multiple universities were assigned to a patent, the patent was counted once for each university. Between 1995 and 2004, 424 U.S. and foreign universities were recognized for carrying at least one biotech-issued patent. Of these universities, 198 were U.S. (46.7 percent) and 226 were foreign (53.3 percent), including 110 European (25.9 percent) and 48 Asian (11.3 percent). An additional filter was added to capture the nanotech subset within the biotech sample.

In deriving the overall composite index, we assigned four indicators: Absolute Number of Patents, Current Impact Assessment, Science Linkage and Technology Cycle Time. Each is defined as follows:

1. **Absolute Number of Patents:** This figure takes into account all Type 1 utility biotechnology patents issued in the U.S. patent system between 2000 and 2004.
2. **Current Impact Index, CII:** CII measures the impact of a university's patents on the latest biotechnology developments. Specifically, it measures how often the previous five years of a university's biotech patents are cited by patents issued in the most recent year, relative to all U.S.-issued patents.
3. **Science Linkage:** This is a measure of the extent to which a university's biotechnology builds upon cutting-edge scientific research. It is defined as the average number of science papers referenced on the front page of its biotech patents.
4. **Technology Cycle Time:** This is a median age of the U.S.-issued patents cited on the front page of a university's patents.

We then assigned weights to the indicators: Absolute Number of Patents (65 percent); Current Impact Index, or CII (15 percent); Science Linkage (10 percent); and Technology Cycle Time (10 percent).

The university that ranks highest for a particular category receives a score of 100 and provides a relative benchmark.

Intellectual property laws differ significantly among countries, creating challenges for foreign universities wishing to patent in the United States. They are likely to score lower than U.S. institutions in overall Absolute Number of Patents issued in the United States, holding other factors, such as scientific quality, constant. In an effort to balance the potential under-representation of foreign patents issued in the United States, we constructed a geographic gravity function in compiling a biotech patent ranking of foreign-based institutions. Foreign universities generally attempt to patent biotech IP in the United States because there is a large potential market for commercial therapeutics; the United States is home to most of the world's largest biopharmaceutical firms; and the U.S. legal system permits the patenting of genetic material.

We used a scoring system so that the university that ranks highest for a particular category, such as CII, would receive a score of 100 and provide a relative benchmark. (A score may range from 0 to 100.) Our analysis covers the period 2000–2004. In the table below, we rank the top 50 universities according to the four indicators.

Biotech Patent Rankings - Top 50 Institutions
Composite Index, 2000-2004

Rank	University	Country	No. of Patents Score	Current Impact Index Score	Science Linkage Score	Tech Cycle Time Score	Composite Score
1	University of Texas	US	100.00	27.63	18.07	18.1	100.00
2	University of California, San Francisco	US	100.00	8.77	11.17	15.3	94.78
3	Johns Hopkins University	US	87.21	23.25	7.14	21.0	86.57
4	Stanford University	US	63.93	43.42	10.78	20.0	70.29
5	Cornell University	US	62.56	19.30	9.54	16.0	63.38
6	Columbia University	US	60.27	25.88	9.71	19.1	63.15
7	University of California, Berkeley	US	63.01	13.16	5.62	21.3	62.71
8	University of California, San Diego	US	59.36	17.54	9.82	17.1	60.35
9	University of Wisconsin	US	56.62	25.00	8.65	19.1	59.55
10	University of London	GB	58.70	4.33	10.62	30.1	58.94
11	Harvard University	US	55.25	25.44	13.89	17.6	58.93
12	Hebrew University of Jerusalem	IL	56.85	13.60	11.18	16.7	57.42
13	University of Michigan	US	52.05	29.39	14.65	14.6	56.58
14	McGill University	CA	52.97	22.37	9.88	20.3	56.08
15	University of Pennsylvania	US	51.60	24.12	13.56	13.1	54.74
16	Rockefeller University	US	51.60	15.35	17.31	18.6	54.19
17	California Institute of Technology	US	38.36	61.40	21.60	19.4	52.56
18	Yale University	US	42.92	39.91	16.98	19.1	51.54
19	University of Melbourne	AU	47.41	6.14	7.40	32.5	49.11
20	Thomas Jefferson University	US	47.03	11.84	12.10	15.3	48.22
21	Tel-Aviv University	IL	46.52	13.60	7.02	18.1	47.81
22	Washington University	US	43.38	16.23	8.81	19.4	45.98
23	University of California, Los Angeles	US	42.47	8.77	11.00	18.3	43.78
24	University of Oxford	GB	30.98	64.47	2.05	17.6	43.67
25	University of British Columbia	CA	39.27	25.00	7.31	14.8	43.27
26	University of Utah	US	38.81	27.63	7.94	13.1	43.27
27	University of Minnesota	US	36.99	21.05	15.07	15.7	41.61
28	Massachusettes Institute of Technology	US	30.59	43.86	12.15	16.3	40.28
29	University of Chicago	US	35.16	18.86	14.84	19.4	40.01
30	University of Alabama	US	36.53	14.91	8.47	19.4	39.54
31	Queen's University of Belfast	NI	9.52	100.00	2.14	68.4	38.82
32	Duke University	US	32.88	25.44	9.55	18.1	38.41
33	University of Florida	US	35.62	14.47	7.42	16.5	38.09
34	University of Maryland System	US	33.79	15.79	11.00	17.6	37.37
35	New York University	US	33.79	16.23	10.15	15.3	37.03
36	University of Queensland	AU	34.65	7.02	4.33	20.6	35.83
37	Baylor College of Medicine	US	29.22	26.75	16.34	12.4	35.57
38	University of Southern California	US	25.57	38.16	11.44	21.7	35.26
39	Michigan State University	US	33.33	10.53	6.85	15.5	35.02
40	University of Iowa	US	26.94	28.07	13.47	20.6	34.54
41	University of North Carolina	US	28.31	25.00	10.58	17.3	34.28
42	Vanderbilt University	US	27.40	22.37	6.68	24.5	33.38
43	University of Washington	US	26.03	25.44	10.40	20.6	32.76
44	Mt. Sinai School of Medicine of CUNY	US	17.81	54.82	15.92	22.0	32.43
45	Boston University	US	18.72	52.63	11.62	19.4	31.84
46	Yeshiva University	US	26.48	20.18	4.52	21.3	31.37
47	Universite Louis Pasteur	FR	18.03	44.30	20.36	21.7	31.02
48	University of Pittsburgh	US	25.11	23.68	7.87	17.8	30.85
49	University of Calgary	CA	26.48	14.47	11.34	14.6	30.21
50	University of Saskatchewan	CA	21.92	25.00	11.24	15.3	28.38

Sources: ipIQ, Milken Institute

Among our more important findings:

- More than 6,300 biotech patents were accounted for by the U.S. Patent and Trademark Office between 2000 and 2004. Biotech patents issued in the United States have increased dramatically, growing from a cumulative total of 433 through 1995 to 11,430 in 2004.
- Nine out of the top 10 universities are U.S. universities.
- UC San Francisco and the University of Texas system tie in Absolute Number of Patents issued by the United States.
- California has four of the top 10 universities, and six of the top 25, on biotech patent ratings.
- Of the top 100 institutions ranked, 28 are foreign universities.
- Queen's University of Belfast, Northern Ireland, ranks first on the Current Impact Index.
- The University of Birmingham in England ranks first on Science Linkage.
- Japan's Ministry of Education ranks first in Technology Cycle Time.
- California Institute of Technology (Caltech) ranks among the top 15 in Absolute Number of Patents issued, Current Impact Index and Science Linkage.
- One out of every five nanotech patents stems from the University of California system.

The University of California system was issued 723 U.S. patents from 2000 to 2004, No. 1 among all universities. The UC's broad-based reputation in R&D is evidenced by its top-notch faculty and scientists. UC San Francisco, UC Berkeley and UC San Diego have attracted clusters of firms engaged in biotech manufacturing and R&D services.[3]

The University of Texas, comprising nine campuses and six health institutions, ties UC San Francisco, with 219 U.S.-issued biotech patents. Four Nobel laureates (more than at any other medical school in the world) work as tenured researchers at Southwestern Medical Center.[4] Johns Hopkins scores third for Absolute Number of Patents issued. The university is home to numerous research centers and institutes committed to the sciences and public health. Stanford ranks fourth on the biotech patenting index. Nine of the top 100 universities are in New York, with Cornell and Columbia among the top 10.

The University of Wisconsin, Madison, ranks ninth overall, supported by groundbreaking research conducted by James A. Thompson, Ph.D., a biologist credited with the first isolation of primate stem cells in 1998 and who has patented both non-human (primate) and human embryonic stem cells.[5] The University of London ranks 10th in Absolute Number of Patents issued by the United States and in the overall composite index, making it the highest-scoring foreign university. Second among non-U.S. universities holding U.S.-issued biotech patents (and 12th overall) is Hebrew University of Jerusalem.

U.S. universities account for 85 percent of the Absolute Number of Patents issued in the United States (and 66 percent of gravity-adjusted patents). After Canadian universities, universities in smaller countries, such as Austria and Israel, receive more U.S. biotech patents than do universities in most large countries.

Commercialization Performance: Based on AUTM data for the United States and Canada

We also evaluated university performance in the overall commercialization pipeline, including all other research fields, as well as biotechnology. We used data from the Association of University Technology Managers' (AUTM) survey of U.S. and

Canadian universities to create Pipeline Performance Measures to determine which universities are better positioned to capitalize on their innovation assets.

The pipeline was evaluated in three stages:

1. A long-term analysis, using data from 1996 to 2004
2. A short-term analysis, spanning from 2000 to 2004
3. A one-year snapshot, based on data from the 2004 AUTM survey

For each stage, we ranked the universities according to three different scenarios:

1. In absolute terms
2. Normalized by million dollars of research expenditures
3. In terms of productivity (e.g., patents filed per invention disclosure)

We used 17 performance indicators for the AUTM data and nine for the comparison of AUTM with ASTP (the Association of European Science and Technology Professionals) information for the one-year 2004 snapshot.

Assessing these scenarios helps us paint a more accurate picture of how universities perform in the innovation pipeline. The short- and long-term evaluations allow us to reduce the bias of aberrations that might be caused by a stellar or mediocre year in research, patenting and licensing activity.

The scoring system does not overly reward an institution on a single measure but does reward for consistent performance across measures.

Our first consideration in developing an overall index is the proper balance between absolute and relative measures of commercialization. For example, holding all other factors constant, a large research university that attracts considerable public funding should have greater commercialization outcomes — such as licensing income and startups — than a smaller university. However, absolute outcome measures don't address the productivity or efficiency of commercialization activity. Thus, we scale the outcome results by research expenditures to gain a relative measure. Nonetheless, absolute measures are important because of the impact of large institutions. Size is significant in assessing the overall influence of research universities. These indicators were filtered for each outcome measure. We give an equal weighting (50 percent) to absolute and relative performance.[6]

Next, we determined the appropriate outcome measures. We chose to focus on primary exit valves, such as Licensing Income, Startups,Licenses Executed and — to gain some measure of what occurred earlier in the pipeline that could lead to future success — Patents granted. Licensing Income and Startups are the most direct measures of outcome. They give a clear valuation of the quality of university-based intellectual property. Therefore, they received the greatest weights, at 35 percent each. Licenses Executed and Patents granted were each assigned a weight of 15 percent because they are earlier-stage outcome measures.

These indicators were filtered by taking the natural logarithmic transformations of the absolute and relative measures. This process results in a scoring system that doesn't overly reward an institution for being substantially above its peers on any single measure but does reward for consistent performance across measures. Universities were benchmarked to the highest-scoring institution (with a possible top score of 100) on each of eight subcomponents comprising the four outcome index measures. Finally, the overall top-scoring university was re-benchmarked to 100.

This methodology results in the Milken Institute University Technology Transfer and Commercialization Index, with the top 25 universities listed in the accompanying table. MIT is the leader on overall Outcome Measures. It scores first in Startups by a wide margin, averaging more than 23 new firms per year — ahead of the entire University of California system (with nine campuses), which reports 20 startups. MIT has been spinning out new firms from its research laboratories for more than 50 years; academic entrepreneurship was a critical part of the culture long before the process was formalized by the establishment of the MIT Technology Licensing Office in the late 1980s.[7] But the university doesn't derive its lofty position from Startups alone; it scores 95.2 on Patents Issued (second to Caltech) and 90.6 on Licensing Income. The university's diverse research strengths in the physical and engineering sciences, in addition to biotechnology, give it unique opportunities for commercialization.

Milken Institute University Technology Transfer and Commercialization Index
2000-2004

Rank	Institution Name	Patents Issued Score	Licenses Executed Score	Licensing Income Score	Startups Score	Overall Score
1	Massachusetts Inst. of Technology (MIT)	95.17	79.89	90.64	100.00	100.00
2	University of California System	97.26	85.25	95.16	83.24	96.59
3	California Institute of Technology	100.00	70.77	87.12	86.60	92.94
4	Stanford University	91.56	84.28	93.76	77.02	92.65
5	University of Florida	84.82	71.41	92.57	69.26	86.11
6	University of Minnesota	78.92	77.46	91.02	69.24	85.55
7	Brigham Young University	66.87	80.60	86.13	77.57	85.41
8	University of British Columbia	74.36	74.09	82.73	77.42	84.23
9	University of Michigan	82.70	72.25	77.98	74.89	82.54
10	New York University	73.68	63.30	100.00	58.16	81.63
11	Georgia Institute of Technology	76.80	60.51	72.79	83.41	80.95
12	University of Pennsylvania	76.41	72.05	83.95	67.15	80.83
13	University of Illinois, Chicago, Urbana-Champaign	72.80	74.55	77.60	72.72	80.35
14	University of Utah	77.08	70.80	81.56	66.01	79.40
15	University of Southern California	70.77	79.81	70.37	75.72	79.28
16	Cornell Research Fdn., Inc.	86.31	75.99	77.99	61.51	78.69
17	University of Virginia Patent Fndtn.	66.53	75.11	79.41	68.48	78.52
18	Harvard University	78.82	76.06	87.54	52.45	77.68
19	University of California, San Francisco	88.60	11.63	99.73	62.39	77.19
20	North Carolina State University	78.41	73.80	74.40	64.77	76.94
21	SUNY Research Foundation	79.51	64.36	84.63	58.01	76.90
22	W.A.R.F./University of Wisconsin	87.59	86.65	90.52	38.99	76.86
23	McGill University	77.47	68.76	72.12	69.24	76.80
24	University of Washington/Wash. Res. Fdn.	75.11	76.10	88.49	50.03	76.54
25	University of North Carolina, Chapel Hill	78.48	76.86	71.14	64.21	76.00

Sources: AUTM, Milken Institute

The UC system is second on the overall index, at 96.6, recording scores no lower than 82.2 on any of the four composite measures. The UC system is first on the Number of Patents, placing it second on the composite measure, which includes Patents per Million Research Expenditures. Additionally, it is second on the Licensing Income composite and first in the Absolute Amount subcomponent. UC San Francisco is the highest-scoring individual campus, at 19th. This is remarkable since the university records a very low score of 11.6 on Licenses Executed, which largely reflects its strategy to focus on licensing IP that is likely to have a substantial impact, principally in biotechnology. That strategy is in turn reflected in total Licensing Income, where UC San Francisco ranks first overall, without the other UC campuses. UC San Diego and UC Berkeley rank in the top 30, as well. Both score high on Absolute Measures, but not so well when normalized for Research Expenditures.

Caltech is third on the index, with an overall score of 92.9. This is notable for a relatively small institution, but its research quality is very high. Caltech is first on the Patents composite score by recording strong positions in Absolute Number of Patents and Patents normalized per Million Research Expenditures. It had scores in the upper 80s for both Licensing Income and Startups, and is well positioned in biotechnology research competency. Similar to MIT, Caltech has strengths in engineering and the physical sciences, assisting its aggregate performance.

Ranking fourth, Stanford University displays its entrepreneurial focus. Stanford records scores above 90 on Patents and Licensing Income, where it ranks fourth, as well. Stanford's business school has played a key role in developing a culture that encourages and rewards researchers who actively engage in commercialization efforts. The University of Florida ranks fifth, which is perhaps surprising to many, but the school has seen remarkable success at its office of technology transfer. While Florida's position is assisted by its Gatorade income, it scores relatively high on all four composites. Florida focuses on translational, as opposed to basic research, and this is witnessed in its outcome success.

Leading the second tier of the top 10 is the University of Minnesota, at sixth. Minnesota scores high on both absolute Licensing Income and Income normalized to Research Expenditures. This combination gives it a composite Licensing score of 91.0. Another surprise to some might be Brigham Young University, which ranks seventh. It was among the national leaders in Licensing Income Relative to Research Expenditures and has achieved exceptional performance in the life-sciences area, especially in biotechnology.

At eighth, the University of British Columbia is the highest-ranking Canadian university, recording a score of 84.2 overall. Its best score is in Licensing Income. Its lowest score is 74.1, in Licenses Executed, thus displaying a consistent performance. The University of Michigan ranks ninth overall. It has consistently high scores, as well, but its best outcome achievement is in Patents. New York University scores 10th. Its position is attributable to its first-place score on Licensing Income. NYU ranks second on Licensing Income Relative to Research Expenditures, just behind Florida State University.

Commercialization Performance: Based on ASTP/AUTM Data for the United States, Canada and Parts of Europe

In the process of analyzing the innovation pipeline, we tried to include the maximum number of universities. However, we were limited by the paucity of comparable global data. Additional transparency should be a top priority, especially since much research funding comes from public sources. One bright spot in this otherwise arid space is *The 2006 ASTP Survey*,[8] which provides disaggregated data on 23 European public research organizations — 16 individual European universities/university hospitals and seven government or nonprofit research institutes.

The accompanying table provides a snapshot (one-year) comparison of U.S., Canadian and European universities overall, for 2004. All European numbers in this section are reported in purchasing price parity U.S. dollars (PPP$). These innovation pipeline measures have been normalized by research expenditures, but benchmark comparisons are fraught with data difficulties. For example, a potential source of bias is introduced by the higher response rate in the AUTM survey, in which 96 of the top 100 U.S. research universities participated. These universities represent 87 percent of total academic research expenditures. In contrast, while the ASTP sample includes many leading European universities, several of the most prestigious research universities did not participate. This suggests that the average European university statistics may be biased downward, relative to their U.S. and Canadian counterparts.

The average research expenditures for universities in U.S. dollars totals $225 million for the United States, $178 million for Canada and $100 million for Europe. Even with the exclusion of several top European research universities, the results highlight the Canadian and U.S. advantage in funding. Among universities, the United States leads in invention disclosures, patents filed and granted, licenses executed and licensing income.

AUTM and ASTP Performance Per Million Research Expenditures

Universities, 2004

	U.S.	Canada	Europe	Ratio	
Average Research Expenditures (US$ Mil.)	*225*	*178*	*100*		
	Per Million Research Expenditures			U.S./Canada	U.S./Europe
Invention Disclosures	0.40	0.14	0.32	2.98	1.25
Patent Applications	0.25	0.06	0.12	4.21	2.06
Patents Granted	0.09	0.01	0.04	6.09	2.38
Licenses Executed	0.11	0.07	0.09	1.58	1.25
Licensing Income (US$)	27,825	12,934	11,988	2.15	2.32
Startups Established	0.01	0.01	0.03	1.74	0.37

Sources: AUTM, ASTP, Milken Institute

European universities surpass their U.S. and Canadian counterparts in just one category: Startups established. European universities establish approximately three times as many new firms, relative to research expenditures, as their counterparts in the United States and Canada. This reflects an emphasis on startup activity as a public-policy priority. However, this higher startup rate says nothing about survival rates and whether startups become publicly traded firms with high levels of employment. The last two columns in the table show the ratio of U.S. performance relative to Canada and Europe. Wherever the ratio is greater than 1.0, the U.S. performance exceeds that of Canada and Europe.

In 2004 European university performance comes closest to the United States in Invention Disclosures and Licenses Executed. Still, the U.S. performance is 25 percent above Europe on these two measures. In addition, the United States has more than twice as many Patents Filed and Granted, relative to Research Expenditures, as Europe. This may reflect the greater focus on biotechnology research and the ability to patent genetic material in the United States. For Licensing Income, U.S. universities have $27,825 per Million Research Expenditures, substantially higher than the $11,988 for European universities. This comparison must be made cautiously, as the licensing income is the result of the cumulative investment in research over many years. Nevertheless, it does tend to indicate that U.S. universities rely on a few substantial deals that generate a disproportionate share of income.

Empirical Analysis: Measuring OTT and Factors Influencing Performance

Numerous factors — ranging from academic culture and public-policy constraints to industry dynamics — influence the success of university biotech transfer. Only some of these are readily quantifiable; elsewhere, empirical data for OTT processes and outcomes may be limited in scope or inaccessible to outside researchers. To better understand the determinants of successful university tech transfer, we devised a multi-pronged strategy, using a variety of tools and statistical databases to analyze and evaluate performance.

The principal source of data on technology transfer processes for all fields is AUTM.

Measurement problems associated with national and international comparisons of university biotech transfer processes make it difficult to determine the exact extent of the commercialization of academic research. In some instances, official reporting may undergo significant delays; in others, current data may be fairly comprehensive, but access to historical data for benchmarking purposes is limited. Biotech-specific research funding and technology transfer data are not extensively available from official sources.

The United States accounts for about 70 percent of world medical research and development, and 50 percent of global drug sales. As a consequence, biotech activity is thus over-represented in the United States since the U.S. share of world GDP is only slightly above 20 percent.

The wave of academic literature on university inventions that began shortly after passage of the Bayh-Dole Act has largely addressed questions of viability, success, costs and benefits within various programs and processes in individual countries or in small, cross-country comparisons. The research varies, from efficiency and effectiveness comparisons to analyses seeking to determine causality.

The choice of variables evaluated in the literature is also diverse, including: the number of spin-offs and startups, patents, licenses, R&D expenditures and revenues. In addition, areas of focus may encompass public and/or private universities, institutes and collaborative organizations. Although these studies span several fields and industries, there is a strong dominance of life sciences and biotechnology in OTT activities. Indeed, many studies document the dominant role of biotechnology in the university tech transfer process. We document the levels of returns on tech transfer activities at individual universities, in terms of university-specific performance data, and the importance of other individual causal factors, such as research quality and geographic location, that might affect the probability of research commercialization. This is important because when such factors are correlated with the output and input measures of an OTT, the separate effects are confounded. The impact of the OTT is central to our econometric analysis.

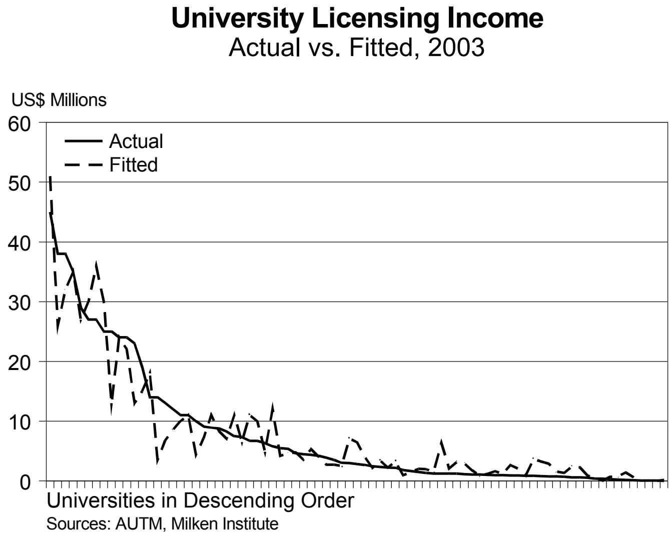
It is important to note that AUTM data are not directly comparable from year to year. Several variables, including licensing income, were not collected prior to 1996. Therefore, our modeling addresses the period from 1996 to 2003. Definitional changes in the survey beginning in 1996 make prior data incomparable and necessitate their exclusion from the econometric investigation. Additionally, only 81 universities continuously reported their data since 1996. The variables considered in our analysis are divided into two groups — Output Measures (dependent variables, or those movements we are attempting to explain) and Input Measures (independent variables, or those that are believed to explain movements in the dependent variables).

Dependent variables include **Licensing Income**, which comprises running royalties, upfront payments, cashed-in-equity and payments under options. **Running Royalties** represent the continuing stream of income that a university receives for inventions. Another form of licensing income is the one-time-only payment. **Licenses Executed** includes the number of license agreements executed in a specified year. **Startup Formation** applies to the establishment of companies dependent upon a university's technology for initiation. Startups that originate internally, that is, through the network of faculty or inventors, provide a measure of the university's capacity to innovate.

Independent variables include: **Labor Cost**, i.e., the staffing costs associated with running a university tech transfer office. It may also serve as a proxy for a university's budget or monetary commitment to technology transfer. We measured estimated compensation costs associated with the operations of the OTT — such as the number of Full Time Equivalents (FTEs) and compiled them into a Labor Cost Index, based on Bureau of Labor Statistics (BLS) wage data. We determined the **Age of the OTT** according to AUTM survey responses for a program start date, which refers to the year in which a professional position was devoted to tech transfer activities at least 50 percent of the time.

Additional independent variables used in our models include the **Milken Institute Tech-Pole Index**, which captures the absorptive capacity of technology transfer within a metropolitan area. The Milken Institute's (MI) Tech-Pole Index is defined as the product of two significant measures: high-tech concentration (characterized by vertical density) and breadth of high-tech activity (characterized by horizontal depth). A high concentration, or clustering, of technology firms in a region assists in creating an environment of linkages and opportunities for university commercialization efforts. The independent variable **Research Papers** captures the quality of research at a university, as measured by data on the number of publications and citations for all academic papers, and those specific to biotechnology that were discussed in the prior section. The 81-university sample was segmented further by breaking out a 21 biotech-intensive subset and investigating each university separately.

The following graph shows the actual versus fitted values from our Licensing Income Model 1, General Sample, statistical analysis for 2003. Keep in mind that we performed these tests on longitudinal data from 1996 through 2003. The 2003 cross section gives an illustration of how accurately the model explains variation in licensing income between U.S. universities that can be attributed to specific factors. More than 92 percent of the variation in licensing income is explained by movements in the four independent variables highlighted above. We developed similar model specifications for each of the other dependent variables: Running Royalties, Licenses Executed and Startups. We also performed this analysis for the biotech-intensive subset.



Our main findings within the empirical analysis show that:

- Research activity, as measured by Publications and Citations, has a high rate of return. Each 10-point increase in our Research Papers score (which ranges from 0 to 100) contributes an additional $1.7 million to a university's annual Licensing Income.
- Holding other factors constant, such as research culture and innovation ability, investments into OTTs seem to generate high returns. For every $1 invested in OTT staff, the university receives a little more than $6 in Licensing Income.
- A networking effect is found, as measured by how long the OTT office has existed, separate from the size of the staff. For each additional year in operation, $228,000 of incremental Licensing Income is generated.
- The absorptive capacity of the surrounding region has a significant impact on the success of a university's commercialization efforts. In the general sample, each 10-point increase in the MI Tech Pole Index (ranging from 0 to 100) results in a $2.1 million gain in Licensing Income. In the biotech-intensive subset, the estimated gain is even larger — $3.6 million for each 10-point increase.
- In explaining Startups, the **Exclusive Share** was highly significant. Exclusive Share represents the share of all Licenses Executed that are exclusive to only one company. It can also be interpreted to mean that a startup will rarely sprout from an invention that has been licensed to more than one company. The results confirm that a 1 percent increase in Exclusive Share resulted in the formation of a little more than one startup.

OTT Rate-of-Return Simulations

To further quantify the effect of the OTT and its staff as a percentage of total Licensing Income, Licenses Executed and Startup companies formed, we completed two alternate simulations. These simulations allow us to use our econometric equations to uncover the effects of additional investment into the OTT, as well as the effect of the office as a whole (capturing the networking advantages of institutional experience). We do so by replacing certain input-variable series (specifically, Labor Cost and Age of the OTT) with alternative historical series meant to estimate "what would have been" had the universities behaved differently. Using the simulations, we can better understand the incremental system-wide impact the tech transfer office has on licensing activity.

The following table uses the 81 universities in our 1996–2003 AUTM general sample data set to quantify the effects of the OTT as a percentage of total university licensing activity. The percentages represent the average Licensing Income, Licenses Executed and Startup companies formed that can be attributed to the additional investment into the office (Simulation I) and those that can be attributed to the office as a whole (Simulation II). Conversely, these numbers can be interpreted as the amount that university licensing activity would decrease, relative to the actual historical experience if investment into the office had stopped in 1996 (Simulation I) or had the office never existed (Simulation II).

Average OTT Impact

Output Contributable to the Tech Transfer Office, 1997-2003

	Licensing Income	Licenses Executed	Startup Companies
Simulation I No Additional Investment	4.9%	5.5%	5.2%
Simulation II No OTT Created	20.9%	23.2%	20.4%

Without an OTT office, the average university would earn only 79 percent of its annual licensing income; conversely, the office is responsible for more than 20 percent of annual licensing income. With an average of $639.1 million and a seven-year mean of $7.89 million, Simulation II estimates that the 81 universities in our data set can attribute $133.3 million more, and $1.7 million on average, individually to tech transfer collaborations involving their OTTs. The tech transfer office has a larger impact on licenses executed, at 23.2 percent of average annual licenses. Tech transfer offices had a slightly smaller impact on Startup companies formed. A little more than 20 percent of companies formed are a result of the addition of the OTT.

It is widely accepted that tech transfer offices contribute to the success of commercialization activities at universities. By using this type of evaluation, the benefits these offices bestow can be quantified.

Conclusions and Recommendations

We have performed a global economic analysis of university innovation and entrepreneurship, and have investigated the commercialization of international university biotechnology research to further the understanding of academic entrepreneurial capitalism. We examined and evaluated the results of individual country approaches, as well as the strategies and tactics of university biotech transfer processes.

Because many aspects of commercialization are place-, culture- and time-specific, we found no single model for tech transfer success. However, those seeking to improve efficiencies and commercialization success can gain insight from our global analysis, econometric findings and best practice examples.

Our study identifies five broad factors influencing successful commercialization of university research:

1. National Innovation Policy

There is no single set of policies for successful university technology transfer. Each government has the responsibility to determine its unique mix. However, there are many common characteristics among policies underpinning success.

In general, we recommend that all governments continually review and update regulations, and educate themselves regarding the policies of other nations, against whom they compete in this dynamic global industry. We advocate policies that are consistent and transparent, all the while recognizing the importance of intellectual property protection, the "rule of law" and the need to minimize partisan regulations, inefficiencies, conflicts and waste. We encourage open communication, cooperation and collaboration across borders to increase university technology transfer success.

A country's attitudes toward risk affect its biotech industry growth opportunities. We advocate the implementation of policies that encourage entrepreneurial capitalism and minimize the social and economic implications sometimes associated with failure. Universities around the world will be well served by integrating interdisciplinary entrepreneurship and business-management courses with life-science programs to stimulate commercialization.

Although we recognize that reporting technology transfer activities is relatively new for many universities, we promote the generation of publicly available disaggregated data (similar to the AUTM and ASTP surveys) that enable benchmarking and comparisons of individual OTTs.

2. Funding and Venture Capital

Although private-sector (especially venture capital) funding has increased exponentially since the passage of the Bayh-Dole Act, most global biotechnology research continues to be funded by federal appropriations. Based upon AUTM survey results, however, the largest source of spin-off funding is family and friends.

Biotech's lengthy timeline — from inception to product development — involves high costs, risks and delayed revenues. Universities and their technology transfer offices need long-term funding commitments, which can be threatened by alternative fiscal priorities and are not universally available. However, while financial support is necessary, evidence suggests that personal desire, enthusiasm, tenacity and quality human capital are directly and positively correlated with commercialization success.

3. Clusters of Biotechnology

Many countries recognize biotechnology as a potential growth industry and are establishing biotech parks to encourage the agglomeration economies associated with university, firm and investor proximity. Research suggests that biotech clusters that overcome geographical borders may be best positioned to leverage the increasingly global, interdisciplinary and collaborative nature of advanced scientific research.

4. University Technology Transfer Mechanisms

Although we observed no single university tech transfer model for successful commercialization, we identify some key ingredients for their success: (1) incentives (including ownership of innovation by universities, rewards to faculty and a motivating division of revenues among scientists, students, laboratories, departments and universities); (2) funding; (3) well-trained human capital (especially personnel with work experience that has taken them in and out of academia, industry and associations); (4) a culture of leadership, support and commitment from top-level university administrations; and (5) benchmarking and evaluation procedures to learn from one another.

5. Commercialization Success: Patents and Licensing

Passage of the Bayh-Dole Act has stimulated the commercialization of university research globally. However, although we found that an increasing number of universities engage in technology transfer, and evidence exists of revenue growth by commercialization generally, most OTTs are small, young operations, and few are profitable. In the United States, based upon information through 2003, the median age of OTTs was 17 years. In that same year, on average, about 10 full-time-equivalent (FTE) staff (median statistic 8.2) were in place, double the size from 1996 data (5 FTEs and a median of 3.7.)

Summary

U.S. universities are the world leaders in transferring intellectual property to the private sector. The United States retains a large lead in biotech research at its top universities. Nevertheless, as European, Asian and other governments in the Americas realize how important universities have become in the global innovation race and, indeed, in the race for national competitiveness, the U.S. lead and advantage of absorptive capacity should not be taken for granted. Furthermore, as cultural barriers to university involvement in commercial applications diminish, the American advantage seems likely to dissipate.

An important aspect of the university-based commercialization process that technology transfer office survey data doesn't capture is the numbers of successful large companies that grew from startups. The Amgens and Genentechs most differentiate the economic impact of U.S. university-based biotechnology commercialization from other technology transfer efforts around the world.

Advances in bio- and nanotechnology promise further improvements in health, quality of life and economic performance. A fuller understanding of technology transfer process may accelerate the pace at which such benefits reach society at large. In this spirit, we have attempted to contribute to that understanding and to provide the impetus for further investigation.

Endnotes:

1. It is interesting to note that the April 2006 SSRN (Social Science Research Network) "Top Business School Rankings" lists Harvard Business School as the top U.S. business school and the University of London's London Business School as the top international business school worldwide.
2. Refers to regular utility patents issued in the U.S. patent system. Other categories of U.S. patents, such as plant patents, design patents, reissues and continuations, are not included. Regular utility patents are considered to be the key category in assessing patent quality.
3. DeVol, Ross C., P. Wong, J. Ki, A. Bedroussian and R. Koepp, *America's Biotech and Life Science Clusters: San Diego's Position and Economic Contribution*, Santa Monica: Milken Institute.
4. http://www8.utsouthwestern.edu/home/research/index.html.
5. http://www.news.wisc.edu/packages/stemcells/thomson_bio.html.
6. DeVol, Ross, R. Koepp, L. Wallace, A. Bedroussian and D. Murphy, *The Greater Philadelphia Life Sciences Cluster: An Economic and Comparative Assessment*, Santa Monica: Milken Institute
7. See Shane, Scott, *Academic Entrepreneurship*, (Northampton, MA: Edward Elgar Publishing Inc. 2004), for a thorough review of the elements that make MIT and others successful.
8. Arundel, Anthony and Catalina Bordoy. 2006. "Final Report: The 2006 ASTP Survey," produced for the Association of European Science and Technology Transfer Professionals, June 7.

II. Introduction

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Increasing entrepreneurship and the commercialization of research have created new roles for universities as engines of economic development. Universities around the world have expanded their mission beyond that of basic research and teaching to become places where knowledge fuels patent development, business collaborations and incubators for startups.

As university research feeds industrial innovation, the hybrid scientist-entrepreneur becomes less rare.[1] Yet it is not uncommon to find a persistent philosophical struggle beneath the mission statements of even those research-intensive universities embracing this paradigm shift. Some university scientists may suffer pangs of conflict associated with increased commercialization, and such reticence may in turn impede economic development. Others may fear that the patent filing process will interfere with the ability to publish their findings. But as the Council on Governmental Relations maintains, faculty members don't have to choose "between patents and publications. Both are feasible and frequently desirable"[2] in the competitive, highly stratified academic world of biotechnological science.

In this study, we examine the biotechnology innovation cycle taking place at universities, from knowledge creation to technology transfer and early-stage commercialization. We define biotech commercialization as the end product of a university's innovation pipeline — the support infrastructure that enables a university to capitalize on its strengths in biotech knowledge and creativity.

Our broader objectives seek to:

- compare university technology transfer processes around the world;
- study those processes and returns to understand what characteristics lead to successful commercialization;
- advance interdisciplinary research in the field of technology transfer for many countries around the world;
- analyze and measure the role of the technology transfer office (OTT) in commercialization.

In most cases, the intellectual property (IP) derived from university research is transferred to the private sector for commercial use via patents, licenses or know-how in return for financial considerations (research support, honoraria, consulting fees, licensing income, options, joint venture agreements, royalties and equity).

Since implementation of the Bayh-Dole Act of 1980 and similar legislation enacted elsewhere around the world, innovation has increasingly shifted to universities. They in turn have instituted incentives for their faculty researchers and have seen an acceleration of the commercialization process. Other factors leading to successful commercialization include the creation of technology transfer offices, government inducements and partnerships, new industry funding mechanisms, venture capital outreach efforts and greater recognition of university-generated patents and products in the marketplace. Yet despite all this, universities overall have not been as successful at marketing their research as many had originally hoped.

One of the principle objectives of our study was to investigate the role and measure the significance of technology transfer offices in the commercialization process. Their performance has been studied from many perspectives, but we set out to study OTT success in terms of revenues.

In meeting our objectives, we developed specific innovation pipeline and outcome metrics of interest for the investor community. Specifically, we:

- evaluate global university research quality/quantity through publication rankings;
- examine global biotech patenting activity, quality and impact;
- assess early-stage commercialization success through various tech transfer outcome measures;
- hypothesize on the principal determinants of OTT commercialization, which include but are not limited to: a Milken Institute Tech-Pole Index, capturing the absorptive capacity of technology transfer; research quality and its importance in the OTT, as measured by research papers; and the returns on investment in the OTT (characterized by the a labor cost index).

Economists have long sought patent value predictability models for such transfers. For example, while the emphasis on blockbuster drugs may diminish (due to the increasing demand for personalized solutions), the knowledge of which patents have the potential to lead to blockbuster drug development is significant to the allocation of resources by scientists, investors, public policy-makers and university decision-makers. However, early patent value determination remains elusive.[3] For this reason, interest is shifting from studying the numbers and impacts of patents and licenses per se to determining value models from the "results" side, through the understanding of institutional variations in the range and efficiency of technology transfer activities.

In this study, we use regression modeling techniques to assess the role of investments in human capital in the OTT. Robert Shiller, economist and author of the best seller *Irrational Exuberance*, writes that "regression analysis is more art than science. … But a skilled practitioner can use it to tell how meaningful a correlation is,[4] and maybe even tell whether that correlation indicates a causal relationship."[5] Within our econometric analysis, we also set out to capture what is specific to universities (e.g., research culture, innovation ability and absorptive capacity). By controlling for fixed effects, we were able to determine that investments into OTTs seem to generate high returns.

With the goal of advancing interdisciplinary research in the field of technology transfer for many countries around the world — and creating a global study of the issue — we compared and evaluated the scientific strength of universities, as measured by the quantity and quality of published research. Our goal was to see where universities around the world rank in relation to their peers.

In terms of providing more useful information for the investor community, we developed metrics for evaluating early-stage commercialization. In doing so, we created a university technology transfer and commercialization index for universities worldwide.

In addition, we developed biotech-specific metrics for evaluating global university research quality, with respect to patenting activity. We provide a ranking of universities worldwide where the intent was to capture the quantity and various quality attributes of biotech patents.

In order to further understanding of academic entrepreneurial capitalism, we also provide brief overviews of nearly 30 countries, based on five determinants of commercialization: national innovation policy, funding and venture capital, clusters of biotechnology, university tech transfer mechanisms and commercialization success via patenting and licensing.

Endnotes:

1. Hicks, Diana, T. Breitzamn, D. Olivastro and K. Hamilton. 2001. "The Changing Composition of Innovative Activity in the U.S.: A Portrait Based on Patent Analysis," *Research Policy.* 30(4). See also: Owen-Smith, Jason, M. Riccaboni, F. Pammolli and W. Posell. 2002. "A Comparison of U.S. and European University-Industry Relations in the Life Sciences," *Management Science.* 48. See also: DeVol, Ross, Perry Wong, Armen Bedroussian, Lorna Wallace, J. Ki. Daniela Murphy and R. Koepp. 2004. *Biopharmaceutical Industry Contributions to State and U.S. Economies*, Santa Monica: Milken Institute.
2. "University Technology Transfer Questions and Answers," The Council on Governmental Relations. Nov. 30, 1993. http://www.cogr.edu/docs/BayhDoleQA.htm.
3. Allison, John R., Lemley, Mark A., Moore, Kimberly A. and Trunkey, R. Derek, "Valuable Patents." July 2003. George Mason Law & Economics Research Paper No. 03-31; UC Berkeley Public Law Research Paper No. 133 Available at SSRN: http://ssr.com/abstract=426020. This article provides an excellent literature review on the quantification of patent value and offers a litigation model for measurement.
4. Correlation is a statistical term that indicates whether variables in a model are related and/or "move together."
5. Shiller, Robert J. 2005. *Irrational Exuberance*, 2nd ed., Princeton and Oxford: Princeton U. Press, p.163.

III. Empirical Analysis: Measuring OTT and Factors Influencing Performance

Section 1

Methodology

Numerous factors — ranging from academic culture and public-policy constraints to industry dynamics — influence the success of university biotechnology transfer. Only some of these are readily quantifiable; other empirical data for OTT processes and outcomes may be limited in scope or inaccessible to outside researchers. To better understand the determinants of successful university tech transfer, we devised a multi-pronged strategy incorporating a number of tools and statistical databases to analyze and evaluate performance. We used two research methods:

- primary research, including interviews with representatives of universities, public agencies and companies engaged in tech transfer;
- secondary research, comprising a literature review and econometric analysis. Data are derived from government reports and statistics, survey data, literature review findings, marketing tools, investor reports and online information.

The principal source of data on technology transfer processes for all industries is the Association of University Technology Managers (AUTM).[1] We used the association's survey, published annually since 1991, of technology licensing (and related) performance for U.S. and Canadian academic and nonprofit institutions, as well as technology investment firms. We also relied on AUTM-based reports using similar metrics in Australia; surveys conducted in the United Kingdom by The University Companies Association (UNICO) and throughout Europe by the Association of European Science and Technology Transfer Professionals (ASTP); and the databases of Thomson Scientific (SCI/SSCI/ACCI), the Swiss Center for Science and Technology Studies (CEST) and ipIQ.

Limitations and Caveats

Some countries prohibit the release of "confidential" university tech transfer data.

Measurement problems associated with national and international comparisons of university biotech transfer processes make it difficult to determine the exact extent of the commercialization of academic research. In some instances, official reporting may undergo significant delays; elsewhere, current data may be comprehensive, but access to historical data for benchmarking purposes is limited. Biotech-specific research funding and technology transfer data are not extensively available from official sources.

Some countries prohibit the release of "confidential" university technology transfer data. The United Kingdom releases this information only at the aggregate level, thereby effectively eliminating in-depth, inter-university comparative analysis. Still other counties are either too early in the stage of national data collection or do not have the information at all.[2] In addition, differing definitions of biotechnology among the nations studied, as well as varying methods of data compilation, do not lend themselves to strict comparisons.

The listing of universities that we analyzed is incomplete, due to sporadically missing and disaggregated data. For example, the University of Texas reports centralized tech transfer figures rather than data on each of its nine campuses.[3] In addition, IP slippage (from researchers who leave academia altogether for entrepreneurialism, for instance) is difficult to ascertain,

so that OTT-reported data may reflect a fraction, albeit a sizable one, of all commercialization activities.[4]
A possible statistical problem occurs because royalty income is measured on a cumulative rather than annual basis. In some universities, licenses 10 years old are still earning income.

The statistical gathering restrictions force a caveat to all interpretations. However, despite these limitations, the available data do provide a clear picture of the development and evolution of the commercialization of university research and present a strong and novel basis for future research.

The United States accounts for about 70 percent of world medical R&D and 50 percent of global drug sales. As a consequence, biotech activity is over-represented in the United States, since the U.S. share of world GDP is only slightly above 20 percent. America's influence as a driving force in the world's biotech R&D anchors our analysis.

Measuring technology-based economic development gains is an imperfect science, given the time lag from initial investment in university research to its profitable industrial application, which typically runs from three to seven years but can extend longer.[5] And because an OTT learns from institutional experience, its age may factor into success or productivity. Castillo, Parker and Zilberman (2001) write that "technology diffusion causes license earnings to grow gradually, so younger OTTs tend to lag significantly in their earnings relative to older OTTs."[6]

The number of university patents issued in the United States for 2003, according to the U.S. Patent and Trade Office statistics, totals 3,259.[7] AUTM survey-response data, however, discloses 3,933 patents issued.[8] Such differences are attributable, in part, to varying definitions. Multiple university collaboration arrangements may also inflate the count.[9] According to one OTT staff member interviewed for this study, "OTTs tend to 'over-patent' to encourage good relations with faculty" — which may help explain high OTT patenting activity, as well as possible low productivity, in that a lower proportion of patents is likely to result in licensing deals.

AUTM data for startups may also be inflated because of duplicate recording. "When a startup is formed by faculty members from two universities, each university tends to record it, which can lead to double counting," said Scott Carter, Assistant Director of Licensing at the California Institute of Technology OTT.[10] As such, analyzing the data over time, rather than for a single year, may better reflect reality.

The commercialization of university biotech research has moved beyond geographic borders through foreign direct investment, alliances, mergers and acquisitions, and now is truly global. Multinational enterprises routinely manufacture offshore and look for research opportunities in less developed nations. We investigated commercialization processes in 30 countries. Biotechnological innovation and its diffusion in many underdeveloped countries are, however, outside of the scope of our analysis. This is not to say that these nations do not have universities that are innovating. But innovation is characterized by advanced business and governance conditions, a highly trained work force and sophisticated infrastructure, all of which pose particular challenges in countries that continue to struggle with the ravages of war, insurgency, unemployment, poverty and disease. Developing nations must provide the necessary medical, technical, financial, legal and entrepreneurial environment to enable the commercialization of research.

Section 2

Literature Review

In this section, we review the existing academic and practitioner literature, and discuss previous work on the performance of university technology transfer offices. The wave of academic literature on university inventions that began shortly after passage of the Bayh-Dole Act has largely addressed questions of viability, success, costs and benefits within various programs and processes in individual countries or in small, cross-country comparisons. The research varies, from efficiency and effectiveness comparisons to analyses seeking to determine causality. We hope this study — global in scope and comprehensive at the disaggregated, individual university level — will add to the understanding.

Drawing upon interdisciplinary findings to advance previous work, this study also breaks novel ground in providing data useful for the investor community (angel investors, venture capitalists (VCs), biopharmaceutical firms and other sources of private equity). With increased transparency of tech transfer efficiencies, the investor community may be assisted in directing investments where they have greater probability of success. Alternatively, this study may help identify where high-quality research isn't being fully leveraged for commercial applications, presenting opportunities for potential investors.

Economy-Wide Impact of University Research Activities

There is a strong dominance of life sciences and biotechnology in OTT activities.

There exists a fairly voluminous theoretical and empirical literature analyzing the interaction between public and private financing of R&D.[11] Some scholars explore country-specific tech transfer activities, although relatively little has been published on OTTs outside the United States, especially in Asia.[12] Studies that offer cross-country comparisons often benchmark performance against the United States.[13] Some investigate international comparisons beyond individual trading blocs.[14]

The choice of variables evaluated in the literature is also diverse,[15] including the number of spin-offs and startups,[16] patents,[17] licenses,[18] R&D expenditures and revenues. In addition, areas of focus may encompass public and/or private universities, institutes[19] and collaborative organizations. Regrettably, analyses are often limited to broad-based generalizations.[20] In these studies, data may be incomplete because of low survey response rates, insufficient access to information or data collected for just a single year.[21] The biotech sectors explored are both broad and narrow, with definitions differing dramatically.[22] "Owen-Smith and Powell (2001) show that technology transfer in the life sciences is substantially different than technology transfer activities in the physical sciences."[23]

Research indicates that patent activity has risen in U.S. universities during the past few decades, relative to the rest of the economy. Henderson et al. document that during the period 1965–1988, patent growth was more rapid, and resulted in more patents per research dollar, inside universities than elsewhere in the economy. A corresponding increase in the collaboration between universities and outside institutions was also documented.[24] Mowery et al. attribute some of the increase in university patenting activity to the increase in federal funding and research in the biomedical arena.[25] Allison et al. provide an excellent literature review on the quantification of patent value and offer a litigation model for measurement.[26]

Although these studies span several fields and industries, there is a strong dominance of life sciences and biotechnology in OTT activities. Indeed, many studies document the dominant role of biotechnology in the university tech transfer process.

The initial public offering of a biotech startup is positively related to the involvement in the firm of a recognized researcher, as measured by citations and Nobel Prizes. According to Stephan et al., every 1,000 citations bring an extra $11.3 million to the IPO, and the association of a Nobel laureate attracts an additional $26.9 million.[27] In another study, Zucker et al. find that in Japan, for example, collaborations with certain university scientists improve a firm's research, increasing patents by 34 percent, products in development by 27 percent and products on the market by 8 percent (from 1989 to 1990).[28] Kim et al. find that the pharmaceutical industry in particular is capitalizing on university research by hiring inventors with university institutional experience.[29] Finally, Bransetter et al., seeking to shed light on the "propensity to cite academic science" in the 1990s, find that "increased patenting in the bio nexus is, in a mechanical sense, the single most important driver of the growth in patent citations over time."[30] On the other hand, the passage of the Bayh-Dole Act provided an important incentive to file for patents in the biotechnology area.

Technology Transfer Offices at Universities

Academics have paid relatively less attention to evaluating the impact and efficiency of OTTs in their ability to transfer and commercialize university technology into the marketplace. The existing literature documents several patterns. The work by Zucker et al. and Stephan et al. present evidence in support of "star" scientists, as measured by citation impact,[31] raising the degree to which universities are involved in the commercialization process. As citations are highly concentrated in any academic profession, these star scientists are a scarce commodity, usually working at the most well-known universities.[32] We also found, in the course of this study, that a few select universities are responsible for the majority of commercialized revenue, a statistic consistent with the conclusions drawn about the importance of star scientists and absorptive capacity of locations.

Many previous studies find the age of OTTs important to commercialization success. An age effect may potentially represent a better network of the university and thereby a superior ability in serving as a matchmaker between sellers and buyers of IP.[33] However, caution should be raised in interpreting age effects, as they may be correlated with the talent of the faculty in generating IP. Indeed, many of the universities that first opened OTTs also had the highest immediate returns to their offices.

Studying the performance of OTTs in Britain, Chapple et al. note generally low efficiency levels, with better performance in regions of higher R&D and GDP levels. OTT age and university size negatively affect efficiency, they conclude, implying the absence of learning effects and fewer patentable inventions as a university becomes larger and more diversified.[34] They suggest that smaller universities may have an advantage because they focus on specialized research areas, while large universities attempt to provide broader-based support. Additionally, it is postulated that older OTTs are staffed by personnel without much private-sector experience, which hinders their performance.

Cesaroni and Piccaluga find that due to "differences in terms of social rules and cultures between for-profit firms and nonprofit research organizations, the latter often suffer from lower bargaining power," suggesting that "research organizations often need to reach a sizable 'critical mass' before having acquired sufficient experience in contracting."[35] Cooper, in a comparative study using AUTM data, found that 15 Canadian universities, when matched to their U.S. counterparts by levels of R&D expenditures, have considerably greater outputs in seven of eight commercialization and technology transfer metrics, such as startups.[36]

Research suggests that a researcher's continued involvement in a licensing deal contributes to the success of that deal.

In the technology transfer field, Thursby research is perhaps the most prolific. Marie Thursby and husband Jerry Thursby, along with various co-authors, have studied university commercialization for more than a decade.[37] Thursby et al. find in their 2005 study of faculty in six major research universities that over the past two decades, the probability that a faculty member will disclose an invention (as measured by licensing) increased tenfold, while research productivity (as measured by publications in basic journals) remained constant.[38]

Lach and Schankerman discuss the hypothesis that universities providing their faculty with greater rewards (as measured by the amount of royalty income allocated to the inventor) for participating in tech transfer activities will experience higher output, in terms of licenses and Licensing Income. They conclude that their hypothesis is correct and offer two possible explanations: the phenomenon known as sorting (universities with better incentives for inventions attract more productive scientists); and an increased effort by scientists already employed by the university to earn the more lucrative rewards.[39] Freidman and Silberman also address the concept of incentives as motivation in university licensing activities. While their results are not as strong as anticipated, they do suggest that a faculty researcher's continued involvement in a licensing deal contributes to the success of that deal, and that the additional involvement translates into higher compensation for the researcher.[40] The report uses the Milken Institute Tech-Pole Index[41] as an input measure.

Some U.S. studies (including Coupé and Mowery et al.) attempt to isolate the effects of the changes in incentives for technology transfer generated by the Bayh-Dole Act.[42] However, it is difficult to separate out the effect of this law from the general time trend affecting commercialization incentives — the law changed incentives for all U.S. universities simultaneously, making the independent variation of the law from the general time trend difficult to achieve.

Recent research by Chukumba and Jensen using U.S. data from AUTM, the National Venture Capital Association Yearbook and the National Research Council finds that "inventor quality and measures of past TTO success (age, the number of disclosures, gross royalties) are all positively and significantly related to the number of licenses to both start-ups and established firms" and that "start-up activity is positively and significantly related to the S&P 500, but negatively and significantly related to the interest rate and rate of return to venture capital."[43]

Econometric studies that control for unobserved fixed effects of universities — for example, the history, research culture or commercial talent of the faculty at the university — are limited in number. This is important because when such factors are correlated with the output and input measures of an OTT (for example, by more talented faculties driving both more input use and higher outputs), the separate effects are confounded. Lockemann notes that much has been written on statistical measures and results that judge the success of institutions, but little on what makes individuals and institutions

Ten schools accounted for a third of U.S. university-issued patents and half of university licensing income.

tick or on the major motivations and forces that drive the transfer process. His paper begins to answer these questions, but more so by anecdotal evidence than by empirical study.[44] Matkin's book, *Technology Transfer and the University*, is a comprehensive collection of data and close observation of tech transfer experiences of four selected universities — UC Berkley, MIT, Penn State and Stanford — that helps shed light on how universities approach technology transfer differently.[45] Rigorous research by Maryanne Feldman on Johns Hopkins contributes to understanding of this specific university and how its approach differs because of the clinical focus of most of its NIH funding.[46]

But how profitable is university biotech commercialization? Research shows that "license fees rarely reach into the six figures for a single patent and more often range from a few thousand to a few tens of thousands of dollars. Royalty rates range from less than 1 percent (for some process technologies) to perhaps 8 percent (for a patented compound with a significant market). The majority of royalty rates are in the 3 percent to 6 percent range, based on net sales."[47]

Based upon the AUTM survey, in the United States in 2003, just 10 schools accounted for approximately a third of all U.S. university-issued patents and nearly half of all university Licensing Income (see the list below). The revenues derived from licensing university intellectual property are heavily concentrated on a few of the top income-producing licenses. For example, a study by Thursby claims that on average, 76 percent of license income is attributable to the university's top five inventions. Consequently, the distribution of royalty revenues is somewhat skewed.[48]

Top 10 U.S. Universities, 2003

Licensing Income		Patents Issued	
Rank	University	Rank	University
1	New York University	1	California Institute of Technology
2	Stanford University	2	Massachusetts Institute of Technology
3	University of Minnesota	3	Stanford University
4	University of Wisconsin	4	Johns Hopkins University
5	University of Florida	5	University of Wisconsin
6	University of California, San Francisco	6	University of California, San Francisco
7	University of Washington	7	University of Chicago
8	Massachusetts Institute of Technology	8	University of Michigan
9	University of Rochester	9	Harvard University
10	California Institute of Technology	10	Penn State University

Sources: AUTM, UC Tech Transfer Annual Report, Milken Institute

Universities may indeed be motivated by the hope that they will develop a product or compound that brings them the phenomenal licensing success Gatorade has generated for the University of Florida. And while critics may caution that commercialization goals will stifle research, success stories like Gatorade, Rituxan and Taxol communicate to universities that research can be applied to benefit in the real world and that innovation costs can be partially recovered in the marketplace. University commercialization success isn't uniform or unqualified, but most standard rate-of-return calculations miss other important considerations, such as social returns. By undertaking basic medical research and promoting translational adaptations, universities are assisting in providing treatments and cures for chronic and debilitating diseases. Universities receive the bulk of their funding from public sources, and the social benefits must factor into the rate of returns for a truly complete measure.

The Missing Investor Perspective

Though the literature enables greater understanding of many of the issues involved in biotech transfer, there is a dearth of analysis from the private investor perspective — the economic returns of these offices. In particular, there is a lack of understanding of how many dollars are forfeited or brought back to the university for every additional dollar invested in its OTT.

Often the unit of analysis is not standardized across inputs and outputs, and these measures have not been both monetized. This makes previous analysis difficult to use, in terms of focusing investment capital toward intellectual property from institutions with the highest rate of returns. Our report is the first to document the levels of returns on technology transfer activities at individual universities, in terms of university-specific performance data and the importance of other individual causal factors, such as research quality and geographic location, which might impact the probability of research commercialization.

Section 3

Econometric Analysis

Part 1: Data Introduction

The main source for our econometric analysis comes from our evaluation of AUTM survey data collected from U.S. universities. The 2003 survey overall response rate was 62 percent, with 165 universities participating. Among the top 100 research universities, the response rate increased from 66 percent in 1992 to 96 percent in 2003. The AUTM data are supplemented with Milken Institute measures we have created in other high-technology studies.

It is important to note that AUTM data are not directly comparable from year to year. Several variables, including Licensing Income, were not collected prior to 1996. Therefore, this study addresses the period from 1996 to 2003. (The 2004 data were not available until our econometric analysis was largely completed; however, we were able to incorporate the figures into the "Innovation Pipeline" chapter of this report. It is unlikely that their inclusion would change results in any meaningful way.)

The two tables below contain summary statistics for the variables we considered in our analysis, divided into two groups — Output Measures (dependent variables) and Input Measures (independent variables). The first table displays descriptive statistics for all 81 university OTTs used in our analysis, whereas the second table isolates those 21 that are biotech-intensive. There were definitional changes in the survey beginning in 1996 that make prior data incomparable and necessitate their exclusion from the econometric analysis. Additionally, only 81 universities continuously reported their data since 1996.

Descriptive Statistics - General Sample
U.S., 1996-2003, n=81

	Mean	Median	Maximum	Minimum	S.D.	Skewness
Output Measures						
Licensing Income	6,386,311	2,034,585	80,059,260	1,978	11,137,966	3.2
Licenses Executed	30	16	287	0	36	2.5
Running Royalties	4,269,654	902,373	67,391,590	0	8,583,743	3.5
Startups	3	2	31	0	4	3.1
Input Measures						
Labor Cost	332,469	246,899	1,715,700	0	284,958	1.9
Age of OTT	17	14	78	0	13	2.5
MI Tech-Pole Index	9	3	100	0	15	3.2
Research Papers	48	47	100	29	11	1.1
Invention Disclosures	93	73	504	2	83	1.8
Exclusive Share	0.6	0.6	1.0	0.0	0.3	-0.2

Sources: AUTM, CEST, Milken Institute

Descriptive Statistics - Biotech Intensive Sample
U.S., 1996-2003, n=21

	Mean	Median	Maximum	Minimum	S.D.	Skewness
Output Measures						
Licensing Income	12,988,618	7,526,251	80,059,260	107,487	14,100,550	1.8
Licenses Executed	52	44	177	1	40	1.1
Running Royalties	8,956,600	3,927,518	48,791,144	0	10,935,603	1.5
Startups	5	3	31	0	5	2.1
Input Measures						
Labor Cost	572,665	504,923	1,692,240	5,397	348,082	1.0
Age of OTT	23	18	78	4	17	1.8
MI Tech-Pole Index	16	11	100	0	22	2.8
Research Papers	59	59	100	37	12	1.3
Invention Disclosures	163	138	504	9	111	1.0
Exclusive Share	0.5	0.5	1.0	0.1	0.2	0.1

Sources: AUTM, CEST, ipIQ, Milken Institute

Output Measures

The AUTM survey collects output and inputs for each year observed; but the Milken Institute Tech-Pole Index and our Research Paper variable, created with data from the Swiss Center for Science and Technology Studies (CEST) and Thomson Scientific, are Input Measures. The top portion of each of the tables on the preceding page displays the measures of output or performance outcomes used. These include: total Licensing Income received, the number of License agreements Executed (exclusive and nonexclusive), Running Royalties and Startup formation.

Licensing Income includes running royalties, upfront payments, cashed-in-equity and payments under options. **Licenses Executed** include the number of license agreements executed in a specified year. **Running Royalties** represent the continuing stream of income that a university receives for inventions. Other forms of Licensing Income are characterized by a one-time only payment.

Licensing Income and Licenses Executed may pose different behavioral characteristics. The measure of Licenses Executed provides a more contemporaneous effect, while Licensing Income is measured cumulatively over time. It should be understood that the dependent variable Licensing Income includes the time lags in the effects of inputs on outputs (there is a significant time lag between when a license is executed and the time it actually generates revenue) and the relatively short eight-year span of data we analyze. Additionally, some licenses are classified as either exclusive or nonexclusive. An exclusive license doesn't allow any other firm to utilize the university intellectual property.

Startup Formation applies to the establishment of companies dependent upon a university's technology for initiation. Startups that originate internally, i.e., through a network of faculty or inventors, provide a measure of a university's capacity to innovate.

We use some of these raw Output Measures at the different stages of commercialization to compute performance, such as the conditional probabilities of the share of disclosures that become patent applications; the share of patent applications that become patents; and the share of patents that become licensing contracts. In essence, we deconstruct the process by working backward from Output Measures to the sequential stages preceding them. The OTT may raise these conditional probabilities as more inputs are utilized.

Input Measures

The lower sections of the above tables display the Input Measures we identified to determine the performance of the OTTs: labor costs, for example, and age of the OTT.

The **Labor Cost** portrays the staffing costs associated with running a university tech transfer office. It may also serve as a proxy for a university's budget or monetary commitment to technology transfer. Because commercialization is very labor-intensive, most expenditures are captured this way, with other capital and land costs likely to be of minor importance. Unfortunately, no cost or budget data are available from AUTM for the OTTs in our sample. Therefore, we measured various other costs associated with the operations of the OTT — such as number of FTEs — and compiled them into a Labor Cost Index, based on Bureau of Labor Statistics (BLS) wage data.

Data are available for FTEs whose main responsibilities include licensing and patenting, as well as for those who operate in support roles, such as administrative staff. "Professional" and "other" FTEs are highly correlated and therefore were not introduced as separate explanatory variables in our model. To correct for this, we transform the unique FTE, using national wage data from the BLS into the total Labor Cost:

The age of the tech transfer office accounts for institutional experience as a matchmaker between academia and industry.

labor cost index = licensed FTE * wage for license FTE + support FTE * wage for support FTE)

Although the labor cost index may not explain much about the quality of the OTT, it does explain the benefit of Licensing Income when hiring additional FTEs.

We determine the **Age of the OTT** according to AUTM survey responses for a program start date, which refers to the year in which a professional position was devoted to technology transfer activities at least 50 percent of the time. It is important to keep in perspective that some universities engaged in commercialization even before they opened tech transfer offices. However, the age of the tech transfer office is important because it accounts for an OTT's institutional experience in acting as a matchmaker between academia and industry.

Additional Input Measures used in our model include the **Milken Institute Tech-Pole Index**, which captures the absorptive capacity of technology transfer within a metropolitan area. The Milken Institute's (MI) Tech-Pole Index is defined as the product of two significant measures: high-tech concentration (characterized by vertical density) and breadth of high-tech activity (characterized by horizontal depth). High-tech concentration, often referred to as a location quotient (LQ), is represented by the relative size of high-tech employment, as well as high-tech industry output, in the local economy, compared to the U.S. average.[49] Horizontal depth, on the other hand, is examined by the proportion of high-tech employment or output in a metro versus the nation. From these two components, we derive our MI Tech-Pole Index.

It is also important to note that two composite indexes were compiled for this measure: one based in terms of employment (EMP) and another in terms of output (GDP), leading us to arrive at a "combined" composite index (MI Tech-Pole Index). A table of the top 50 metros in the 2003 Milken Institute Tech-Poles Index (as ranked by the Combined Composite Index) follows.

Milken Institute Tech-Pole Index
Top 50, 2003

	Combined Composite Index		GDP Composite Index			EMP Composite Index		
Rank	Metro	Index	Metro	Score	Index	Metro	Score	Index
1	San Jose, CA	100	San Jose, CA	17.39	100	San Jose, CA	14.82	100
2	Washington, DC-MD-VA-VW	54.027	Washington, DC-MD-VA-WV	8.97	51.581	Washington, DC-MD-VA-WV	8.369	56.472
3	Seattle-Bellevue-Everett, WA	42.061	Portland-Vancouver, OR-WA	7.534	43.326	Los Angeles-Long Beach, CA	7.191	48.522
4	Los Angeles-Long Beach, CA	40.049	Seattle-Bellevue-Everett, WA	7.355	42.296	Boston, MA	6.357	42.895
5	Boston, MA	32.87	Dallas, TX	6.666	38.332	Seattle-Bellevue-Everett, WA	6.199	41.825
6	Dallas, TX	32.445	Los Angeles-Long Beach, CA	5.491	31.577	Dallas, TX	3.936	26.559
7	Portland-Vancouver, OR-WA	26.906	Phoenix-Mesa, AZ	4.416	25.394	Orange County, CA	2.952	19.919
8	Phoenix-Mesa, AZ	18.82	Boston, MA	3.973	22.846	San Diego, CA	2.872	19.378
9	Atlanta, GA	16.05	Albuquerque, NM	3.492	20.078	Chicago, IL	2.85	19.231
10	Chicago, IL	15.93	Atlanta, GA	2.676	15.388	Philadelphia, PA-NJ	2.71	18.289
11	Philadelphia, PA-NJ	15.148	Austin-San Marcos, TX	2.235	12.85	New York-Newark, NY-NJ-PA	2.612	17.623
12	Orange County, CA	15.116	Chicago, IL	2.196	12.629	Atlanta, GA	2.477	16.711
13	San Diego, CA	14.688	Denver, CO	2.155	12.389	Detroit, MI	2.443	16.483
14	San Francisco, CA	13.682	Philadelphia, PA-NJ	2.088	12.008	San Francisco, CA	2.301	15.526
15	New York-Newark, NY-NJ-PA	13.302	San Francisco, CA	2.059	11.838	Denver, CO	1.924	12.982
16	Albuquerque, NM	13.302	Boise City	2.04	11.731	Raleigh-Durham-Chapel Hill, NC	1.9	12.821
17	Denver, CO	12.686	Newark, NJ	1.959	11.266	Oakland, CA	1.891	12.76
18	Detroit, MI	12.146	Raleigh-Durham-Chapel Hill, NC	1.907	10.968	Minneapolis-St. Paul, MN-WI	1.853	12.501
19	Austin-San Marcos	12.105	Oakland, CA	1.795	10.323	Houston, TX	1.823	12.302
20	Raleigh-Durham-Chapel Hill, NC	11.894	Orange County, CA	1.794	10.314	Phoenix-Mesa, AZ	1.815	12.247
21	Oakland, CA	11.541	Middlesex-Somerset-Hunterdon, NJ	1.761	10.128	Austin-San Marcos, TX	1.684	11.36
22	Houston, TX	10.931	San Diego, CA	1.739	9.999	Middlesex-Somerset-Hunterdon, NJ	1.656	11.174
23	Newark, NJ	10.661	Houston, TX	1.663	9.56	Huntsville, AL	1.579	10.656
24	Middlesex-Somerset-Hunterdon, NJ	10.651	Kansas City, MO-KS	1.648	9.476	Portland-Vancouver, OR-WA	1.554	10.486
25	Boulder-Longmont, CO	9.538	New York-Newark, NY-NJ-PA	1.562	8.982	Boulder-Longmont, CO	1.522	10.271
26	Minneapolis-St. Paul, MN-WI	9.469	Boulder-Longmont, CO	1.531	8.805	Newark, NJ	1.49	10.057
27	Kansas City, MO-KS	8.36	Indianapolis, IN	1.367	7.861	Wichita, KS	1.49	10.051
28	Wichita, KS	7.681	Detroit, MI	1.358	7.808	New Haven- Bridgeport-Stamford, CT	1.213	8.182
29	Boise City, ID	7.367	Minneapolis-St. Paul, MN-WI	1.119	6.436	Baltimore, MD	1.123	7.579
30	Huntsville, AL	6.708	Fort Worth-Arlington, TX	1.006	5.787	Kansas City, MO-KS	1.074	7.244
31	Indianapolis, IN	6.481	Wichita, KS	0.923	5.31	Tampa-St. Petersburg-Clearwater, FL	1.019	6.877
32	New Haven-Bridgeport-Stamford	6.437	Baltimore, MD	0.911	5.237	Albuquerque, NM	0.967	6.526
33	Baltimore, MD	6.408	Nassau-Suffolk, NY	0.834	4.797	Nassau-Suffolk, NY	0.94	6.343
34	Fort Worth-Arlington, TX	5.964	Colorado Springs, CO	0.817	4.699	Fort Worth-Arlington, TX	0.91	6.142
35	Nassau-Suffolk, NY	5.57	New Haven-Bridgeport-Stamford, CT	0.816	4.692	Salt Lake City-Ogden, UT	0.903	6.093
36	Colorado Springs, CO	5.278	Tucson, AZ	0.753	4.328	Colorado Springs, CO	0.868	5.857
37	Tampa-St. Petersburg-Clearwater, FL	5.192	Ventura, CA	0.667	3.835	St. Louis, MO-IL	0.828	5.588
38	Rochester, NY	4.366	Tampa-St. Petersburg-Clearwater, FL	0.61	3.506	Rochester, NY	0.818	5.518
39	Pittsburgh, PA	4.283	Pittsburg, PA	0.596	3.429	Melbourne-Titusville-Palm Bay, FL	0.779	5.254
40	Ventura, CA	4.174	Sacramento, CA	0.596	3.427	Pittsburg, PA	0.761	5.138
41	St. Louis, MO-IL	4.102	Rochester, NY	0.559	3.214	Indianapolis, IN	0.756	5.101
42	Tucson, AZ	4.085	San Antonio, TX	0.539	3.099	Ventura, CA	0.669	4.513
43	Salt Lake City-Ogden, UT	3.919	Huntsville, AL	0.48	2.76	Cincinnati, OH-KY-IN	0.631	4.254
44	Sacramento, CA	3.651	Bergen-Passaic, NJ	0.478	2.715	Orlando, FL	0.598	4.035
45	Melbourne-Titusville-Palm Bay, FL	3.22	St. Louis, MO-IL	0.455	2.616	Columbus, OH	0.577	3.891
46	Bergen-Passaic, NJ	3.131	Monmouth-Ocean, NJ	0.384	2.209	Sacramento, CA	0.574	3.874
47	Cincinnati, OH-KY-IN	3.051	Miami, FL	0.372	2.141	Tucson, AZ	0.569	3.842
48	San Antonio, TX	3.005	Cincinnati, OH-KY-IN	0.321	1.847	Hartford, CT	0.561	3.785
49	Orlando, FL	2.834	Hartford, CT	0.316	1.817	Milwaukee-Waukesha, WI	0.522	3.522
50	Hartford, CT	2.801	Salt Lake City-Ogden, UT	0.303	1.745	Bergen-Passaic, NJ	0.52	3.51

The 2003 MI Tech-Pole Index tables show that the San Jose, Calif., metro ranks first on the index, thanks to Silicon Valley's dominance as a high-tech center. A GDP composite index score of 17.4 means that San Jose is practically twice as important as Washington, D.C., metro area, in terms of high-tech output. Out of the 315 metros ranked in 2003, Washington, D.C., finished second, with a GDP composite index score of 9.0. Similarly, an employment composite index score of 14.8 means that San Jose is nearly twice as important as Washington, D.C., in terms of employment, which again ranks second, with a score of 8.4. On the combined composite index, which has been rebased to the top-scoring metro equaling 100, the top five rankings are: San Jose; Washington, D.C.; Seattle; Los Angeles; and Boston. Finally, if a university wasn't located in one of the metros ranked, the score for the nearest metro (as measured by distance in miles) was included.

The input variable **Research Papers** captures the quality of research at a university, as measured by data on the number of publications and citations for all academic papers, and those specific to biotechnology. This data is compiled from the Center for Science and Technology Studies (CEST) and Thomson Scientific, which includes 683 universities around the world from 1998 to 2002. A university must have at least 50 publications over the five-year period in internationally recognized scientific journals (please see the "Innovation Pipeline" chapter for a more detailed description). Universities are ranked according to three indicators:

1. **Number of Publications:** A *size* indicator that reflects the absolute number of university publications.
2. **Activity:** A *concentration* indicator, measured by the number of publications in specific subfields as a percentage of a university's total publications, divided by the world's publications in that subfield, as a share of the world's total publications.
3. **Impact:** A *quality* indicator that reflects the number of citations of a university in a specific subfield as a percentage of the number of the university's total publications in that field, divided by the total citations worldwide in the specific field, as a share of the world's total publications in that field.

In our econometric model, each U.S. university is benchmarked to the top-ranked university that earns a score of 100. We test to see whether a greater number of biotech publications leads to increased Licensing Income and/or patents issued. We also investigate the correlation between the quality of research and running royalties.

Invention Disclosures includes the total number of disclosures, as counted by an OTT. Disclosures often lead to filed patents. A U.S. patent application filed may include provisional applications, new filings and reissues. Once approved by the USPTO, the filed patent becomes a U.S. patent issued.

The **Exclusive Share** of Licenses Executed represents the percentage of all a university's licenses that are exclusive to one company.

Part 2: Basic Features of the AUTM Data

In this section, we discuss some salient features of the AUTM data.

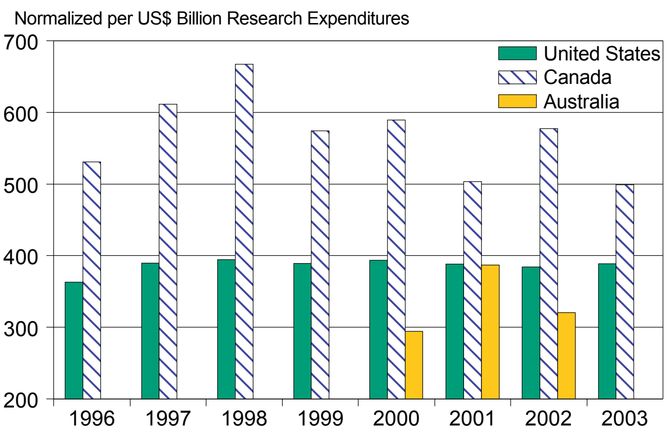
Basic Time Trends

We used AUTM data for the United States and Canada (1996–2003 inclusive), as well as AUTM-based reports for Australia (2000–2002), to create the following bar graphs. All variables are normalized per billion dollars of research expenditures. For each display of these trends, we summarize the most salient features of the changes over time.

Invention Disclosures

- The number of invention disclosures per billion dollars of research expenditures has stayed relatively stable in the United States from 1996 to 2003, hovering between 363 and 395.
- Canadian universities recorded a significantly higher number of invention disclosures, compared to U.S. universities — between 499 and a high of 667, which was recorded in 1998. Despite the higher invention disclosure rates, however, Canadian universities were awarded fewer patents per billion dollars of research expenditures, compared to the United States.
- Invention disclosure rates at Australian universities were closer to those at U.S. universities. In 2000, on average, there were 294 invention disclosures filed in Australian universities. In 2001 the number rose to 387 but fell to 320 in 2002.

Invention Disclosures
Yearly Average, 1996-2003

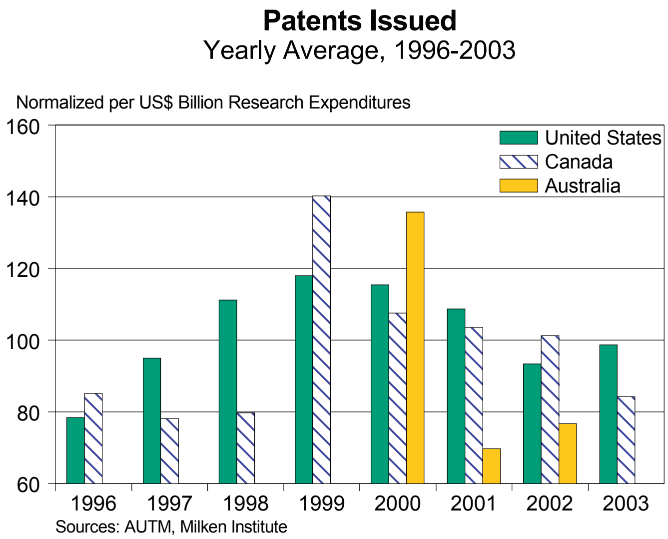


Sources: AUTM, Milken Institute

Patents Issued

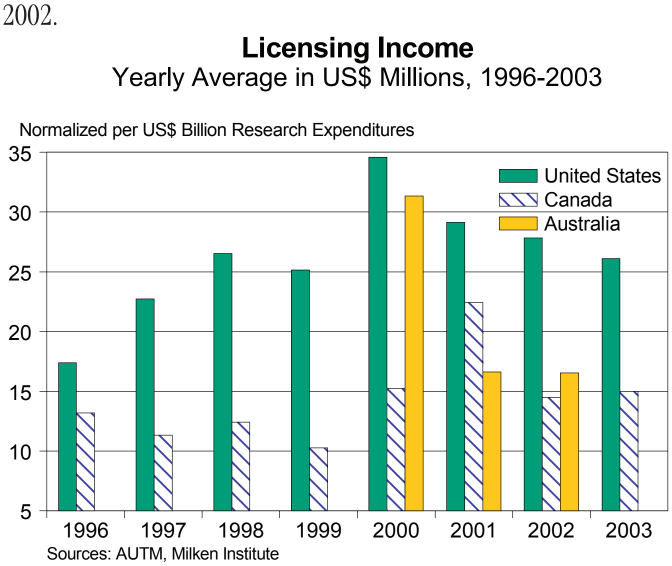
- In 1996, 78 patents (on average) per billion dollars of research expenditures were issued to U.S. universities, increasing during the high-tech boom. After reaching a high of 118 in 1999, the number declined slightly through 2002, picking up again in 2003, with an average of 99 patents issued.
- The average number of patents issued to Canadian universities was below that of U.S. universities for all but three years. In 1999, Canadian universities were issued 140 patents per billion dollars of research expenditures, compared to 118 in the United States. By 2003, both countries' universities issued fewer patents, with a U.S. average of 98, and 84 for Canada.

- No clear pattern can be established in the number of patents issued to Australian universities, based on the available data. Interesting, however, is that in 2000, the highest average number of patents issued per billion dollars of research expenditures occurred in Australia. At 135, the number was nearly twice as high as the number of patents issued in 2001 and 2002.



Licensing Income

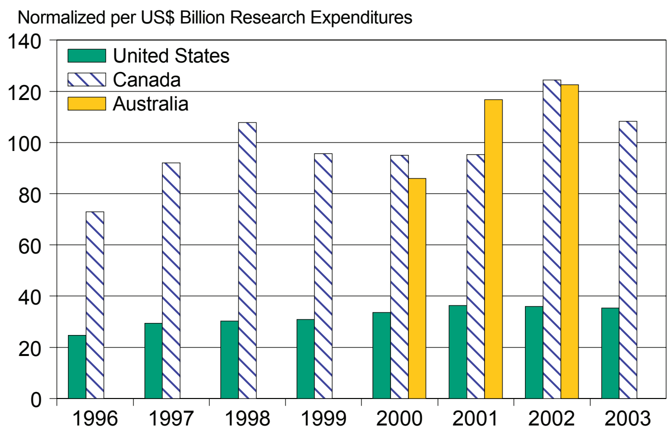
- Despite the lower number of FTEs per billion dollars of research expenditures, U.S. universities achieved better commercialization success than their Canadian counterparts. Average Licensing Income per billion dollars of research expenditures exceeded $17 million in 1996, peaking at $34.5 million in 2000. Licensing Income declined through the early 2000s, approaching the 1998 level in 2003.
- Licensing Income at Canadian universities showed little variation from 1996 to 2003, with the exception of 2001, when it peaked at $22 million per billion dollars of research expenditures.
- In 2000, average Licensing Income at Australian universities was slightly over $31 million, nearly twice as high as it was in 2001 and 2002.



FTEs (Licensing and Others)

- The average number of FTEs per billion dollars in research expenditures in U.S. universities grew steadily over the 1996–2003 period, increasing from 25 to 35.
- In Canadian universities, the average number of FTEs was nearly three times that of the United States.
- Little can be said about Australian universities and associated FTE staff; data prior to 2000 wasn't collected in a systematic fashion. However, analysis of the available data shows that on a normalized basis, the average number of FTEs at Australian universities increased steadily and has been much higher than at U.S. universities. In 2001, the average number of FTEs per billion dollars of research expenditures exceeded that at both U.S. and Canadian universities.

FTEs (Licensing and Other)
Yearly Average, 1996-2003

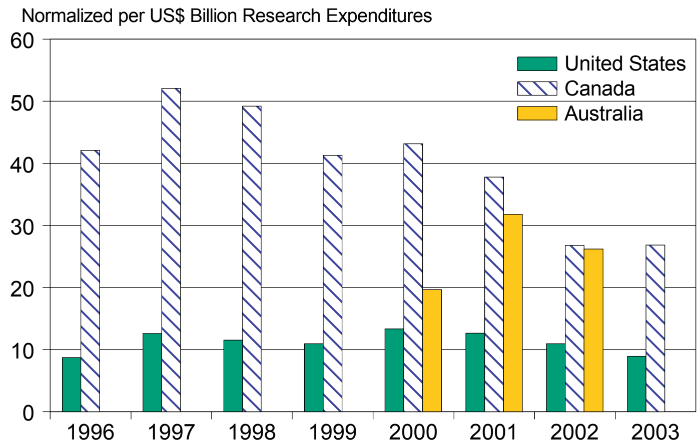


Sources: AUTM, Milken Institute

Startups

- In the years 1996–2003, the number of startups per billion dollars of Research Expenditures in U.S. universities ranged from eight in 1996 to a high of 13 in 2000. The number of startups in 2003 dropped to the 1996 level.
- Startup formation from Canadian universities was significantly higher than in U.S. universities. In 1996, the number of startups was nearly five times that of U.S. universities. The number peaked in 1997, reaching 52, then declined to 27 in 2003, the lowest level in the analyzed period. However, this doesn't capture the quality of Canadian startups, which is the survival rate and the number of startups that grow into large firms.
- In Australia, the number of startups normalized per billion dollars of research expenditures reached a high of 31 in 2001 and declined to 26 in 2002.

Startups
Yearly Average, 1996-2003



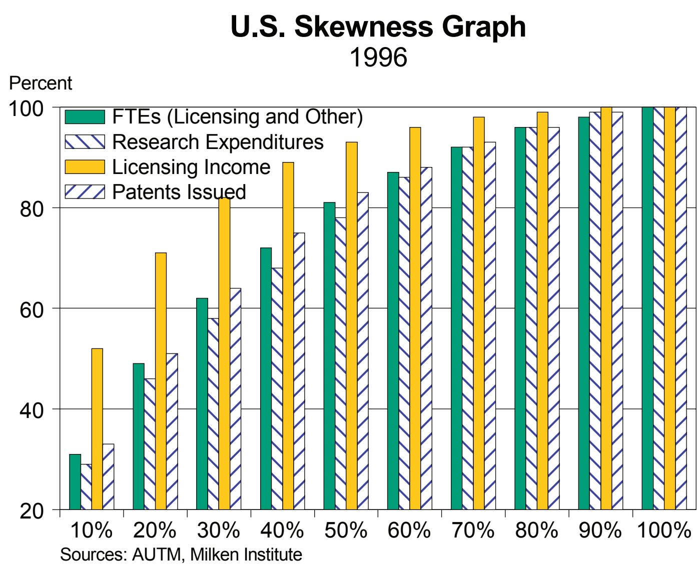
Sources: AUTM, Milken Institute

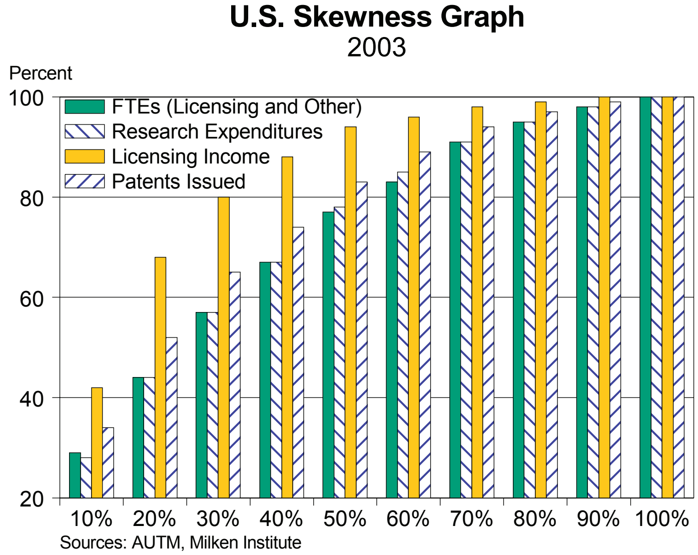
Concentrations of Innovation Activity Across U.S. Universities

It is well known that innovative returns are highly skewed, in the sense that only a fraction of patents and disclosures end up having any economic value. This section documents that it is also true that the *location* of innovation is highly skewed: a handful of top universities are responsible for the majority of commercialization. Unlike the skewness in returns across patents, this is not due to chance or *ex ante* uncertainty, as the same universities year after year generate the bulk of the aggregate commercialization activity.

In addition, skewness in outputs is often larger than in inputs across universities, suggesting that there may be some economies of scale or value in specialization in the commercialization process; productivity of the OTT may be higher in the places where the level of innovative activity is higher. Because our sample of 81 universities contains the top research universities, the skewness across all U.S. universities is even larger.

The following graphs display this remarkable concentration in activity among the top U.S. universities across several input and output measures. The share of the aggregate value (the summation across all 81 universities for which there is data from 1996 to 2003) variable (y-axis) attributable to the deciles of highest-ranking universities of that measure (x-axis) is shown. For example, the top 10 percent of universities are responsible for about 30 percent of all FTEs in the sample and about half the Licensing Income in 1996 and 2003.





As evidenced by these graphs, both inputs and outputs are highly skewed in the top U.S. universities in both years.

- In 1996, MIT employed 23 FTEs, the most among U.S. universities, followed by Stanford with 19.5 FTEs. More than 30 percent of the FTEs employed at U.S. universities were concentrated in the top 10 percent of our sample. The top 20 percent of U.S. universities employed 197 FTEs in 1996, accounting for half of all university FTEs.
- In 2003, the University of Washington employed 45 workers in its technology transfer office, ranking first among the 81 universities sampled. Again, the top 10 percent of U.S. universities (with respect to FTEs) accounted for 30 percent of all FTEs working in university OTTs. While the number of FTEs employed in the top 20 percent of U.S. universities rose from 197 to 387 in the period 1996–2003, the relative distribution among the universities remained virtually the same.
- In 1996 and 2003, Johns Hopkins University and MIT reported the highest research expenditures. The 18 top U.S. universities (or top 22 percent) accounted for nearly 60 percent of research expenditures in 1996 and 2003.
- In 1996, approximately 53 percent of all university-generated Licensing Income was attributable to the top 10 percent of all U.S. universities in our sample. With $51 million, Stanford received the largest share of Licensing Income in 1996.
- In 2003, Licensing Income generated at Stanford remained the highest in our sample, despite its decline to $45 million.
- Licensing Income at the top 10 percent of U.S. universities increased from $147 million in 1996 to $265 million in 2003. However, in 2003, the top 10 percent of U.S. universities accounted for 42 percent of the university-generated total Licensing Income, down from 52 percent in 1996.
- The distribution of patents issued did not change significantly from 1996 to 2003. In 1996, there were 427 patents issued to the top 10 percent of U.S. universities — 113 of them to MIT. In 2003, Caltech received 169 patents, accounting for 7 percent of total U.S. university patents issued that year.

Part 3: Econometric Model: Determinants of Performance

For the econometric evaluation of university tech transfer, we used statistics for 81 American universities. A majority of the data was obtained from the annual AUTM surveys 1996 to 2003, while we created some exogenous variables, using alternative data sources. For each of the Output Measures — Licensing Income, licensing executed, running royalties and startup formation — we estimated four different types of specifications:

- Model 1 and Model 2 represent the specifications for the data set including all 81 universities (referred to as the "general" data set).
- Model 3 and Model 4 depict a subset of the 81 universities: 21 biotech-intensive schools, whose inclusion is based on ipIQ patent data.

In Models 1 and 3, we used variables derived by the Milken Institute — tech poles and research papers. Models 2 and 4 used fixed effects only. Fixed-effect models are used to lump all other non-specified variables together, allowing estimates of separately introduced variables to be measured. This setup allows for clear comparison between Milken variables and the fixed effects. The variables allow us to objectively quantify some of the subtle differences among universities and attribute them to specific characteristics.

Licensing Income

Licensing Income illustrates returns as a dollar value. Licensing Income includes running royalties (representing the continuing stream of income) and one-time payments, such as up-front payments, milestone payments, cashed-in equity etc., which a university receives for inventions. Because this variable includes one-time only payments, it tends to be a somewhat cyclical stream. During the dotcom and tech boom in the late 1990s and 2000, the cashed-in equity was very large at several universities.

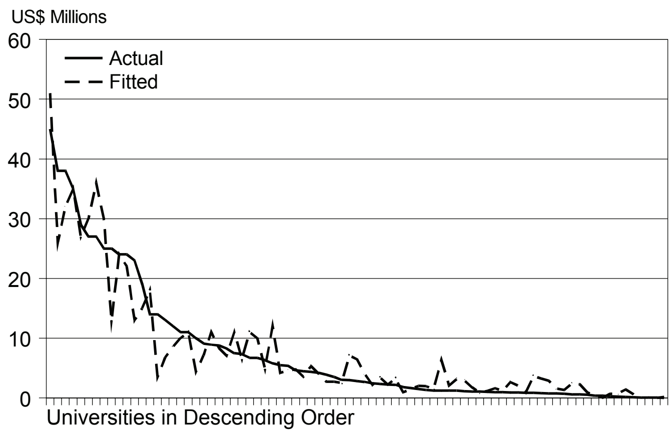
Dependent Variable: Licensing Income
Sample Period 1996 to 2003

	Model 1 **General**	Model 2 **General Fixed Effects**	Model 3 **Biotech**	Model 4 **Biotech Fixed Effects**
Labor Cost	6.04*** (1.78)	10.74*** (2.324)		8.339** (3.840)
Age of OTT	228,148.7*** (64,652.53)	205,228.1 (139,145.7)	418,772.8*** (47,727.25)	528,683.3 (347,971.3)
MI Tech-Pole	210,312.7*** (53,346.99)		360,748*** (35,546.81)	
Research Papers	171,195.8** (83,420.93)		170,151.9** (67,573.92)	
AR(1)	0.8075*** (0.026)		0.5265*** (0.070)	
Sample Size	567	648	147	168
R-Squared	0.917	0.760665	0.924	0.797912
Akaike Info Criterion	32.9354	34.11435	33.38046	34.43011
Schwartz Criterion	33.07319	34.6874	33.62458	34.8578
F-Stat	358.7621	21.8989	149.2506	26.02312
Durbin-Watson Stat	1.78569	1.63068	2.215553	1.721447

*** Statistically significant at the 1 percent level or better
** Statistically significant at the 5 percent level or better
Note: General Sample Observations=648, Biotech Sample Observations=168

The accompanying graph shows the actual versus fitted values from our Licensing Income Model 1, general sample, statistical analysis for 2003. Keep in mind that we performed these tests on longitudinal data from 1996 to 2003. The 2003 cross section gives an illustration of how accurately the model explains variation in Licensing Income between U.S. universities that can be attributed to specific factors.

University Licensing Income
Actual vs. Fitted, 2003



Sources: AUTM, Milken Institute

The following independent variables were tested in explaining variation in Licensing Income:

Variables:

- **Labor Cost** is significant for all but Model 3 — (biotech-intensive, non-fixed effects), which may be because the OTT office generally played a less significant role at biotech-intensive universities — perhaps reflecting industry's keen interest during the 1996–2003 period in biotech inventions. For every $1 invested in OTT staff, the university receives a little more than $6 in Licensing Income. Using salaries obtained from the national Bureau of Labor Statistics for 2003, one additional licensing FTE added $385,231 of Licensing Income; and each administrative FTE generated $170,690 of Licensing Income. Model 2 (general fixed effects) behaves in a similar way: for each $1 invested in OTT staff, Licensing Income increased by nearly $11 at U.S. universities generally, and based upon Model 4, by over $8 at those that are biotech-intensive.

- **Age of the OTT** is highly significant in non-fixed-effects Models 1 and 3, but of just borderline significance in Models 2 and 4. We can assume that the fixed effects successfully account for different levels of institutional experience at the university OTTs, making the Age variable obsolete. An OTT's institutional experience has a more substantial effect on the biotech-intensive universities, Models 3 and 4; each year brings an additional $418,000 and $528,000, respectively, in Licensing Income, compared to $228,000 for U.S. universities generally. Model 4 (fixed effects, biotech-intensive university sample) shows a lack of significance of the Age of the office, but an impressive significance of the Labor Cost variable. This is possibly explained by the Age variable, which may be picking up the degree of entrepreneurship of biotech faculty. Biotech commercialization success may lead to the establishment of a university OTT — the "star scientist" phenomenon. In addition, the more institutional experience an OTT has in matchmaking, the better its networking capabilities may become.

- **Fixed Effects** are used to pick up the seemingly immeasurable differences among universities — qualities including but not limited to campus culture, researcher quality and reputation. While such attributes are hard to quantify, Fixed Effects can be used to account for the fine distinction between universities without using a "culture variable" (the definition of which may be highly subjective). The Fixed Effects create individual intercept terms for each university, which are all significant in the general data set, Model 2. All but one of the intercept terms are significant in the biotech-intensive sample, Model 4.[50] Another benefit to using Fixed Effects is the ability to interpret each university individually.

- The **Milken Institute Tech-Pole Index** measures the effect that university location has on the ability to produce Licensing Income. Knowledge — university intellectual property, in this case — is absorbed more readily in regions with an existing technology industry base. A high concentration, or clustering, of technology firms in a region assists in creating an environment of linkages and opportunities for university commercialization efforts. The index allows us to objectively measure some of the qualities that are otherwise difficult to capture. Because of this, it is unwise to include the Tech-Pole numbers in a fixed-effects model, where we are controlling for aspects other than the effect of the OTT office. It can be assumed that a university in a location with a higher Tech-Pole Index will have higher Licensing Income than a university in a location with a lower Tech-Pole Index. Being situated among high-tech industries would increase demand for university inventions (absorptive capacity), especially from biotech-intensive universities. This is exactly what the models including the variable show. Both coefficients are positive (approximately $210,000 and $360,000 for every additional point of the Tech-Pole Index), and the coefficient for the biotech-intensive university sample is more than $150,000 larger than the general sample coefficient.

- The independent variable **Research Papers** was created using the CEST and Thomson Scientific data set, and is a representation of the size and quality of research at a university, based on the Number of Publications and the Impact of those publications as represented by Citations. A general score was used for the overall sample, Models 1 and 2, and a biotech-specific score was used for the biotech-intensive sample, Models 3 and 4. Both are significant and contribute approximately $170,000 of Licensing Income for every 1-point increase in the Research Papers score.

Excluded Variables

In the process of finding an accurate econometric model, we considered numerous independent variables for inclusion. The following list includes some that had a theoretical justification for inclusion but which, after testing, failed to enhance the model or explained movement already captured by another variable.

Time Trend
We included a Time Trend variable in several specifications in an effort to capture a possible upward secular trend because the dependent variables — e.g., Licensing Income, number of Startups — were mainly increasing over time. We excluded the Time Trend because it experienced severe redundancy with the OTT Age variable. We chose to keep the latter, theorizing that the upward progression of the output variables could be a combination of time and the maturation of the technology transfer office. The OTT Age variable explained more of the variation over time between universities.

The Private University Dummy

We also tried a dummy variable equal to 1 if the university was private and 0 if the university was public. It is a dummy in the sense that it isn't a continuous variable (either 1 or 0). We hypothesized initially that private universities would have a culture that emphasized the commercialization of intellectually property to a greater degree than public universities. On one hand, the private university category includes Harvard, Stanford and MIT. On the other hand, the public category boasts the California university system, Florida State and University of Wisconsin, all successful in tech transfer activities. When included, this dummy did not add enough explanatory value to warrant retention.

The Medical School Dummy

The Medical School Dummy variable was not statistically significant. It is possible that a continuous measure, such as the size of the medical school faculty, might have had a separate discernable impact if included in the specification. However, we believe that our MI Tech-Pole variable explained some of the effects of a medical school, and the fixed effects account for the existence of a medical school in our fixed-effects models.

Venture Capital Statistics (VC Deals, VC Companies, VC Investment)

Here we were attempting to adjust for the availability of venture capital on a national basis. One would hypothesize that in an environment of higher venture capital funding, more commercialization activity would occur, especially in the Startup category. Unfortunately, our venture capital data was not region-specific and failed to add any explanatory value to our equation.

Research Expenditures

Research Expenditures comprise expenditures from federal or industrial sources. Industrial sources may include private corporations, which often monitor their funded amounts. In 2003, 66 percent of all Research Expenditures came from federal sources, compared to only 7 percent from industry sources. Although total Research Expenditures increased remarkably since 1991, the mix of funding remained fairly stable. The Research Papers variable did a better job of capturing the quantity and quality of research. Research Expenditures is a very early-stage measure of the quantity, but not the quality, of research.

Industry Share of Total Research Expenditures

Industry Share represents the share of university research expenditures that comes from industry sources. In theory, as the Industry Share increases, we would expect that university tech transfer output would increase, since the companies funding the research expect commercially viable results. An unfortunate side effect of this measurement is that schools with very little research funding, but one or two corporate sponsors, may receive a high Industry Share but lack the research infrastructure to achieve substantial technology transfer success.

Features of the models' descriptive statistics worth noting include:

- **R-Squared** represents the overall fit of the model, in terms of the independent variables' ability to explain movement in the dependent variables, but does not penalize for lost degrees of freedom (observations minus independent variables). The fit is between 0 and 1; and the closer to 1, the better the explanatory power. The four models have high R-Squared values (all above 0.75), with Model 3 (biotech-intensive sample) scoring highest at 0.924. Model 4, using fixed effects, is not quite as significant, at 0.798. The same relationship exists with the general sample. The R-squared in Model 1 is higher (at 0.91) than the fixed effects model (at 0.76).

- **Akaike Info Criterion (AIC) and Schwartz Criterion (SC)** measure goodness of fit, like R-Squared. But unlike R-Squared, they penalize for the addition of variables into the equation, so that the lower the value, the better the fit. Among the four specifications, Model 1 has the lowest AIC and SC numbers, followed by Models 2 and 3 (whose descriptive statistics are very close); Model 4 has the highest statistics. The statistics do not vary by much, implying that the models are similar in goodness of fit.
- **F-Statistic** measures the ability of the variables as a group to explain Licensing Income. Like R-Squared, a higher F-Statistic implies a better group of independent variables. The models using the Milken Institute variables (MI Tech-Pole Index and Research Papers) fare better than the fixed-effects estimations when considering this statistic. All are high enough to accept the group of variables as significant.
- **Durbin-Watson (DW) Statistic** is an indicator of the presence of serial correlation (the correlation between error terms or unexplained variation). If serial correlation is present in a model, it can result in incorrect inferences to be drawn. A Durbin-Watson Statistic close to 2 is desirable. When the statistic varies significantly from 2, it can be assumed that the model suffers from serial correlation. Models 1 and 3 both have an autoregressive term to correct for serial correlation (a method of correcting for correlation between error terms); as a result, the four DW Statistics do not imply the presence of serial correlation.

Running Royalties

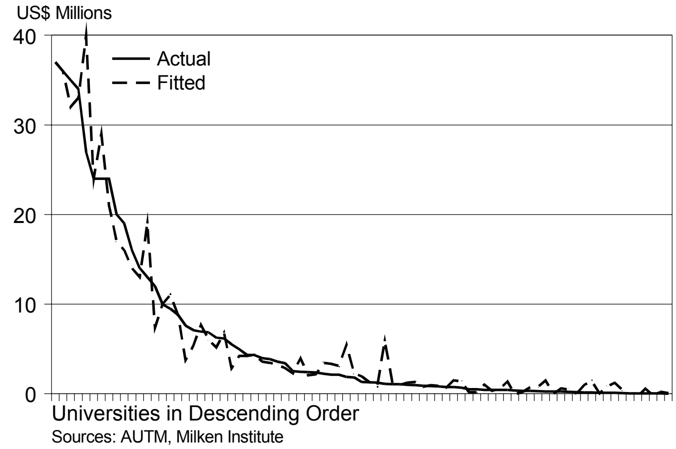
Like Licensing Income, the Running Royalties variable illustrates returns as a dollar value and represents the continuing stream of income (excluding one-time payments, such as up-front payments, milestone payments, cashed-in equity etc.) that a university receives for inventions. Because this variable excludes one-time-only payments, it represents a less cyclical stream of income that is slightly easier to estimate than the highly variable Licensing Income. Running Royalties is a subset of Licensing Income, which explains why the coefficients estimated here are noticeably smaller. The series may be easier to estimate, but the short time period of estimation can still be seen as a disadvantage.

Dependent Variable: Running Royalties
Sample Period 1996 to 2003

	Model 1 **General**	Model 2 **General Fixed Effects**	Model 3 **Biotech**	Model 4 **Biotech Fixed Effects**
Labor Cost	5.8045*** (1.12487)	10.62071*** (1.480426)	3.11961* (1.701202)	8.960955*** (2.294613)
Age of OTT	212,048.3*** (64,367.03)	97,083.76 (88,642.45)	428,660.1*** (100,599.1)	144,345.3 (207,911.4)
MI Tech-Pole	181,265.7*** (50009.46)		198,007.9*** (59,316.99)	
Research Papers	15,064.55 (71224.51)		149,973.8 (102,960.4)	
AR(1)	1.36*** (0.048)		0.842144*** (0.040949)	
AR(2)	-0.492*** (0.04905)			
Sample Size	486.00	648.00	147.00	168.00
R-Squared	0.95	0.84	0.96	0.88
Akaike Info Criterion	31.94	33.21	32.10	33.40
Schwartz Criterion	32.12	33.79	32.39	33.83
F-Stat	496.45	35.24	276.24	48.36
Durbin-Watson Stat	1.90	0.77	1.99	0.83

*** Statistically significant at the 1 percent level or better
* Statistically significant at the 10 percent level or better
Note: General Sample Observations=648, Biotech Sample Observations=168

This accompanying graph shows the actual versus fitted values from our Running Royalties Model 1, general sample, statistical analysis for 2003. Once again, we performed these tests on longitudinal data from 1996 to 2003. The 2003 cross section gives an illustration of the model's accuracy in explaining variation in running royalties between U.S. universities that can be attributed to specific factors.



- **Labor Cost** is significant in all models. Consistent with the theory that the incremental benefit of FTEs in biotech-intensive universities is relatively smaller than in all universities, the biotech-intensive Models 3 and 4 do have smaller values than their general sample counterparts. OTT employees prove to be an integral part of the licensing of university inventions. In every model, each $1 investment in OTT staff returns between $3 and $11 of Running Royalty income. According to Model 1 (and wage estimates from the Bureau of Labor Statistics), in 2003, one additional licensing FTE in the OTT results in an additional $370,562; and an administrative FTE generated $146,387 of Running Royalty income. The employees of the OTT have the smallest effect in Model 3, the biotech-intensive, non-fixed-effects model, with just over $3 for every $1 invested.
- **Age of the OTT** is significant in the non-fixed-effects Models 1 and 3 only. This may be attributable to the nature of the fixed effects: age of the OTT office (institutional experience) is perhaps a quality that the fixed effects account for, making the inclusion of the Age variable insignificant. Institutional experience adds more to Running Royalties income at a biotech-intensive university ($428,000), nearly twice as much as at a university in the general sample (about $212,000). This behavior mirrors the Licensing Income specifications.
- **Fixed Effects** in the Running Royalties specifications are statistically significant but do not generate as desirable an estimation as the non-fixed-effect models.
- The **Milken Institute Tech-Pole Index** proves to be statistically significant in both Model 1 and Model 3. Like Licensing Income, the MI Tech-Pole Index matters more for the biotech-intensive universities; however, this discrepancy is smaller, as are the numbers. A 1-point increase on the MI Tech-Pole Index caused more than $181,000 Running Royalty income at a general university and close to $200,000 of income at a biotech-intensive university.
- The **Research Papers** variable, while not statistically significant in the non-fixed-effects models, is left in our

equation because its inclusion is theoretically sound; it should be removed only when skewing the estimation of the remaining variables. A 1-point increase in the Research Papers score increases a general sample university's income from Running Royalties by just over $15,000 and a biotech-intensive university's Running Royalties by nearly $200,000.

Features of the descriptive statistics worth noting include:

- **R-Squared** is very high in both Models 1 and 3 (0.95 and 0.96) — higher than their respective Licensing Income models. Fixed-effects Models 2 and 4 (0.84 and 0.88) are higher as well.
- **Akaike Info Criterion and Schwartz Criterion** give us an idea of the "goodness of fit" of our variables while punishing for loss of degrees of freedom. Among the Running Royalties specifications, Model 1 has the lowest AIC and SC numbers, followed closely by Model 3. Once again, the lower the numbers, the better the explanatory power.
- **F-Statistic** for each equation is high, and we can conclude that the group of independent variables used to describe Running Royalties is significant for each specification. Each F-Statistic is higher than the corresponding equation for Licensing Income.
- **Durbin-Watson Statistic** for Models 1 and 3 does not allude to the presence of serial correlation (error terms are correlated); both have an autoregressive term to correct for the problem. Models 2 and 4, on the other hand, suggest that they might suffer from serial correlation.

Licenses Executed

The estimations for Licenses Executed give us a non-monetary perspective on output. We can estimate the number of licenses that will be produced given a specific set of inputs. The Labor Cost, Age of OTT, MI Tech-Pole and Research Papers coefficients estimated are very small, which makes interpretation slightly less straightforward than the two previous estimations.

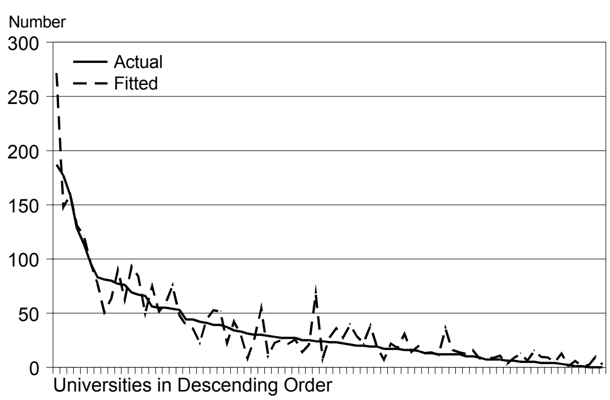
Dependent Variable: Licenses Executed
Sample Period 1996 to 2003

	Model 1 **General**	Model 2 **General Fixed Effects**	Model 3 **Biotech**	Model 4 **Biotech Fixed Effects**
Labor Cost	0.0000279*** (0.00000635)	0.000036*** (0.00000545)	0.0000423*** (0.0000117)	0.0000494*** (0.0000101)
Age of OTT	0.71579*** (0.194502)	0.421161 (0.326513)	0.888325** (0.286691)	0.191526 (0.914)
MI Tech-Pole	0.304704** (0.147392)		0.325645* (0.184278)	
Research Papers	0.980751*** (0.234019)		0.708889** (0.325472)	
AR(1)	0.728826*** (0.031729)		0.565804*** (0.072745)	
Sample Size	567	648	147	168
R-Squared	0.878926	0.871393	0.774425	0.827217
Akaike Info Criterion	8.002172	8.189229	8.840714	8.731185
Schwartz Criterion	8.147616	8.762273	8.962773	9.15887
F-Stat	221.0081	46.68573	96.81404	31.55469
Durbin-Watson Stat	2.111594	1.563024	2.026415	1.707619

*** Statistically significant at the 1 percent level or better
** Statistically significant at the 5 percent level or better
* Statistically significant at the 10 percent level or better
Note: General Sample Observations=648, Biotech Sample Observations=168

This accompanying graph shows the actual versus fitted values from our Licenses Executed Model 1, general sample, statistical analysis for 2003. These tests were performed on longitudinal data from 1996 to 2003. The 2003 cross section gives an illustration of the model's accuracy in explaining variation in Licenses Executed between U.S. universities that can be attributed to specific factors.

University Licenses Executed
Actual vs. Fitted, 2003



Sources: AUTM, Milken Institute

- **Labor Cost** is significant in all models. For every $100,000 invested, OTT staff will return 2.79, 3.6, 4.23 and 4.94 licensing deals, respectfully. In 2003, one licensing FTE was responsible for executing 1.78 licenses at a general university, while a non-licensing employee can take credit for executing 0.788 license. It is interesting to note that both biotech-intensive Models 3 and 4 estimate more Licenses Executed. Whether biotech-intensive universities have more productive inventors or more productive tech transfer office staff is material for conjecture. The answer may be a combination: more productive inventors force the OTT to be more productive.
- **Age of the OTT** is highly significant in Models 1 and 3, but not significant in Models 2 and 4, with fixed effects. This is consistent with the tendency that the fixed effects are successfully accounting for individual university experience. The Age of the OTT has a greater impact at biotech-intensive universities. It seems that Age has less of an impact on license productivity than Labor Cost, with a university in the general sample gaining 7.2 licenses for an additional 10 years of existence and a biotech-intensive university earning 8.9 licenses. This suggests that professional OTT staff can have a significant impact on the number of Licenses Executed, even in an office with limited years of operation.
- The **Milken Institute Tech-Pole Index** is significant. It estimates that a 10-point increase of the MI Tech-Pole score causes an additional three licenses to be executed for both the general and biotech-intensive university models. A possible interpretation is that biotech-intensive universities might not license a higher quantity of inventions based on their location, but rather higher-quality inventions based on location.
- **Research Papers** are estimated to contribute 9.8 executed licenses for an additional 10 points to a university's Research Papers score. The result is slightly lower at a biotech-intensive university (Model 3), with an additional 7.1 License Executions for an extra 10 points to the Research Papers score.

Features of the descriptive statistics worth noting include:

- **R-Squared** values are good, ranging from approximately 0.77 (Model 3) to 0.87 (Models 1 and 2). Unlike any estimation thus far, the biotech-intensive, fixed-effects equation (Model 4) has a higher R-Squared than the biotech-specific non-fixed-effects equation (Model 3).
- While the R-Squared value is better in Model 4 than in Model 3, the **Akaike Info Criterion and Schwartz Criterion** of both are very close, suggesting that the two have a very similar "goodness of fit." Each equation poses a value for AIC and SC, between 8.0 and 9.2.
- **F-Statistics** are more erratic. However, all imply that the variables used in each equation are significant as a group.
- **Durbin-Watson Statistic** of Model 2 warns of the danger of serial correlation.

Startups

Startups is a dependent variable consisting of companies that originate as a result of university intellectual property and are registered with the OTT. This output measure considers not only the invention capability of a university but also the entrepreneurial zeal of the faculty. Earlier we mentioned that Invention Disclosures and exclusive share of Licenses Executed are treated as Output Measures; however, that is not the case here. Invention Disclosures and the exclusiveness of licensing have a significant and positive impact on the formation of Startups and therefore must be included in the model.

The majority of "royalty-rich" OTTs receive revenues from established firms, viewing startup formation as a secondary goal.

The higher the proportion of Exclusive Licenses granted, the higher the probability of Startup formation. Put another way, if the founders of a startup based upon university-derived intellectual property do not have exclusive rights to it, they face the risk that a competitor will render their firm's investment to be worthless. Additionally, the startup would have greater difficulty in securing financing from VC and angel investors without exclusive rights to the IP.

The research of Chukumba and Jensen,[51] while not inconsistent with our econometric model findings, warrants mention here. They find that OTTs typically focus their efforts on licensing inventions to established firms. Indeed, those universities that are able to generate many startups may not be the same universities that also have large royalty incomes. This is consistent with the observation that the majority of "royalty-rich" OTTs receive revenues from established firms, viewing startup formation as a secondary goal. Exclusive licensing mitigates the risk of other companies using the same patent and creates an unleveled playing field.

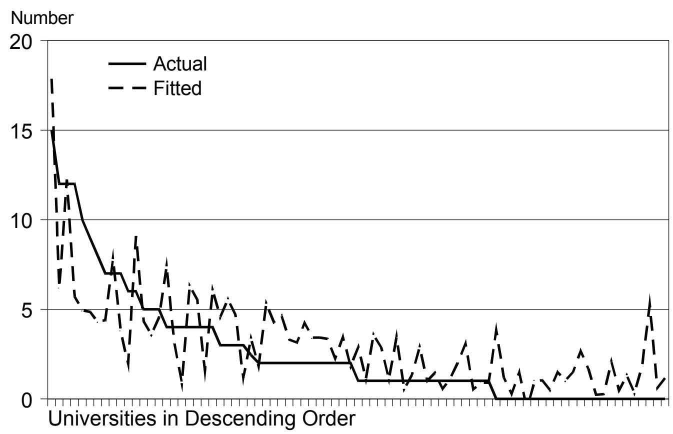
Dependent Variable: Startups
Sample Period 1996 to 2003

	Model 1 **General**	Model 2 **General Fixed Effects**	Model 3 **Biotech**	Model 4 **Biotech Fixed Effects**
Labor Cost	0.00000189** (8.91E-07)	-0.000000187 (8.85E-07)		-0.000000331 (1.65E-06)
Age of OTT	0.039542* (0.020973)	0.148834*** (0.0530)	0.045225 (0.039595)	0.300088** (0.149662)
MI Tech-Pole	0.050811*** (0.017679)		0.045312* (0.02660)	
Research Papers	0.055429* (0.028609)			
Exclusive Share	1.062568*** (0.382035)		2.3267* (1.306831)	
Invention Disclosures			0.021064*** (0.004891)	
AR(1)	0.646159*** (0.036237)		0.585155*** (0.075177)	
Sample Size	567	648	147	168
R-Squared	0.70942	0.667937	0.776954	0.736886
Akaike Info Criterion	4.28356	4.552306	4.879343	5.111606
Schwartz Criterion	4.406039	5.125351	5.103117	5.539292
F-Stat	89.68046	13.85959	47.37407	18.45868
Durbin-Watson Stat	2.169109	1.752269	1.991056	1.706666

*** Statistically significant at the 1 percent level or better
** Statistically significant at the 5 percent level or better
* Statistically significant at the 10 percent level or better
Note: General Sample Observations=648, Biotech Sample Observations=168

This accompanying graph shows the actual versus fitted values from our Startups Model 1, general sample, statistical analysis for 2003. Tests were performed on longitudinal data from 1996 to 2003. The 2003 cross section gives an illustration of the model's accuracy in explaining variation in startups between U.S. universities that can be attributed to specific factors.

University Startups
Actual vs. Fitted, 2003



Sources: AUTM, Milken Institute

- **Labor Cost** proves not to be as significant when estimating Startups as for the previous three output variables — Licensing Income, Running Royalties and Licenses Executed. More than the productivity and effort of the employees in the tech transfer office, the number of university startup firms may depend on how entrepreneurial the inventor or licensee is. Another consideration is the level of sophistication and reputation of the OTT staff and university. The data show that the OTT has very little effect, so little that it would take over a half-million-dollar investment in OTT staff to produce one Startup (according to Model 1). The other two estimations — fixed-effects Models 2 and 4 — that include the variable actually estimate a negative, albeit insignificant, impact on the number of Startups at a general and biotech-specific university.
- **Age of the OTT** has a greater impact at biotech-intensive universities, Models 3 and 4, with the significant estimate at three Startups for every additional 10 years of existence (Model 4). According to Model 1, a university from the general sample would take 75 years to obtain the same results (about one Startup for every additional 25 years of existence), while the general sample, fixed-effects Model 2 estimates a highly significant coefficient of 1.5 Startups for every 10 years of OTT existence. The institutional experience of the OTT may aide in the creation of startups by forming strong relationships with businesspeople in the private sector, and these relationships may eventually turn into partnerships for startup companies.
- **Fixed Effects** for the general sample, Model 1, are almost all significant; about half are significant in the biotech sample, Model 3. The Labor Cost in both fixed-effects Models 2 and 4 were insignificant, lending credit to the theory that startups are highly dependent upon entrepreneurial spirit (a relatively hard quality to objectively quantify, but a quality picked up by the fixed-effects models).
- **Milken Institute Tech-Pole Index** should, in theory, have a significant impact on the amount of Startups because of the location of the university. This conjecture holds with both coefficients notably significant. In both general and biotech-intensive Models 1 and 3, an additional approximate 20 points to the MI Tech-Pole Index score will result in one new Startup.

- **Research Papers** is only used in Model 1, with about one extra Startup created for every additional 20 points added to the score.
- **Exclusive Share** represents the share of all executed licenses that are exclusive to only one company. We can assume that the higher this share is, the more likely it will be that a Startup will be formed. It can also be interpreted that a startup would rarely sprout from an invention that has been licensed to more than one company. The results confirm that a 1 percent increase in Exclusive Share resulted in the formation of a little over one Startup.
- **Invention Disclosures** is used in Model 3 and is highly significant. Invention Disclosure was found to explain more of the variation in biotech startups than Research Papers. More Invention Disclosures hint at commercially viable inventions better than Research Papers, which can be turned into startup companies. This seems to be the case, with one Startup formed for approximately every 50 Invention Disclosures.

Features of the descriptive statistics:

- **R-Squared** values range from 0.67 to 0.78, acceptable values for the statistic. The biotech-intensive Models 3 and 4 fare better than general sample Models 1 and 2.
- **Akaike Info Criterion and Schwartz Criterion** are all very close, although it is important to note that the equation with the highest R-Squared (Model 3) does not have the most desirable AIC and SC values, which means Model 1 probably has the best overall fit.
- **F-Statistics** show that as groups, the variables included in each model are significant. While Model 2's F-stat is lower, its accompanying probability (the probability that the coefficients jointly are not different from zero) is zero, meaning that Model 2 is highly significant in explaining variation in Startups among universities.
- **Durbin-Watson Statistics** are all very close to 2. Both Models 1 and 3 have autoregressive terms included to correct for serial correlation.

Part 4: OTT Rate-of-Return Simulations

We have already estimated the return on investment to the employees of the technology transfer office with our econometric models. To further quantify the effect of the OTT and its staff as a percentage of total Licensing Income, Licenses Executed and Startup companies formed, we have completed two alternate simulations.

These simulations allow us to use our econometric equations to uncover the effects of additional investment into the OTT, as well as the effect of the office as a whole (capturing the networking advantages of institutional experience).We do so by replacing certain input-variable series (specifically, Labor Cost and the Age of the OTT) with alternate historical series meant to estimate "what would have been," had the universities behaved differently. Using the simulations, we can better understand the incremental system-wide impact the tech transfer office has on licensing activity.

Our first simulation assumes that after 1996 universities did not increase their investment in the OTT. For example, we calculated that Caltech invested approximately $152,000 in wages and salaries into its technology transfer office in 1996 and steadily increased this investment to nearly $478,000 (adjusted for inflation) in 2003, an increase of 215 percent in seven years. In total, we estimate that the 81 universities in the AUTM data set increased OTT staff funding by $25.6 million: from $18.9 million in 1996 to $44.5 million in 2003 (again, adjusted for inflation). OTT investment experienced a 135 percent increase in the seven years following 1996.

Licensing and commercialization would occur without an OTT, just not as efficiently.

While our original estimation includes the actual increase of investment into the office, our first simulation assumes no change in investment over the subsequent seven years. Essentially, the first simulation estimates Caltech's and other universities' output variables, using the 1996 Labor Cost levels for all seven years of the data set. This simulates the return (in the form of Licensing Income, Licenses Executed and Startup companies formed) that the university would have received, had it not increased investment in the OTT after1996. To maintain the effect of networking, the Age variable remains unchanged in the first simulation.

The second simulation assumes that the university never created an office for technology transfer; thus, the Labor Cost and Age of the OTT variables are equal to zero for each of the seven years in our data set. The resulting estimations for Licensing Income, Licenses Executed and Startup companies formed are without an OTT and therefore illustrate the university's licensing capability without the help of an office specializing in the commercialization of university research. Licensing and commercialization would occur without an OTT, just not as efficiently. This assumes that intellectual property would be disclosed to the universities by research staff and that firm agreements would be in place regarding the distribution of any Licensing Income. Academic entrepreneurs find a way to move their IP into the private sector due to their passion for its potential impact and remuneration opportunities.

The following table uses the 81 universities in our 1996–2003 AUTM data set to quantify the effects of the OTT as a percentage of total university licensing activity. The percentages represent the average Licensing Income, Licenses Executed and Startup companies formed that can be attributed to the additional investment into the office (Simulation I) and those that can be attributed to the office as a whole (Simulation II). Conversely, these numbers can be interpreted as the amount that university licensing activity would decrease relative to the actual historical experience if investment into the office had stopped in 1996 (Simulation I) or if the office had never existed (Simulation II).

Average OTT Impact
Output Contributable to the Tech Transfer Office, 1997-2003

	Licensing Income	Licenses Executed	Startup Companies
Simulation I No Additional Investment	4.9%	5.5%	5.2%
Simulation II No OTT Created	20.9%	23.2%	20.4%

Simulation I: What If University Investment Remained at 1996 Levels?

Simulation I
Summary Table,* 1997-2003 Average

University	Actual Licensing Income	Simulated Licensing Income	Actual Licenses Executed	Simulated Licenses Executed	Actual Startups	Simulated Startups
	US$ Millions					
University of California System	99.7	95.8	224	207	20	18.8
Massachusetts Institute of Technology	33.4	32.5	103	98	22	21.1
University of Washington	26.1	24.7	91	85	7	6.4
Stanford University	50.6	50.0	133	130	12	11.5
University of Wisconsin	25.5	23.7	116	106	3	2.7
Johns Hopkins University	8.8	7.7	101	94	6	5.1
University of Michigan	5.9	5.2	55	51	7	6.2
State University of New York	14.6	13.6	39	35	5	4.5
Harvard University	19.3	19.0	68	67	3	2.8
University of Minnesota	17.8	16.7	84	79	7	6.9
University of Pennsylvania	11.5	10.8	67	63	6	6.0
Duke University	3.3	3.1	45	42	2	2.0
University of Florida	27.4	26.5	31	26	4	3.8
University of Chicago	3.1	2.9	17	17	2	1.5
Iowa State University	4.9	4.6	198	197	3	3.2
Rutgers University	5.4	4.9	37	34	4	3.5
Texas A&M University System	6.1	5.8	57	55	3	2.6
Baylor College of Medicine	9.2	8.6	40	36	2	2.0
Washington University	8.2	7.7	67	64	2	1.6
University of Texas Southwestern Medical Center	7.9	7.2	25	22	1	1.1
U.S. Total	639.14	607.84	2,734	2,584	247	234

*Top 20 Universities based on Labor Cost Value

The first simulation estimates the answer to this question. According to this scenario, if investment had stayed at 1996 levels, the average university would generate 4.9 percent less Licensing Income each year. The average one-year Licensing Income of the universities in our data set is $7.89 million, providing an estimate that $387,000 in yearly Licensing Income can be primarily attributed to the post–1996 investment into the tech transfer office. The 81 universities earn a collective average of $639.1 million in Licensing Income from 1997 to 2003. Of this, additional human capital investments in university tech transfer offices are responsible for $31.3 million.

For specific examples, we refer to the University of Wisconsin and the University of Washington. The University of Wisconsin earned an average of $25.5 million in Licensing Income from 1997 to 2003, and its technology transfer function can claim almost $2 million of that sum as the result of further funding ($1.3 million) between 1996 and 2003. The tech transfer office at the University of Washington earned $1.4 million of Licensing Income due to increased investment into the office. Additional funding for the OTT had the greatest impact on the University of California system, which earned an average of $99.7 million in Licensing Income over the period. Of this, an estimated $4 million is a result of further funding. The results of Simulation I are also impressive at Johns Hopkins University, where the extra OTT funding resulted in over $1 million more in Licensing Income per year.

Simulation I estimates that post-1996 OTT investment is responsible for an average of 5.5 percent of Licenses Executed per university per year. The 81 universities in our AUTM data set averaged 30 Licenses Executed annually. According to Simulation I, without further investment increases into the OTT, this average would drop to 28.4. For all 81 universities in the data set, we can attribute 150 fewer Licenses Executed per year to the lack of post-1996 investment into the tech transfer office.

Returning to our specific examples, the University of Minnesota executed 84 licenses per year. If we assume that its Office of Patents and Technology Marketing did not receive any funding beyond its 1996 level, Simulation I estimates that the University of Minnesota would instead license 79 inventions per year, five fewer than the office did license. At the Baylor College of Medicine, Simulation I estimates that rather than successfully licensing 40 inventions, the office would only license 36 inventions; continued investment into the Baylor Licensing Group is responsible for the successful licensing of four additional inventions per year from 1997 to 2003. At the University of California, 17 of 224 licenses were executed annually because of post-1996 investment into the tech transfer offices. Simulation I estimates that Johns Hopkins and the University of Pennsylvania licensed seven and four more inventions, respectively, as a result of additional funding on an annual basis.

Startups suffer from the lack of additional investment in OTTs, as well. Simulation I estimates that without this additional investment, the average university would lose 5.2 percent of yearly Startup companies formed. With an average of three startups in any given year, any given university in our study would instead create 2.8 Startups in a year without the added investment in its OTT.

The universities were the starting point for 247 companies a year, and the further funding is responsible for 13 of those endeavors. Harvard University facilitated the creation of 20 Startup companies (3.0 on average) from 1997 to 2003. Our simulation calculates that without the additional funds funneled into the Harvard OTT, this number would decline to 18 (2.8 on average). The Stanford University office of technology licensing aided in the formation of nearly four additional companies (0.5 on average) between 1997 and 2003, and the UC system helped cultivate more than eight startups (1.2 on average), with additional funds over the same period. Additional funding at the University of Florida also helped create nearly two (0.2 on average) more startups.

Simulation II: What if the technology transfer office were never created?

Simulation II
Summary Table,* 1997-2003 Average

University	Actual Licensing Income	Simulated Licensing Income	Actual Licenses Executed	Simulated Licenses Executed	Actual Startups	Simulated Startups
	US$ Millions					
University of California System	99.7	83.2	224	156	20	14.8
Massachusetts Institute of Technology	33.4	28.3	103	79	22	19.1
University of Washington	26.1	22.7	91	75	7	5.7
Stanford University	50.6	47.4	133	117	12	10.5
University of Wisconsin	25.5	19.4	116	86	3	1.8
Johns Hopkins University	8.8	6.0	101	83	6	4.3
University of Michigan	5.9	3.7	55	44	7	5.5
State University of New York	14.6	11.1	39	27	5	3.8
Harvard University	19.3	16.9	68	58	3	2.3
University of Minnesota	17.8	13.7	84	67	7	5.8
University of Pennsylvania	11.5	9.6	67	56	6	5.4
Duke University	3.3	2.1	45	36	2	1.6
University of Florida	27.4	25.3	31	20	4	3.1
University of Chicago	3.1	2.1	17	13	2	1.2
Iowa State University	4.9	2.0	198	180	3	2.1
Rutgers University	5.4	3.8	37	29	4	3.0
Texas A&M University System	6.1	4.6	57	48	3	1.7
Baylor College of Medicine	9.2	7.2	40	30	2	1.5
Washington University	8.2	6.5	67	59	2	1.2
University of Texas Southwestern Medical Center	7.9	6.4	25	19	1	0.9
U.S. Total	639.14	505.84	2,734	2,101	247	197

*Top 20 Universities based on Labor Cost Value

Simulation II is designed to quantify the effects of the OTT as a whole by assuming no investment in terms of technology transfer office Labor Cost, as well as assuming that the Age of the Office remains zero over the seven years of our data set. This scenario attempts to evaluate the impact of an OTT never having been established. The results imply the significance of the office in percentage terms. Without an office, the average university would earn only 79 percent of its annual Licensing Income; conversely, the office is responsible for over 20 percent of annual Licensing Income. With an average of $639.1 million and a seven-year mean of $7.89 million, Simulation II estimates that the 81 universities in our data set can attribute $133.3 million more and $1.7 million on average individually to tech transfer collaborations involving their OTTs.

Referring to Harvard and Stanford as specific examples, the universities earned on average $19.3 and $50.6 million in Licensing Income, respectively. Harvard University's Office of Technology Development can argue that $2.4 million of this income is a direct effect of its involvement in the technology transfer process. Similarly, the Office of Technology Licensing at Stanford can take full responsibility for $3.2 million of the university's Licensing Income, and the UC office can claim $16.5 million of the system's total Licensing Income per year, from 1997 to 2003. The University of Wisconsin earned $6.1 million more in Licensing Income per year because of the existence of its tech transfer office. At the State University of New York (SUNY) system, $3.5 million in Licensing Income is attributable to the OTT: $11.1 million of $14.6 million.

The tech transfer office has a larger impact on Licenses Executed, at 23.2 percent of average annual licenses. Without the office, a university among those studied could expect executed licenses to be 76.8 percent of what they could be with the support and guidance of an OTT. In total, the offices are responsible for 633 of 2,734 total Licenses Executed per year from

1997 to 2003; on average, the OTT is directly responsible for almost eight of 34 licensed inventions each year. Out of 55 Licenses Executed at the University of Michigan, 11 inventions licensed are an effect of the facilitation of the University of Michigan's OTT. The Office of Technology Licensing at Stanford accounts for 16 of the university's 133 successfully licensed inventions per year. The University of California system would have executed 68 fewer licenses without its tech transfer offices. MIT's tech transfer office was responsible for the facilitation of 24 of 103 licenses annually during the period.

Tech transfer offices had a slightly smaller impact on Startup companies formed. A little over 20 percent of companies formed are a result of the addition of the OTT. In average terms, this translates into slightly more than four Startups for each university over the seven-year period. On average, the OTTs were responsible for 50 of the 247 Startup companies formed among the universities studied. According to Simulation II, the Office of Technology and Intellectual Property was responsible for almost six Startups (0.8 on average) formed at the University of Chicago during the seven-year period. At Rutgers, seven of the 26 Startups (1.0 on average) formed were the result of the OTT's participation in tech-transfer activities. UC tech transfer offices were responsible for the establishment of 36 university Startup companies (5.2 on average) during the period. Washington University's OTT was responsible for almost six (0.8 on average) of its 13 Startup companies formed.

These two simulations have allowed us to ask and, more important, to answer two "what if" questions. It is widely accepted that technology transfer offices contribute to the success of commercialization activities at universities. By using this type of evaluation, the benefits that these offices bestow can be quantified.

Endnotes:

1. Consumer price index (CPI) numbers have been used to adjust research expenditures and Licensing Income from the AUTM data to 2003 dollars. The 2004 numbers have also been adjusted to 2003 dollars due to the timing of the release of this study.
2. http://www.oecd.org/dataoecd/38/32/33707275.pdf#search='van%20Beuzekom,%202004.
3. See also the reference to the University of California system in Chapter IV, "Innovation Pipeline, Caveats," of this study.
4. David Audretsch et al. (2006), drawing upon the research of Thursby and Thursby (2005), discuss how "the mandate of the TTO is not to measure and document all of the intellectual property created by university research. … Rather what is measured and documented is the intellectual property and commercialization activities with which the TTO is involved … (the) commercialization (of IP) may or may not involve the TTO." Their research also points out work by Shane (2004), who writes about the likely underestimation of commercialization activities.
5. Castillo, Parker and Zilberman. 2001. See also: Friedman, J. and J. Silberman. 2003. "University Technology Transfer: Do Incentives, Management and Location Matter?" *The Journal of Technology Transfer*.
6. Castillo, Parker and Zilberman. 2001. See also: Friedman, J. and J. Silberman. 2003.
7. These are USPTO-issued utility patents assigned to a U.S. college, university or association of U.S. colleges and universities. See: http://www.uspto.gov/go/taf/univ/doc/doc.info.htm.
8. This figure represents U.S. patents issued and reported for FY 2003 by those institutions responding to the AUTM survey. See: http://www.autm.net/UserFiles/File/FY03SurveySummary.pdf.
9. AUTM defines U.S. patents issued as the number of U.S. patents issued or reissued to the university. Certificates of plant variety protection issued by the USDA are also included.
10. In a Milken Institute telephone interview conducted May 24, 2006.
11. Among these findings is supporting evidence that startups and spin-offs of university biomedical researchers who choose to pursue commercialization through the federal Small Business Innovation Research program have a higher probability of follow-on VC investment, program completion and better innovative performance, as measured by patents. See: Toole, Andrew and D. Czarnitzki. 2005. "Biomedical Academic Entrepreneurship Through the SBIR Program." NBER WP 11450. In addition, university participation in the Advanced Technology Program of the U.S. Department of Commerce has a positive effect on innovation outcomes, as measured by patents. See: Darby, Michael, L. Zucker and A. Wang. 2003. "Universities, Joint-Ventures, and Success in the Advanced Technology Program." NBER WP 9436. See also: Hegde, Deepak. 2005. "Public and Private Universities: Unequal Sources of Regional Innovation?" *Economic Development Quarterly,* 19(4).
12. See the "County Profiles" chapter in this study. See also the research of Hu, Mei-Chih and J. Mathews. 2003. "National innovative capacity in East Asia," MGSM WP 17. Sydney: Macquarie Graduate School of Mgt. See also: Ernst, Dieter and David Mowery. 2004. "University-industry linkages in the Pacific Rim: public policy issues." Honolulu, HI. East-West Center, mimeo. See also: Sigurdson, Jon. 2004. "People's Republic of China's technological capability," paper presented at the 2004 Laeba Annual Conference, Beijing, Dec. 3–4.
13. Abramson, H., J. Encarnacao, P. Ried and U. Schmoch (eds.). 1997. *Technology Transfer Systems in the United States and Germany: Lessons and Perspectives*. Washington, D.C.: National Academy Press. See also: Lambert Review of Business-University Collaboration. 2003. http://www.hm-treasury.gov.uk.

See also: Geuna, Aldo and B. Martin. 2003. "University Research Evaluation and Funding: An International Comparison." Kluwer Academic Publishers. Minerva 41. See also: Brusoni, Stefano and A. Geuna. 2003. "An international comparison of sectoral knowledge bases: persistence and integration in the pharmaceutical industry." *Research Policy* 32. See also: EPOHITE. 2003. "Cross Country Comparison of the Relation between Country Performance and Policy Settings." Contribution to WP 3.

14. An example is EuropaBio. "Biotechnology in Europe: 2005 Comparative study." Lyon: BioVision.
15. See: Bessy, Christian, E. Broussear, St. Saussier. 2002. "The Diversity of Technology Licensing Agreements." Paris: CEE & ATOM. See also: De Juan, Veronica. 2002. "Comparative Study of Technology Transfer Practices in Europe and the United States." *Journal of the Association of University Technology Managers*. Vol. XIV.
16. A 2005 review conducted by Library House on behalf of the British VC Association, "Creating Success from University Spin-outs," found evidence that university spin-offs are at a disadvantage to their corporate counterparts. The authors conclude that there is a need to level the playing field. The research also suggests that later-stage spin-offs — post-market validation — have the best chance of

success. See also: Feldman, Maryann. 2000. "Where Science Comes to Life: University Bioscience, Commercial Spin-offs, and Regional Economic Development." *Journal of Comparative Policy Analysis: Research and Practice,* 2.

17. Finnegan, Henderson, Farabow, Garrett and Dunner, LLP, "Biotechnology Innovation Report 2005."

See also: Geuna, Also and L. Nesta. 2005. "University Patenting and Its Effects on Academic Research: The Emerging European Evidence." *Research Policy.* See also: Hellman, Thomas. 2005. "The Role of Patents for Bridging the Science to Market Gap," NBER WP 11460.

18. Brousseau, Eric, C. Chasserant and C. Bessy. "An International Survey on Technology Licensing Practices: the Diversity of Technology Licensing Agreements and the Causes." Paris: LES International. See also: Thursby, Jerry, R. Jensen and Marie Thursby. 2002. "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities." July. See also: Thursby, Marie, J. Thursby and S. Mukherjee. 2005. "Are There Real Effects of Licensing on Academic Research? A Life Cycle View," forthcoming.

19. OECD. "Steering and Funding of Research Institutions." Country Reports. www.oecd.org/dataoecd/ 24/35/2507946.pdf.

20. Unico. "UK University Commercialisation Survey: Financial Year 2003."

21. OECD. 2003. "Turning Science Into Business: Patenting and Licensing at Public Research Organisations."

22. The German definition of biotech covers all aspects of molecular biology, genetics and genetic engineering. *Gentechnik,* or "gene technology," divided into *rote* (red) and *gruene* (green), is broadly used in German science, policy, education and industry to define the medical and pharmaceutical aspects of biotech. See also: Unico. "UK University Commercialisation Survey: Financial Year 2003." See: www.unico.org.uk/prerelease.htm.

23. W. Powell, D. White, K. Koput and J. Owen-Smith. 2001. "Evolution of a Science-Based Industry: Dynamic Analyses and Network Visualization of Biotechnology," unpublished manuscript. See also: Owen-Smith, Jason, M. Riccaboni, F. Pammolli and Walter W. Powell. 2002. "A Comparison of U.S. and European University-Industry Relations in the Life Sciences," *Management Science*, 48 (1). See also: Owen-Smith, Jason and W. Powell. 2003. "The expanding role of university patenting in the life sciences: assessing the importance of experience and connectivity," Research Policy 32. See also: Owen-Smith, Jason and W. Powell. 2004. "Knowledge Networks as Channels and Conduits: The Effects of Spillovers in the Boston Biotechnology Community," *Organization Science*, 15 (1). See also: Powell, W., D. White, K. Koput, and J. Owen-Smith. 2005. "Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences," *American Journal of Sociology*, 110.

24. Henderson, Rebecca, A. B. Jaffe and M. Trajtenberg. 1995. "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965–1988," NBER WP no. 5068.

25. Mowery, David, R. Nelson, B. Sampat and A. Ziedonis. 2001. "The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980," *Research Policy,* 30 (1).

26. Allison, John, M. Lemley, K. Moore and R. Trunkey. 2003. "Valuable Patents." Boalt WP in Public Law, UC Berkeley.

27. Stephan, Paula, M.J. Higgins and J. Thursby. 2004. "Capitalizing the Human Capital of University Scientists: The Case of Biotechnology IPOs ©."

28. Zucker, Lynne and M. Darby. 2001. "Capturing Technological Opportunity via Japan's Star Scientists: Evidence from Japanese Firms' Biotech Patents and Products," *Journal of Technology Transfer,* 26 (1–2).

29. Kim, Jinyoung, S.J. Lee and G. Marschke. 2005. "The Influence of University Research on Industrial Innovation." NBER WP 11447.

30. Bransetter, Lee and Y. Ogura. 2005. "Is Academic Science Driving a Surge in Industrial Innovation? Evidence from Patent Citations," NBER WP no. 11561.

31. Zucker, Lynne G., M.R. Darby and J.S. Armstrong. 2001. "Commercializing Knowledge: University Science, Knowledge Capture and Firm Performance in Biotechnology." NBER WP 8499. See also Stephan, Paula, M. J. Higgins and J. Thursby. 2004.

32. The University of British Columbia announced in March 2006 that Nobel laureate Carl Wieman would be joining the faculty of UBC from the University of Colorado at Boulder, where his "star" status had been a magnet for attracting research funding and high-quality students.

33. Owen-Smith, Jason and W. W. Powell. 2003. "The Expanding Role of University Patenting in the Life Sciences: Assessing the Importance of Experience and Connectivity." *Research Policy,* 32(9).

34. Chapple, Wendy, A. Lockett, D. Siegel and M. Wright. 2004. "Assessing the Relative Performance of U.K. University Technology Transfer Offices: Parametric and Non-Parametric Evidence." Rensselaer WP 0423.

35. Cesaroni, Fabrizio and Andrea Piccaluga. 2002. "Patenting Activity of European Universities: Relevant? Growing? Useful?" SPRU NPRnet Conference: "Rethinking Science Policy: Analytical Frameworks for Evidence-Based Policy," University of Sussex. Brighton.
36. Cooper, Denys G. T. 2005. Canadian University Outputs Compared with Matched Pairs of US Universities, unpublished
37. One of their earliest papers asks the question "Who is Selling the Ivory Tower?" — Thursby, Jerry and Marie Thursby. 2000. NBER WP 7718. Another (with Richard Jensen) investigates the importance of invention characteristics — Thursby, Jerry, R. Jensen and Marie Thursby. 2000. "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities." July.
38. Thursby, Marie, J. Thursby and S. Mukherjee. 2005. "Are There Real Effects of Licensing on Academic Research? A Life Cycle View," NBER WP.
39. Lach, Saul and M. Schankerman. 2003. "Incentives and Invention in Universities." NBER WP 9727.
40. Friedman, Joseph and J. Silberman. 2003. "University Technology Transfer: Do Incentives, Management and Location Matter?" *Journal of Technology Transfer,* 21(1).
41. DeVol, Ross. 1999. *America's High-Tech Economy.* Santa Monica: Milken Institute.
42. Coupé, Tom. 2003. "Science Is Golden: Academic R&D and University Patents." *Journal of Technology Transfer,* 21(1).
43. Chukumba, Celestine and R. Jensen. 2005. "University Invention, Entrepreneurship, and Start-Ups." Dept. of Economics and Econometrics, University of Notre Dame.
44. Lockemann, P.C. 2004. "Technology Transfer: Political Pressure, Economic Necessity, Social Phenomenon, Financial Reward, or Intellectual Pleasure?" *Comparative Technology Transfer and Society*, 2(2). An earlier article in this same journal provides a historical overview of basic patterns within the scholarship related to technology transfer since 1950. See: Seely, Bruce. 2003. "Historical Patterns in the Scholarship of Technology Transfer," 1(1).
45. Matkin, Gary. 2000. *Technology Transfer and the University*." American Council on Education, Oryx Press.
46. Feldman, Maryann and P. Desrochers. 2004. "Truth for Its Own Sake: Academic Culture and Technology Transfer at Johns Hopkins University." *Minerva.* See also: Feldman, M. and P. Desrochers. 2003. "Research Universities and Local Economic Development: Lessons from the History of the Johns Hopkins University," *Industry and Innovation*, 10(1). See also: Feldman, M. 1994. "The University and Economic Development: The Case of Johns Hopkins University and Baltimore." *Economic Development Quarterly*. 8(1).
47. University Technology Transfer Questions and Answers. The Council on Governmental Relations. Nov. 30, 1993. www.cogr.edu/docs/BayhDoleQA.htm.
48. Thursby and Thursby. 2000. "Who Is Selling the Ivory Tower? Sources of Growth in University Licensing." NBER WP 7718.
49. Specifically, a location quotient in terms of employment measures a metro's high-tech share of total employment relative to that same share for the United States. A high-tech industry LQ of 1.0 for a metro says that high-tech activity has the same concentration as the national average. If the LQ is greater than 1.0, high-tech employment is more concentrated in the metro area than in the country on average, while an LQ of less than 1.0 means that high-tech employment is less concentrated in the metro relative to the national average. LQs serve as effective tools for capturing the relative importance of a particular industry to a local economy. Often, a metro will have a large LQ in a specific high-tech industry, sometimes due to the presence of one or two firms. However, that may say little about its national contribution.
50. We use Stanford University as the control because of its consistently high performance across a number of measures.
51. Chukumba, Celestine and R. Jensen. 2005.

IV. University Biotech Innovation Pipeline

IV: The University Innovation Pipeline

The phrase "university innovation pipeline" refers to the support and process infrastructures that enable a university to convert its research and creativity into intellectual property that is commercialized. A rich innovation pipeline plays a pivotal role in a university's ability to commercialize its overall and biotech-specific research. It also constitutes an important asset to municipal, state/provincial, national and regional economies, and their ability to sustain long-term economic development and competitiveness.

This chapter analyzes national and international university biotech and overall innovation pipelines, using three measures: Publication Rankings, Patenting Activity and OTT Outcome Measures.

Section 1: Publication Rankings: Global Data Analysis and Findings

Methodology

This section compares and evaluates the scientific strength (research output) of universities around the world, as measured by the quantity and quality of published research. It ranks published works in the field of biotechnology over the period 1998–2002, using databases from Thomson Scientific, Science Citation Index (SCI), Social Sciences Citation Index (SSCI) and the Swiss Center for Science and Technology Studies (CEST). Publication and citation counts are important output measures of scientific research, and this analysis aims to contribute toward improved transparency in biotech research achievement.

We used 683 universities in the analysis of all academic fields, including 217 in the United States (32 percent); 303 in Europe (44 percent, of which Eastern European universities represent 6 percent); 56 in Japan; 30 in Canada; and 11 in China.

Biotechnology covers research in the following eight specified subfields:

Biotechnology by Subfields

1. Biology
2. Biotechnology and Applied Microbiology
3. Multidisciplinary
4. Biochemistry and Biophysics
5. Experimental Biology
6. Microbiology
7. Cell and Developmental Biology
8. Molecular Biology and Genetics

Within the field of biotechnology, we evaluated the eight subfields represented in 492 universities, including 161 in the United States (33 percent); 222 in Europe (45 percent, including 5 percent for Eastern Europe); 44 in Japan; 23 in Canada; 9 in Australia; 5 in China; and 17 in the rest of Asia.

We based our evaluation of the performance of universities on assessments of three indicators — the Number of Publications, Activity and Impact — at the aggregate level of biotechnology, after assigning a unique weight to each of the eight subfields, based on its relative importance to the overall biotechnology category.

We also assigned weights to the three indicators: Number of Publications (40 percent); Activity (20 percent); and Impact (40 percent) A lower weight was accorded for Activity because a university's concentration in biotechnology, relative to overall research papers, cannot be considered as important as the Number of Publications and Impact. Activity does, however, provide important information on how focused a university is in a particular research field. In each measure, the universities are benchmarked to the best-performing university, which earned a score of 100.

***1*. Number of Publications (40 percent weight):** This is a *size* indicator that reflects the number of each university's biotech publications (published papers). Since much of a university's success in biotechnology is owed to its overall number of biotech publications, we took the sum of the publications from the eight subfields for each university. We also looked at the university's share of publications in all subfields reflected in the world share of publications in those subfields.

Publications count is not affected by the quality of the papers. If publication output (in a given field) is higher at one university than at another, it suggests that the faculty size and/or productivity at the first university is higher than at the second.

***2.* Activity (20 percent weight):** This is a *concentration* indicator measured by the number of publications (published papers) in a particular field or subfield. This indicator was applied to each of the eight subfields and used to derive the overall biotechnology Activity measure.

We first compiled the Number of Publications in each subfield for a specific university as a percentage of the total number of biotech publications published by the university, divided by the number of publications worldwide in each subfield as a percentage share of total biotechnology publications worldwide. We then counted the number of biotechnology publications from a specific university as a percentage of the total number of publications published by that university, divided by the worldwide total of university biotech publications as a share of the worldwide total of university publications.

We observed the quotient (q) of publications in each subfield and the total biotechnology publications of all universities. The product of the Activity (a) and quotient (q) of the university in a specific subfield was obtained (a*q). We then assigned a specific weight to each subfield. The last step in arriving at the total Activity for a university is to calculate the sum of the weighted (a*q) measures.

***3.* Impact (40 percent weight):** This is a *quality* indicator that reflects the frequency with which publications are cited by other authors. It is measured by the number of citations of a university in a specific field or subfield as a share of the total number of university publications in that field or subfield, divided by the total world citations in that field or subfield as a share of the total world publications in that field or subfield.

Citation counts capture the interest publications receive from other writers, for a range of motives: concepts, models, ideas or counterarguments. Thus, citation analysis reflects the international resonance of the publication. Evidence suggests that "these reference motives are not so different or 'randomly given' to such an extent that the phenomenon of citation would lose its role as a reliable measure of impact."[1] We suggest that the higher the citation count, the better the quality of the paper, and agree that "the international attention which a research contribution receives from the author's peers is recognized as being regarded as an important aspect of the complex and the ambiguous phenomenon of quality."[2]

The Impact of an individual university is based on fractional field counting, which counts the cited publication as a fraction of all the references mentioned in the publication.[3] For example, if a cited publication mentions 20 references, the publication itself gets counted as 1/20 of the count. To arrive at the total Impact of a university, we constructed a method that captures the importance of each subfield and does not penalize universities that do not have citations in the other fields.

Caveats

We recommend that citation data, as a measure of scientific strength, be used and interpreted with knowledge of its strengths and limitations. For example, it is generally established that "star scientists" receive higher citation rates from their peers and are concentrated in a few universities. Increasingly, "citation" sources include nontraditional references, such as direct web postings and hypertext links, as well as acknowledgments published within papers.[4]

Not all university publication data is available, especially in Asia. Language biases result in fewer citations for non-English-language publications.[5] China's English-language journals, for example, are still rather local, and Chinese scientific journals lack international visibility. In addition, our ranking may tend to over-represent universities with academics who not only publish but also work as journal editors and reviewers.

Increasingly, "citation" sources include nontraditional references, such as direct web postings and hypertext links, as well as acknowledgements published within papers.

Our analysis covers the period 1998–2002, the most recent publicly available global data. In the dynamic world of biotech, innovation is constant, and as such, relative rankings are subject to change. More recent data will be an interesting source for future research.

Findings

Not surprisingly, U.S. research universities dominate the top 50 rankings worldwide across the three performance indicators (Number of Publications, Activity and Impact). Harvard leads the list, followed by the University of Tokyo; the University of London; the University of California (UC) San Francisco; and the University of Pennsylvania. Positions six through 10 are all from the United States: UC San Diego; Johns Hopkins University; Washington University; the University of Washington; and UC Los Angeles.

The dominance of U.S. universities is highlighted by several findings: they hold eight of the top 10 positions; 14 of the top 20 positions; and 28 of the top 40 positions. The top 10 U.S. universities account for 11.8 percent of world publications. And within the United States, California universities play a dominant role: three University of California campuses rank among the top 10; Stanford ranks 12th; and UC Berkeley, ranks 25th. California universities hold five of the top 25 positions. Britain and Japan each have three universities among the top 25.

A prevalence of medical schools characterizes the group of universities ranked highest according to the Number of Publications.

European universities generally demonstrate the highest Activity in the subfields biochemistry and biophysics; U.S. universities are more diversified, showing high Activity also in microbiology, cell and developmental biology, and molecular biology and genetics. The positioning of European universities behind the United States reflects the status of the European Higher Education Area (EHEA), which is still in process; no European country has yet fulfilled all its policy goals set in the Bologna and Lisbon process. The Impact score further suggests that U.S. retains an advantageous position relative to Europe in academic-based biotechnology research.

A prevalence of medical schools characterizes the group of universities ranked highest according to the Number of Publications. For example, within the top 20 universities, only Rockefeller University doesn't have a medical school. It does, however have a medical training program, and its affiliated hospital is a leading clinical research center. Additionally, it has a 25-year-old M.D./Ph.D. program with the nearby Graduate School of Medical Sciences at Cornell University and the Sloan-Kettering Institute. So it is able to overcome this potential challenge by its close affiliations and unique institutional arrangements. Massachusetts Institute of Technology, ranked 21st, is without a medical school, as well. The high Publication ranking for MIT is a testament to the productivity and quality of its non-clinical life-sciences faculty. Universities with medical schools and affiliated teaching hospitals attract greater research funding from public sources, such as the National Institutes of Health, providing more opportunities for research and collaboration with clinical-based faculty.[6]

The following universities rank highest in their respective countries in terms of Number of Publications; their overall rankings are given in parentheses: Universités de Paris I-XIII, France (23rd); University of Toronto, Canada (30th); Karolinska Institutet, Sweden (35th); Université de Genève, Switzerland (39th); Universität Konstanz, Germany (58th); University of Helsinki, Finland (59th); Universiteit Utrecht, Netherlands (60th); Université Catholique de Louvain (Katholieke Universiteit Leuven), Belgium (61st); Hebrew University of Jerusalem, Israel (77th); Università degli Studi di Roma I-III, Italy (90th); University of Queensland, Australia (99th).

Other universities that score highest in their countries for Number of Publications include: Universität Wien (University of Vienna), Austria (106th); Danmarks Tekniske Universitet, Denmark (109th); Universidade Nova de Lisboa, Portugal (128th); Universidad Autónoma de Madrid, Spain (136th); National University of Ireland (164th); University of Iceland (210th); National Yang-Ming University, Taiwan (229th); University of Otago, New Zealand (234th); National University of Singapore (263rd); Chinese University of Hong Kong (352nd); Charles University, Czech Republic (373rd); Universidad de Chile (383rd); University of Cape Town, South Africa (389th); Honan National University, South Korea (399th); University of Crete, Greece (426th); Universidade Federal do Rio Grande do Sul, Brazil (457th); Universiti Putra Malaysia (470th); Józef Attila University, Hungary (486th); and the Indian Institute of Technology, India (487th).

The United States accounts for 46 percent of the worldwide scientific biotech publications in the period 1998–2002, while European universities account for 35 percent, Japan 9 percent and Canada 5 percent. But it would be shortsighted to reduce differences between U.S. universities and European universities to such mass effects as publication counts. Research quality is affected by national policies, funding, industry clustering and other factors. Because our analysis of publications is complemented by other indicators (Impact and Activity), relatively small but specialized institutions can score as well as large research universities. For instance, the University of Wales, Aberystwyth, distinguishes itself through its above-average citation rate.

University of Wales, Aberystwyth

The University of Wales, Aberystwyth, established in 1872, is a founding member of the federal University of Wales. The degrees it awards are those of the federal university, of which it is one of six constituent institutions. Its Institute of Biological Sciences focuses current research on "proteomic, metabolomic and bioinformatics approaches to biological problems."

Researchers from the University of Wales and six other universities have undertaken a five-year project to develop a robot that can mimic the human brain. The university has also partnered with the Institute for Grasslands and Environmental Research, also in Aberystwyth, to study the "biological and agricultural sciences, with applications in fields such as pharmaceuticals, diagnostics, vaccines, bioprocessing and instrumentation."

The following table summarizes the University Biotechnology Publication Ranking. Harvard University, with a Publications score of 100, is credited with 11,098 biotech publications over the period 1998–2002. The university has an Activity score of 74.8 and Impact of 63.3. One of Harvard's strengths is the diversity of research papers in several biotech subfields: biochemistry and biophysics, 3,143; cell and developmental biology, 2,322; multidisciplinary, 2,142; molecular biology and genetics, 1,898; and microbiology, 1,073. In contrast, the University of London, second in terms of Number of Publications, with 9,633, has a higher concentration within biochemistry and molecular biology genetics.[7]

The University of Tokyo, at third, recorded 9,418 publications from 1998 to 2002, heavily concentrated within biochemistry and biophysics — more than 43 percent of the total. Cross-field collaboration among researchers doesn't appear to be as frequent at the university, with just 742 multidisciplinary papers listed. Because biotech research is increasingly cross-disciplinary, universities that can leverage collaboration may have a competitive advantage.

Milken Institute University Biotechnology Publication Ranking

Top 50, 1998-2002

Rank	University	Country	Biotech Publ. by Univ. Score	Activity Score	Impact Score	Overall Score
1	Harvard University, Cambridge	USA	100.0	74.8	63.3	100.0
2	University of Tokyo	Japan	84.9	77.5	43.5	83.3
3	University of London	UK	86.8	60.0	50.0	83.1
4	University of California, San Francisco	USA	54.5	83.0	63.8	79.6
5	University of Pennsylvania, Philadelphia	USA	51.8	77.2	55.9	72.9
6	University of California, San Diego	USA	42.0	72.8	64.5	71.2
7	Johns Hopkins University, Baltimore	USA	47.5	70.8	59.1	70.8
8	Washington University, St. Louis	USA	37.9	85.4	58.6	69.4
9	University of Washington, Seattle	USA	47.1	69.7	55.4	68.4
10	University of California, Los Angeles	USA	47.0	66.2	54.3	67.0
11	Yale University, New Haven	USA	37.5	74.5	59.0	66.7
12	Stanford University	USA	37.9	68.3	59.8	65.7
13	Rockefeller University, New York	USA	14.1	100.0	67.0	65.3
14	University of Wisconsin at Madison	USA	36.9	76.6	53.3	64.0
15	University of Cambridge	UK	34.6	67.4	58.3	63.1
16	Baylor College of Medicine, Houston	USA	30.5	80.9	55.3	62.9
17	University of Oxford	UK	31.8	72.6	58.1	62.9
18	Duke University, Durham	USA	31.5	72.4	55.8	61.5
19	Osaka University	Japan	43.4	69.2	45.2	61.4
20	Kyoto University	Japan	41.7	71.1	45.7	61.2
21	Massachusetts Institute of Technology (MIT), Cambridge	USA	27.4	60.2	64.2	60.6
22	University of Texas at Dallas	USA	25.8	77.5	56.8	60.5
23	Universités de Paris (I - XIII)	France	48.4	59.3	41.7	59.7
24	Columbia University, New York	USA	32.0	58.3	58.3	59.5
25	University of California, Berkeley	USA	32.4	54.1	59.8	59.4
26	Case Western Reserve University, Cleveland	USA	25.7	82.5	52.0	59.3
27	Cornell University, Ithaca	USA	32.2	68.3	52.4	59.2
28	University of North Carolina at Chapel Hill	USA	27.9	71.6	54.8	59.1
29	Yeshiva University	USA	20.7	85.8	54.5	58.8
30	University of Toronto	Canada	40.9	57.3	48.4	58.7
31	McGill University, Montreal	Canada	30.2	73.4	51.0	58.7
32	University of Michigan, Ann Arbor	USA	36.5	61.3	50.0	58.4
33	Vanderbilt University, Nashville	USA	25.9	82.5	49.7	58.2
34	University of Iowa, Iowa City	USA	24.4	78.7	51.9	57.7
35	Karolinska Institutet, Stockholm	Sweden	30.7	73.5	48.0	57.5
36	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	26.4	73.4	51.7	57.2
37	University of Alabama at Birmingham	USA	23.1	85.5	47.6	56.5
38	State University of New York (SUNY) at Stony Brook	USA	15.4	76.5	58.5	55.9
39	Université de Genève	Switzerland	12.7	66.4	65.8	55.7
40	University of Wales, Aberystwyth	UK	0.5	22.5	100.0	55.7
41	New York University (NYU)	USA	21.1	68.0	56.2	55.5
42	University of Utah, Salt Lake City	USA	19.6	72.1	55.0	55.1
43	Universität Basel	Switzerland	10.4	75.0	60.9	54.2
44	University of Chicago	USA	23.1	61.4	54.3	53.9
45	University of Massachusetts at Amherst	USA	16.1	70.6	56.0	53.5
46	University of Dundee	UK	10.1	85.9	54.2	53.4
47	Oregon Health & Sciences University, Portland	USA	12.3	80.6	53.9	53.1
48	University of Edinburgh	UK	17.3	73.1	51.9	52.7
49	Universités de Strasbourg (I - III)	France	13.4	69.8	56.4	52.1
50	Universität Zürich	Switzerland	17.4	73.1	50.7	52.1

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

The collective Universités de Paris (I-XIII), with 5,368 publications, scores second among European universities and sixth overall, and ahead of Cambridge and Oxford in the UK. While not scoring as high on the Impact of citations, it does indicate an opportunity for Universités de Paris to improve on this important measure of research quality. At other European universities, researchers at Sweden's Karolinska Institutet produced 3,403 papers; and Switzerland's Université de Genève, Univerität Basel and Univerität Zürich; the UK's University of Wales and University of Dundee; and France's Universités de Strasbourgh (I-III) are top performers. Baylor College of Medicine in Texas, and the University of Toronto and McGill University in Canada, score well among North American universities. Osaka University produced 4,821 publications (ninth). Kyoto University follows closely, with 4,630 (11^{th}). The University of Science and Technology of China (USTC) had 1,347 publications, a fairly high number, but with a very low Impact.

The following table details some key issues concerning mix of publications Among the subfields where Harvard University edges out its competitors are: multidisciplinary, cell and developmental biology, and molecular biology and genetics. The University of Tokyo has a higher Publications count than any other university observed in biochemistry and biophysics. The University of London leads in four fields: biology; biotechnology and applied microbiology; experimental biology; and microbiology.

Milken Institute University Biotechnology Publication Ranking

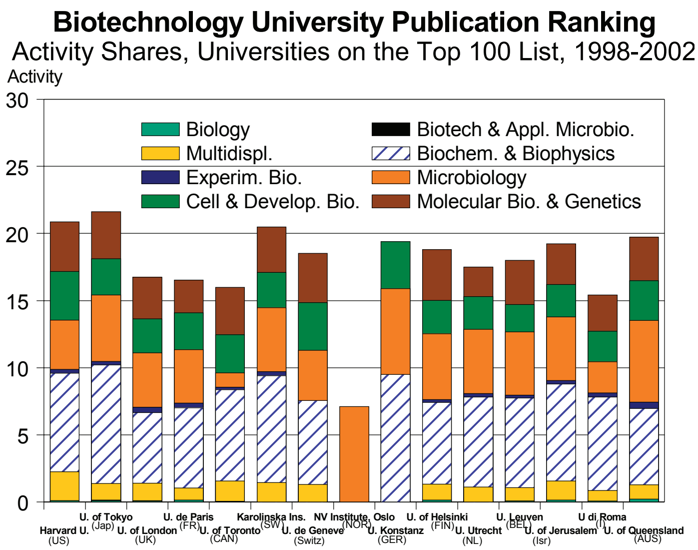
Number of Biotech Publications by Subfield, Top 50, 1998-2002

Rank	University	Country	Biology	Biotech & Applied Microbiology	Multi-disciplinary	Biochem. & Biophysics	Experim. Biology	Micro-biology	Cell & Developmental Biology	Molecular Biology & Genetics
1	Harvard University, Cambridge	USA	238	58	2,142	3,143	272	1,073	2,322	1,850
2	University of Tokyo	Japan	235	156	742	4,083	226	1,388	1,053	1,535
3	University of London	UK	277	163	1,101	2,742	621	1,543	1,368	1,818
4	University of California, San Francisco	USA	0	0	1,044	2,105	87	519	1,402	892
5	University of Pennsylvania, Philadelphia	USA	64	0	817	1,911	146	651	1,025	1,131
6	University of California, San Diego	USA	117	0	1,047	1,398	188	338	953	616
7	Johns Hopkins University, Baltimore	USA	68	0	917	1,650	96	582	743	1,221
8	Washington University, St. Louis	USA	58	0	720	1,387	136	443	666	792
9	University of Washington, Seattle	USA	191	0	868	1,519	158	764	653	1,077
10	University of California, Los Angeles	USA	104	0	898	1,782	123	607	611	1,090
11	Yale University, New Haven	USA	85	0	778	1,274	99	397	813	721
12	Stanford University	USA	101	0	1,077	1,019	93	486	670	762
13	Rockefeller University, New York	USA	0	0	354	421	0	200	293	292
14	University of Wisconsin at Madison	USA	0	56	621	1,315	122	769	517	497
15	University of Cambridge	UK	126	0	556	1,014	244	378	592	933
16	Baylor College of Medicine, Houston	USA	0	0	382	745	53	280	812	1,116
17	University of Oxford	UK	119	0	525	1,112	247	538	283	702
18	Duke University, Durham	USA	107	0	652	1,175	139	358	501	560
19	Osaka University	Japan	66	154	420	2,216	84	547	604	730
20	Kyoto University	Japan	102	102	602	1,993	134	425	662	610
21	Massachusetts Institute of Technology (MIT), Cambridge	USA	0	87	985	750	0	205	578	439
22	University of Texas at Dallas	USA	0	0	398	1,344	0	98	569	458
23	Universités de Paris (I - XIII)	France	270	0	455	1,801	295	866	866	815
24	Columbia University, New York	USA	77	0	665	928	89	219	758	818
25	University of California, Berkeley	USA	207	60	944	1,011	198	245	499	434
26	Case Western Reserve University, Cleveland	USA	0	0	471	970	70	294	422	625
27	Cornell University, Ithaca	USA	229	58	619	1,106	120	507	483	457
28	University of North Carolina at Chapel Hill	USA	61	0	343	1,040	69	430	569	583
29	Yeshiva University	USA	0	0	244	1,048	0	254	387	367
30	University of Toronto	Canada	97	0	607	1,686	124	266	746	1,012
31	McGill University, Montreal	Canada	80	56	325	1,071	80	318	500	918
32	University of Michigan, Ann Arbor	USA	141	0	701	1,463	128	398	564	652
33	Vanderbilt University, Nashville	USA	0	0	269	1,369	55	283	493	402
34	University of Iowa, Iowa City	USA	0	0	300	848	71	630	244	619
35	Karolinska Institutet, Stockholm	Sweden	0	0	366	1,353	115	548	415	606
36	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	113	0	378	1,055	60	385	457	478
37	University of Alabama at Birmingham	USA	0	0	253	1,059	0	579	313	360
38	State University of New York (SUNY) at Stony Brook	USA	73	0	217	694	73	131	261	262
39	Université de Genève	Switzerland	0	0	143	423	0	182	363	301
40	University of Wales, Aberystwyth	UK	0	0	0	0	0	54	0	0
41	New York University (NYU)	USA	0	0	322	627	0	261	646	487
42	University of Utah, Salt Lake City	USA	61	0	371	665	104	119	324	527
43	Universität Basel	Switzerland	0	0	134	426	0	123	238	238
44	University of Chicago	USA	140	0	450	714	107	163	404	588
45	University of Massachusetts at Amherst	USA	68	0	208	539	0	220	532	224
46	University of Dundee	UK	0	0	59	558	0	102	216	186
47	Oregon Health & Sciences University, Portland	USA	0	0	141	524	0	169	200	332
48	University of Edinburgh	UK	123	0	172	453	135	397	292	346
49	Universités de Strasbourg (I - III)	France	0	0	132	510	0	170	329	345
50	Universität Zürich	Switzerland	77	0	221	580	103	346	236	370

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

The next graph identifies Activity shares of the top 100 universities, taking into account the cumulative value of all eight biotech subfields. Harvard University and the University of Tokyo have almost equal proportions of Activity in each subfield, with the exception of multidisciplinary. The greatest share in biochemistry and biophysics, and microbiology, is claimed by the Universität Konstanz (Germany), followed by the University of Helsinki (Finland) and Universiteit Utrecht (Netherlands).

Rockefeller University has the highest Activity in total biotech research. The University of Dundee has the second-highest research focus in biotechnology, scoring 85.9 out of 100. The State University of New York (SUNY) at Stony Brook is a very close third, scoring 85.8, and the University of Alabama at Birmingham, fourth, with a score of 85.5. Scoring 85.4, Washington University is fifth. Other notable universities as measured by Activity include: UC San Francisco, at 83.0: and Vanderbilt University, at 82.5. Among all universities (including those that are not in the top 50 in the University Biotechnology Publications Ranking), Japan's Nara Institute of Science and Technology is second (98.0) and Tokyo Medical and Dental University is third (87.7). The University of Texas Health Science Center at San Antonio scores 84.1. Saitama University, in Japan, records a score of 82.6, and Case Western Reserve University scores 82.5.



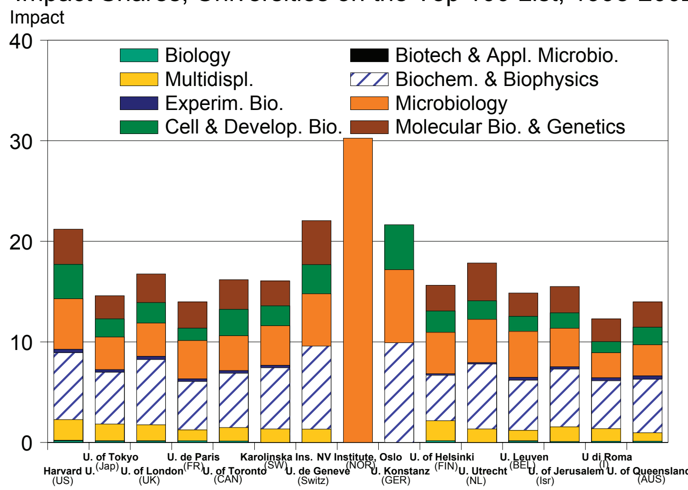
The results of Impact shares are similar. Harvard University has highly cited papers across all eight biotech subfields, while the National Veterinary Institute (Oslo) and the Universität Konstanz in Germany demonstrate strength in microbiology and biochemistry and biophysics.

The University of Wales, Aberystwyth, excels in the Impact indicator, with a score of 100. But this remarkable performance is an outlier, stemming from its high Impact within the subfield microbiology, where its research efforts are focused. Still, among overall top 50 performers, Rockefeller, at second, is 33 index points behind. Among universities with a large research base, UC San Diego scores 64.5, ranking third. UC San Diego has consistently high Impact scores but stands out for its exemplary performance within the subfield cell and developmental biology, where it receives a 67 percent higher citation rate than the university average in the sample.

MIT follows, with a score of 64.2, ranking it fourth among top 50 performers. This depicts the high Impact of its research without the aid of affiliated clinical researchers. It, too, has consistently strong Impact scores but owes its position to papers in cell and developmental biology, and molecular biology and genetics, being cited 72 percent and 61 percent, respectively, more than the university average in the sample. Not far behind on research Impact is UC San Francisco, scoring 63.8 and ranking fifth among the top 50. UCSF is highly regarded in cell and developmental biology, publishes 13.6 percent of the world's papers in this field and is cited 69 percent more than the university average. Additionally, multidisciplinary research is a UCSF strength, with 10.4 percent of all papers in the field and being 57 percent cited more frequently than the university average.

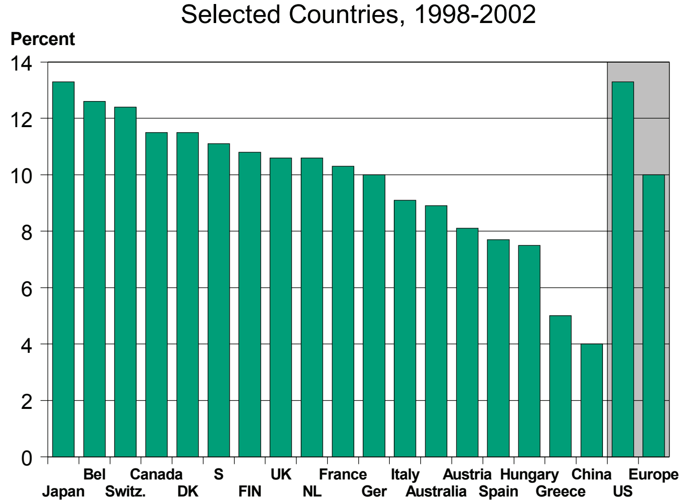
The Institut National des Sciences Appliquées de Toulouse is second in terms of Impact overall, at 90.3; with National Veterinary Institute, Oslo, being third, essentially recording the same score. Carl von Ossietzky Universität Oldenburg (Germany) ranks fourth. The University of Idaho ranks fifth, followed by Université de Perpignan (France) and California Institute of Technology.

Biotechnology University Publication Ranking
Impact Shares, Universities on the Top 100 List, 1998-2002



The United States and Japan score highest internationally (13.3 percent) for biotech publications as a share of total university publications. Belgium (12.6 percent) and Switzerland (12.4 percent) score highest in Europe.

Biotech Publ. as a Share of Total Uni. Publ.
Selected Countries, 1998-2002



Rockefeller University records the highest research output (44 percent) when normalized by biotech publications as a share of total publications produced by the university. Rockefeller University's exceptional research structure has positioned the university to be among the top 50 universities on the Milken Institute's biotechnology university publication ranking. The University of Dundee in the UK and the University at Texas at Dallas also distinguish themselves with an especially high share of biotech publications.

The University of Texas at Dallas, established in 1969, began as a small graduate research center and still offers a strong emphasis in the sciences. For instance, the Department of Molecular and Cell Biology offers an extensive range of undergraduate and graduate programs, while the Nanotech Institute develops new science and technology exploiting the nanoscale.

Compilation of a biotechnology Publications ranking system is dependent upon subjective weighting of total Number of Publications, Activity and Impact. Depending on the researcher's objective, alternative weights will affect the university rankings. One could make a reasonable argument, for example, that number of citations (Impact) should receive a higher weight than the Number of Publications, as the former reflects peer assessments of the scientific contribution.

University of Dundee, UK

The University of Dundee departments of anatomy and physiology, biochemistry, biology and chemistry combined to form the School of Life Sciences, which opened in 2000 and consists of eight research divisions and a teaching unit in five buildings.

Dundee hosts the third-largest biotech cluster in the UK (after Cambridge and the region around Oxford), up from seven companies to 40 in the past 10 years, and 12 of them spin-offs from the university.

In November 2005, the University of Dundee won the Queen's Anniversary Prize for Higher Education for its work in drug discovery. The prizes are awarded biennially to institutions of higher education for work of exceptional benefit nationally or internationally, and constitute the highest honor in UK higher education.

Chinese universities seem most likely to improve their publication scores, the result of increased emphasis on biotech research and improvement in the Number of Publications.

Nevertheless, we believe our methodology gives a reasonable depiction of where individual universities fall among the continuum of their peers. Further research will be helpful to determine whether recent changes in publications patterns alter these rankings in a meaningful way. Chinese universities seem most likely to improve their publication scores due to increased emphasis by the government on biotechnology research, higher funding and improvement in the Number of Publications in recent years.

The two charts on the fllowing two pages contain additional information regarding university publication rankings. The first gives biotech publications as a percent share of total university publications; the second portrays university publication statistics pertinent to all fields.

Milken Institute Biotechnology University Publication Ranking

Percent Share of Biotech Publications by University, Top 50, 1998-2002

Rank	University	Country	Total Univ. Publ.	Total Biotech Publ. by Univ.	% Share Biotech Publ.
1	Harvard University, Cambridge	USA	58,563	11,098	19%
2	University of Tokyo	Japan	53,711	9,418	18%
3	University of London	UK	76,143	9,633	13%
4	University of California, San Francisco	USA	26,017	6,049	23%
5	University of Pennsylvania, Philadelphia	USA	31,982	5,745	18%
6	University of California, San Diego	USA	23,688	4,657	20%
7	Johns Hopkins University, Baltimore	USA	32,783	5,277	16%
8	Washington University, St. Louis	USA	18,527	4,202	23%
9	University of Washington, Seattle	USA	34,266	5,230	15%
10	University of California, Los Angeles	USA	36,204	5,215	14%
11	Yale University, New Haven	USA	22,733	4,167	18%
12	Stanford University	USA	25,279	4,208	17%
13	Rockefeller University, New York	USA	3,574	1,560	44%
14	University of Wisconsin at Madison	USA	23,543	3,897	17%
15	University of Cambridge	UK	23,994	3,843	16%
16	Baylor College of Medicine, Houston	USA	13,452	3,388	25%
17	University of Oxford	UK	21,331	3,526	17%
18	Duke University, Durham	USA	20,516	3,492	17%
19	Osaka University	Japan	31,257	4,821	15%
20	Kyoto University	Japan	27,618	4,630	17%
21	Massachusetts Institute of Technology (MIT), Cambridge	USA	18,293	3,044	17%
22	University of Texas at Dallas	USA	10,929	2,867	26%
23	Universités de Paris (I - XIII)	France	43,791	5,368	12%
24	Columbia University, New York	USA	24,723	3,554	14%
25	University of California, Berkeley	USA	25,408	3,598	14%
26	Case Western Reserve University, Cleveland	USA	13,612	2,852	21%
27	Cornell University, Ithaca	USA	23,100	3,579	15%
28	University of North Carolina at Chapel Hill	USA	20,109	3,095	15%
29	Yeshiva University	USA	10,148	2,300	23%
30	University of Toronto	Canada	35,108	4,538	13%
31	McGill University, Montreal	Canada	18,846	3,348	18%
32	University of Michigan, Ann Arbor	USA	30,021	4,047	13%
33	Vanderbilt University, Nashville	USA	13,403	2,871	21%
34	University of Iowa, Iowa City	USA	15,519	2,712	17%
35	Karolinska Institutet, Stockholm	Sweden	22,212	3,403	15%
36	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	18,181	2,926	16%
37	University of Alabama at Birmingham	USA	12,676	2,564	20%
38	State University of New York (SUNY) at Stony Brook	USA	8,745	1,711	20%
39	Université de Genève	Switzerland	9,760	1,412	14%
40	University of Wales, Aberystwyth	UK	1,275	54	4%
41	New York University (NYU)	USA	14,748	2,343	16%
42	University of Utah, Salt Lake City	USA	11,074	2,171	20%
43	Universität Basel	Switzerland	6,699	1,159	17%
44	University of Chicago	USA	16,837	2,566	15%
45	University of Massachusetts at Amherst	USA	10,522	1,791	17%
46	University of Dundee	UK	4,362	1,121	26%
47	Oregon Health & Sciences University, Portland	USA	7,217	1,366	19%
48	University of Edinburgh	UK	11,397	1,918	17%
49	Universités de Strasbourg (I - III)	France	9,653	1,486	15%
50	Universität Zürich	Switzerland	12,243	1,933	16%

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

Milken Institute University Publication Ranking for All Fields

(683 universities), Top 50 Universities, 1998-2002

Rank	UNIVERSITY	Country	Impact	World Share of Publ.	Number of Publ.	Impact Score	Publ. Score	Score
1	University of London	UK	115	13.02%	76,143	65.3	100.00	100.00
2	Harvard University, Cambridge	USA	145	12.55%	58,563	82.4	76.91	96.35
3	University of Tokyo	Japan	99	9.32%	53,711	56.3	70.54	76.68
4	University of California, Los Angeles	USA	127	6.77%	36,204	72.2	47.55	72.40
5	University of Washington, Seattle	USA	131	6.36%	34,266	74.4	45.00	72.23
6	Johns Hopkins University, Baltimore	USA	132	7.47%	32,783	75.0	43.05	71.40
7	University of Pennsylvania, Philadelphia	USA	126	6.67%	31,982	71.6	42.00	68.70
8	Stanford University	USA	141	4.46%	25,279	80.1	33.20	68.53
9	University of Toronto	Canada	118	6.72%	35,108	67.0	46.11	68.44
10	University of California, Berkeley	USA	140	5.40%	25,408	79.5	33.37	68.29
11	University of Michigan, Ann Arbor	USA	128	5.16%	30,021	72.7	39.43	67.83
12	Universités de Paris (I - XIII)	France	96	8.24%	43,791	54.5	57.51	67.77
13	University of California, San Francisco	USA	137	7.34%	26,017	77.8	34.17	67.74
14	University of California, San Diego	USA	137	4.61%	23,688	77.8	31.11	65.89
15	Yale University, New Haven	USA	137	5.15%	22,733	77.8	29.86	65.14
16	Columbia University, New York	USA	132	5.37%	24,723	75.0	32.47	65.00
17	Massachusetts Institute of Technology (MIT), Cambridge	USA	143	4.68%	18,293	81.3	24.02	63.67
18	University of Cambridge	UK	127	4.72%	23,994	72.2	31.51	62.70
19	University of Pittsburgh	USA	127	5.54%	22,706	72.2	29.82	61.68
20	University of Minnesota, Twin Cities	USA	123	4.00%	24,372	69.9	32.01	61.63
21	Duke University, Durham	USA	131	4.13%	20,516	74.4	26.94	61.31
22	University of Wisconsin at Madison	USA	124	4.01%	23,543	70.5	30.92	61.31
23	Cornell University, Ithaca	USA	124	3.90%	23,100	70.5	30.34	60.96
24	University of Oxford	UK	127	3.85%	21,331	72.2	28.01	60.59
25	Royal School of Library and Information Science, Copenhagen	Denmark	176	3.40%	57	100.0	0.07	60.53
26	Washington University, St. Louis	USA	130	4.27%	18,527	73.9	24.33	59.39
27	Osaka University	Japan	100	6.05%	31,257	56.8	41.05	59.19
28	University of Chicago	USA	130	3.78%	16,837	73.9	22.11	58.05
29	University of North Carolina at Chapel Hill	USA	122	4.45%	20,109	69.3	26.41	57.90
30	Princeton University	USA	143	3.56%	10,817	81.3	14.21	57.73
31	University of Illinois at Urbana-Champaign	USA	125	3.76%	17,773	71.0	23.34	57.07
32	Kyoto University	Japan	101	5.02%	27,618	57.4	36.27	56.65
33	California Institute of Technology (Caltech), Pasadena	USA	138	8.41%	11,321	78.4	14.87	56.42
34	Northwestern University, Evanston	USA	125	2.94%	16,429	71.0	21.58	56.01
35	University of California, Santa Barbara	USA	142	2.22%	8,361	80.7	10.98	55.44
36	Mayo Clinic-College of Medicine, Rochester	USA	117	7.07%	18,452	66.5	24.23	54.86
37	Boston University	USA	121	3.23%	16,543	68.8	21.73	54.72
38	University of California, Davis	USA	114	4.93%	18,878	64.8	24.79	54.17
39	Karolinska Institutet, Stockholm	Sweden	106	6.30%	22,212	60.2	29.17	54.07
40	University of Iowa, Iowa City	USA	121	3.44%	15,519	68.8	20.38	53.91
41	Pennsylvania State University, University Park	USA	114	3.40%	18,541	64.8	24.35	53.90
42	McGill University, Montreal	Canada	113	3.49%	18,846	64.2	24.75	53.80
43	Univ. Catholique de Louvain / Katholieke Univ. Leuven	Belgium	105	3.54%	21,998	59.7	28.89	53.56
44	University of Southern California (USC), Los Angeles	USA	122	2.82%	14,557	69.3	19.12	53.49
45	Universiteit van Amsterdam	Netherlands	120	3.08%	15,358	68.2	20.17	53.44
46	University of Medicine and Dentistry (UMDNJ), New Brunswick	USA	113	3.18%	18,181	64.2	23.88	53.27
47	Ohio State University, Columbus	USA	112	3.17%	18,388	63.6	24.15	53.09
48	Università degli Studi di Roma (I - III)	Italy	87	5.40%	28,759	49.4	37.77	52.74
49	Rockefeller University, New York	USA	145	1.60%	3,574	82.4	4.69	52.67
50	University of Helsinki	Finland	111	3.27%	17,889	63.1	23.49	52.35

Sources: Center for Science and Technology Studies (CEST); Thomson Scientific (SCI/SSCI/AHCI); Milken Institute

Section 2: International Biotech Patents Issued in the United States

Methodology

AUTM data collection is limited because 1) it covers patents stemming from all research fields, despite empirical evidence that approximately two-thirds of patents filed in university tech transfer offices are generated from the life sciences; and 2) it is restricted to participating universities. Since we are interested primarily in capturing university patents stemming from the biotech research, patent data compiled through ipIQ, which specializes in intellectual property analysis within the technology sector, is utilized.

While data from AUTM place more emphasis on a university's office of technology transfer and its licensing-related activities, ipIQ's proprietary indicators concentrate on the productivity or quality associated within a university's biotech patents. IpIQ data serve as a complement to the AUTM survey in assessing a university's biotech research quality. AUTM and ipIQ data analyzed jointly may suggest that while a university's biotech patent receives high marks on citation quality, its potential in generating licensing revenue is not fully maximized.

Using available data from ipIQ, we have created a biotech patent assessment of colleges and universities worldwide that obtain U.S.-issued patents.

AUTM vs. ipIQ
Comparison Between Data Sets

AUTM	ipIQ
• Covers patents in all industries	• Specific to biotech/nanotech
• Based on actual survey	• Based on proprietary data and USPTO
• Limited to U.S., Canadian and Australian universities	• Covers all U.S.-issued foreign and domestic patents by university
• Examines more direct measures (i.e. income, expenditures, FTEs)	• Examines more indirect measures (i.e. CII, Tech Strength, Science Linkage)
• Emphasis more on licensing (i.e. Licensing Inc., Licenses Executed, Royalties)	• Emphasis more on patent quality (i.e. citations per patent)
• Breaks data out by university	• Breaks data out by university

IpIQ's proprietary data collection incorporates U.S. patent and international patent codes, and examines all Type 1 (utility)[8] patents issued to universities within biotechnology. In cases where multiple universities were assigned to a patent, the patent was counted once for each university. Between 1995 and 2004, 424 U.S. and foreign universities were recognized for carrying at least one biotech-issued patent. Of these universities, 198 were U.S. (46.7 percent) and 226 were foreign (53.3 percent), including 110 European (25.9 percent) and 48 Asian (11.3 percent). An additional filter was added to capture the nanotech subset within the biotech sample size.

IpIQ examines specific measures of patent quantity and quality, such as: Absolute Number of Patents; the Current Impact Index (CII); Science Linkage (SL); and Technology Cycle Time (TCT). Definitions of the terms follow, in the "Methodology" section.

The rankings indicate each university's relative performance with respect to its biotech portfolio. The higher the ranking, the greater the presumed competitive edge. The four indicators are explained below:

In deriving an overall composite index, we assigned appropriate weights to the Absolute Number of Patents, Current Impact Index assessment, Science Linkage and Technology Cycle Time. Universities with superior R&D funding must be recognized, as these schools normally attract the best faculty. These universities are typically associated with higher numbers of biotech patents issued.

1. **Absolute Number of Patents (65 percent):** For our overall composite index, this figure takes into account all Type 1 utility biotechnology patents issued in the U.S. patent system between 2000 and 2004.

2. **Current Impact Index, CII (15 percent):** CII measures the impact of a university's patents on the latest biotechnology developments. Specifically, it measures how often the previous five years of a university's biotech patents are cited by patents issued in the most recent year, relative to all U.S.-issued patents. It is a normalized measure of citations received from other patents and reflects the technological "prior art" of a newly patented invention. For our composite index, a CII of 1.0 represents the average citation frequency. By the same token, a CII of 2.0 indicates twice the average citation frequency, while a CII of 0.50 exhibits only 50 percent of the average citation frequency. Because patent quality is best determined by the number of citations per patent, we gave importance to the CII.

3. **Science Linkage (10 percent):** This is a measure of the extent to which a university's biotechnology builds upon cutting-edge scientific research. It is defined as the average number of science papers referenced on the front page of its biotech patent.

4. **Technology Cycle Time (10 percent):** This is a median age of the U.S.-issued patents cited on the front page of a university's patents.

Caveats

Intellectual property laws may differ significantly among countries, creating challenges for foreign universities wishing to patent in the United States. They are likely to score lower than U.S. institutions in overall Absolute Number of Patents issued in the United States, holding other factors, such as scientific quality, constant. In an effort to balance the potential under-representation of foreign patents issued in the United States, we constructed a geographic gravity function in compiling a biotech patent ranking of foreign-based institutions.

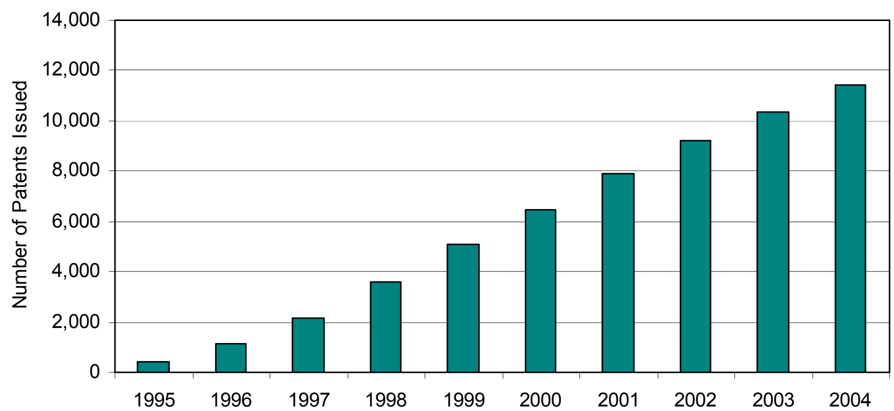
A geographic gravity function entails the assumption that the closer a university's physical location to U.S. Patent and Trademark Office, or USPTO (just outside Washington, D.C.), the greater its influence on probability of patent issuance. The gravitational pull that the U.S. patent system exerts on a foreign university's probability of seeking a patent is measured by the distance in miles from its country's capital to Washington, D.C. In other words, applying the logarithm (the number of miles between a foreign capital and Washington) to a foreign university's current number of biotech patents issued would constitute the normalized number of patents issued in the United States. For example, an Asian university would see its effective number of patents quadrupled by this calculation. The geographic gravity function was applied only to the Absolute Number of Patents issued, and not to the Current Impact Index or Technology Cycle Time.

Due to the proprietary nature of this data, we do not provide individual university biotech patent statistics. Instead, we used a scoring system, so that the university that ranks highest for a particular category, such as CII, receives a score of 100 and provides a relative benchmark. A score may range from 0 to 100. Our analysis covers the period 2000–2004.

Findings

- U.S.-issued university biotech patents have increased dramatically, growing from a cumulative total of 433 since they were first issued through 1995 to 11,430 in 2004, as illustrated in the following table. Between 2000 and 2004, the cumulative number of university-issued biotech patents issued in the United States increased by 77 percent, for a compound annual growth rate of 17.4 percent.

Cumulative Biotech Patents Issued
All Universities, 1995-2004



Source: ipIQ

- According to the **Current Impact Index**, biotech patents represent 50 percent of average citation frequency. Specifically, CII measures how often the previous five years of a university's biotech patents are cited by patents issued in the most recent year, relative to all U.S. patents.
- The average number of patent science references, or **Science Linkage**, cited on the front page of a university's biotech patent is 29.4.
- A **Technology Cycle Time** of 7.7 indicates the median age in years of U.S.-issued patents cited on the front page of a university's biotech patents.

Overall Biotech Patent Characteristics: 2000–2004

Category	Statistic
Number of Biotech Patents	6,320
Current Impact Index	0.5
Science Linkage	29.4
Tech Cycle Time	7.7

Source: ipIQ

In the following table, we rank the top 100 universities according to the four indicators. A score of 100 indicates top performance in that indicator category.

The table illustrates that:

- Nine out of the top 10 universities are U.S. universities.
- UC San Francisco and the University of Texas (UT) system tie in Absolute Number of Patents issued by the United States.
- California has four of the top 10 universities, and six of the top 25, on biotech patent ratings.
- Of the top 100 institutions ranked, 28 are foreign universities.
- Queen's University of Belfast, Northern Ireland, ranks first on Current Impact Index.
- University of Birmingham in England ranks first on Science Linkage.
- Japan's Ministry of Education scores first in Tech Cycle Time.
- California Institute of Technology (Caltech)rates among the top 15 in Absolute Number of Patents issued, Current Impact Index and Science Linkage.
- One out of every five nanotech patents stems from the University of California system.

Biotech Patent Rankings - Top 100 Institutions
Composite Index, 2000-2004

Rank University	Country	No. of Patents Score	Current Impact Index Score	Science Linkage Score	Tech Cycle Time Score	Composite Score
1 University of Texas	US	100.00	27.63	18.07	18.1	100.00
2 University of California, San Francisco	US	100.00	8.77	11.17	15.3	94.78
3 Johns Hopkins University	US	87.21	23.25	7.14	21.0	86.57
4 Stanford University	US	63.93	43.42	10.78	20.0	70.29
5 Cornell University	US	62.56	19.30	9.54	16.0	63.38
6 Columbia University	US	60.27	25.88	9.71	19.1	63.15
7 University of California, Berkeley	US	63.01	13.16	5.62	21.3	62.71
8 University of California, San Diego	US	59.36	17.54	9.82	17.1	60.35
9 University of Wisconsin	US	56.62	25.00	8.65	19.1	59.55
10 University of London	GB	58.70	4.33	10.62	30.1	58.94
11 Harvard University	US	55.25	25.44	13.89	17.6	58.93
12 Hebrew University of Jerusalem	IL	56.85	13.60	11.18	16.7	57.42
13 University of Michigan	US	52.05	29.39	14.65	14.6	56.58
14 McGill University	CA	52.97	22.37	9.88	20.3	56.08
15 University of Pennsylvania	US	51.60	24.12	13.56	13.1	54.74
16 Rockefeller University	US	51.60	15.35	17.31	18.6	54.19
17 California Institute of Technology	US	38.36	61.40	21.60	19.4	52.56
18 Yale University	US	42.92	39.91	16.98	19.1	51.54
19 University of Melbourne	AU	47.41	6.14	7.40	32.5	49.11
20 Thomas Jefferson University	US	47.03	11.84	12.10	15.3	48.22
21 Tel-Aviv University	IL	46.52	13.60	7.02	18.1	47.81
22 Washington University	US	43.38	16.23	8.81	19.4	45.98
23 University of California, Los Angeles	US	42.47	8.77	11.00	18.3	43.78
24 University of Oxford	GB	30.98	64.47	2.05	17.6	43.67
25 University of British Columbia	CA	39.27	25.00	7.31	14.8	43.27
26 University of Utah	US	38.81	27.63	7.94	13.1	43.27
27 University of Minnesota	US	36.99	21.05	15.07	15.7	41.61
28 Massachusettes Institute of Technology	US	30.59	43.86	12.15	16.3	40.28
29 University of Chicago	US	35.16	18.86	14.84	19.4	40.01
30 University of Alabama	US	36.53	14.91	8.47	19.4	39.54
31 Queen's University of Belfast	NI	9.52	100.00	2.14	68.4	38.82
32 Duke University	US	32.88	25.44	9.55	18.1	38.41
33 University of Florida	US	35.62	14.47	7.42	16.5	38.09
34 University of Maryland System	US	33.79	15.79	11.00	17.6	37.37
35 New York University	US	33.79	16.23	10.15	15.3	37.03
36 University of Queensland	AU	34.65	7.02	4.33	20.6	35.83
37 Baylor College of Medicine	US	29.22	26.75	16.34	12.4	35.57
38 University of Southern California	US	25.57	38.16	11.44	21.7	35.26
39 Michigan State University	US	33.33	10.53	6.85	15.5	35.02
40 University of Iowa	US	26.94	28.07	13.47	20.6	34.54
41 University of North Carolina	US	28.31	25.00	10.58	17.3	34.28
42 Vanderbilt University	US	27.40	22.37	6.68	24.5	33.38
43 University of Washington	US	26.03	25.44	10.40	20.6	32.76
44 Mt. Sinai School of Medicine of CUNY	US	17.81	54.82	15.92	22.0	32.43
45 Boston University	US	18.72	52.63	11.62	19.4	31.84
46 Yeshiva University	US	26.48	20.18	4.52	21.3	31.37
47 Universite Louis Pasteur	FR	18.03	44.30	20.36	21.7	31.02
48 University of Pittsburgh	US	25.11	23.68	7.87	17.8	30.85
49 University of Calgary	CA	26.48	14.47	11.34	14.6	30.21
50 University of Saskatchewan	CA	21.92	25.00	11.24	15.3	28.38
51 University of Georgia	US	23.29	11.84	11.93	20.3	27.68
52 University of California, Davis	US	26.48	4.39	8.05	12.9	27.44
53 Helsinki University	FI	16.62	28.95	27.64	18.3	27.13
54 Rijks Universiteit	NL	22.96	10.53	3.65	21.7	26.16
55 Emory University	US	19.18	25.00	10.87	15.9	25.96
56 Queen's University at Kingston	CA	19.18	20.61	13.84	16.7	25.58
57 University of Massachusetts	US	19.63	20.18	7.41	19.1	25.35
58 Brown University	US	7.31	70.61	13.89	16.5	25.26
59 Oregon Health Sciences University	US	20.55	14.04	11.60	16.7	25.14
60 State University of New York	US	21.00	10.53	7.40	22.0	24.98
61 Rutgers University	US	19.63	18.42	6.72	19.7	24.97
62 Indiana University	US	15.98	36.40	10.74	11.9	24.90
63 Pennsylvania State University	US	17.81	24.12	11.68	14.9	24.54
64 University of Illinois	US	18.72	13.16	18.25	17.6	24.36
65 University of Alberta	CA	19.18	12.72	9.66	23.6	24.33
66 University Pierre Et Marie Curie	FR	19.67	7.02	4.89	27.1	23.41
67 University of Kentucky	US	20.55	7.02	5.73	18.3	23.11
68 University of California, Irvine	US	15.53	21.93	15.72	17.8	23.00
69 North Carolina State University	US	18.72	13.16	6.42	19.1	22.95
70 Vlaams Interunivetsitair Instituut Voor Biotec	BE	19.69	7.89	2.60	23.6	22.82
71 Fordham University	US	1.83	64.47	23.87	32.5	22.67
72 Purdue University	US	15.98	24.12	7.52	15.5	22.41
73 Washington State University	US	18.72	10.96	7.47	14.8	22.04
74 Iowa State University	US	15.07	21.49	5.83	23.2	21.88
75 University of Colorado	US	12.79	27.19	14.73	17.3	21.44

Biotech Patent Rankings - Top 100 Institutions
Composite Index Cont'd, 2000-2004

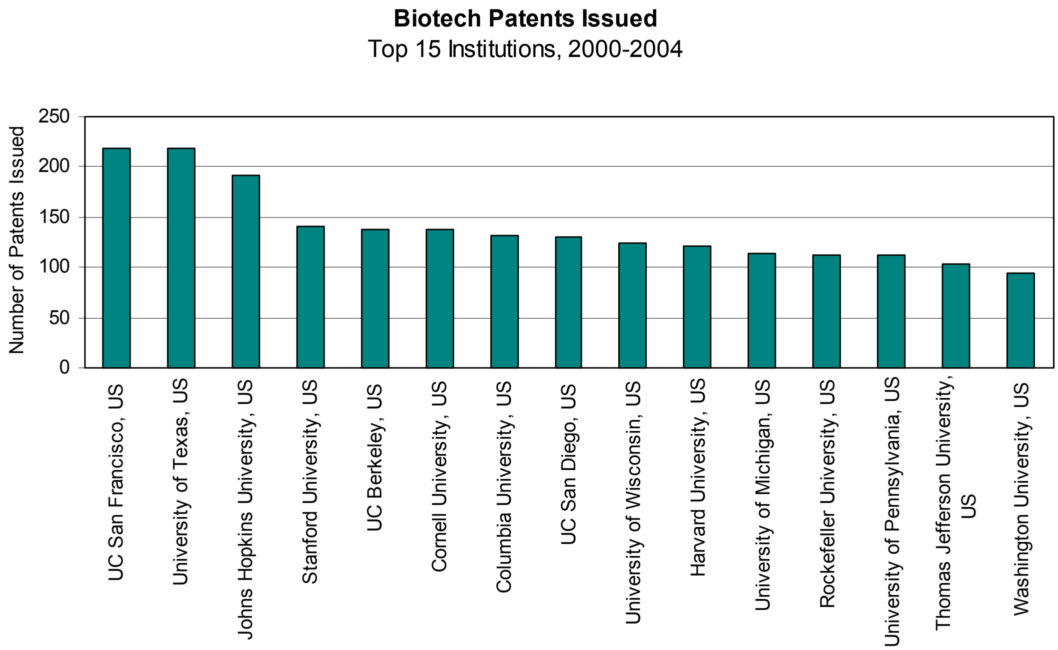
Rank	University	Country	No. of Patents Score	Current Impact Index Score	Science Linkage Score	Tech Cycle Time Score	Composite Score
76	National University of Singapore	SG	18.20	5.70	3.85	22.8	21.10
77	Princeton University	US	11.87	32.46	7.28	18.6	20.85
78	Ministry of Ed., Culture, Sports, Science & Tech.	JP	5.25	10.73	1.50	100.0	20.85
79	Cambridge University Tech Services Ltd.	GB	16.31	5.26	4.06	33.3	20.79
80	University of Oklahoma	US	15.53	16.67	9.18	15.7	20.72
81	University of Rochester	US	9.59	37.72	12.73	18.8	20.68
82	Erasmus University	NL	14.76	19.30	5.13	20.0	20.62
83	Universität Zürich	CH	13.21	22.81	6.99	21.0	20.34
84	University of California, Santa Cruz	US	2.28	52.63	7.08	46.4	20.25
85	Osaka Unversity	JP	19.24	5.70	4.55	8.6	20.17
86	University of Southern Mississippi	US	0.00	97.81	0.00	0.0	20.16
87	The University of Medicine and Dentistry of New Jersey	US	15.07	11.40	9.08	22.0	20.09
88	Northwestern University	US	14.16	12.28	14.24	21.3	20.06
89	University of South Australia	AU	1.82	68.86	0.35	28.9	19.84
90	University of Arkansas	US	18.26	7.46	2.63	11.5	19.80
91	University of Oregon	US	1.37	73.68	4.51	20.0	19.78
92	University of Nebraska	US	16.44	9.21	6.76	16.0	19.72
93	Newcastle University Ventures Ltd.	GB	6.52	53.07	2.00	15.7	19.20
94	University of Glasgow	GB	16.31	5.70	6.39	17.8	19.07
95	Victoria University	GB	16.31	7.46	1.91	19.1	18.99
96	Louisiana State University	US	13.24	17.54	9.10	16.7	18.99
97	Ottawa University	CA	10.05	29.39	7.83	20.3	18.90
98	Tufts University	US	11.87	22.81	9.44	15.7	18.76
99	Case Western Reserve University	US	10.96	25.44	11.85	14.9	18.72
100	Arizona State Board of Regents	US	12.33	20.18	4.69	20.6	18.66

Sources: ipIQ, Milken Institute

Absolute Number of Patents

The Absolute Number of Patents issued to foreign institutions was rescaled by implementing a geographic gravity function. While American universities captured a larger share of the Absolute Number of biotech patents issued in the United States, foreign universities find it beneficial to protect their valuable inventions in the United States. Foreign universities generally attempt to patent biotech IP in the United States for several reasons: there is a large potential U.S. market for commercial therapeutics; the United States is home to most of the world's largest biopharmaceutical firms; and the U.S. legal system permits the patenting of genetic material.

The following chart lists the 15 universities with highest Absolute Number of U.S.-issued biotech patents from 2000 to 2004.



Source: ipIQ

Seven of the nine fully operational University of California campuses[9] rank in the top 100 biotech universities for Absolute Number of Patents issued: San Francisco, Berkeley, San Diego, Los Angeles, Santa Cruz, Davis and Irvine. In all, 10 California universities rank among the top 100.

The University of California system was issued 723 U.S. patents from 2000 to 2004. UC's broad-based reputation in R&D is evidenced by its top-notch faculty and scientists. UC San Francisco, UC Berkeley and UC San Diego have attracted clusters of firms engaged in biotech manufacturing and R&D services.[10] "One in four U.S. biotech companies is located within 35 miles of a UC campus," according to the UC web site. "One in three California biotech firms (and one in six nationwide) was founded by UC scientists, and 85 percent of California biotech firms employ UC alumni with graduate degrees."[11] Many of these firms have located there in order to be within close proximity of these institutions.

The University of Texas, comprising nine campuses and six health institutions, ties UC San Francisco, with 219 U.S.-issued biotech patents. Four Nobel laureates (more than at any other medical school in the world) work as tenured researchers at Southwestern Medical Center.[12]

Johns Hopkins scores third for Absolute Number of Patents issued. The university is home to numerous research centers and institutes committed to the sciences and public health. Plans for a massive East Baltimore neighborhood revitalization include a 2 million-square-foot biotech park to be located near JHU.[13]

Nine of the top 100 universities are in New York. Five of the state's institutions (Columbia U., Cornell U., SUNY Stony Brook, Mount Sinai School of Medicine and the University of Rochester Medical School) are collaborating with Redox Pharmacuticals, based in New York City, on the use of Doxovir as an HIV-1 inhibitor. Doxovir was first developed at the Technion-Israel Institute of Technology, which earns a ranking of 154 on the overall composite index, the fourth-highest Israeli institute on the list.[14]

Massachusetts has five universities in the top 100. In 2001 the New England region was home to more than 11,000 medical school faculty members, and Massachusetts claimed 71 percent of that total.[15]

Universities have an edge in product commercialization and development if they are able to attract more R&D dollars, have affiliated medical schools and are surrounded by life-science clusters.

The University of Wisconsin, Madison, ranks ninth overall, supported by groundbreaking research conducted by James A. Thompson, Ph.D., a biologist credited with the first isolation of primate stem cells, in 1998, and who has patented both non-human (primate) and human embryonic stem cells.[16] His discoveries led to the creation of a spin-off nonprofit subsidiary of the Wisconsin Alumni Research Foundation, WiCell Research Institute, primarily concerned with human embryonic stem cell research.[17]

The University of London ranks 10th in Absolute Number of Patents issued by the United States and in the overall composite index, making it the highest-scoring foreign university. It comprises a number of colleges, including the Imperial College of Science, Technology and Medicine; Kings College; Queen Mary College; the Royal Free Hospital School of Medicine; the Royal Veterinary College; St. Georges Hospital; and the Medical School of the University College London. Dr. Stephen Minger of King's College heads work at the spin-off firm CereStem Ltd., which is using stem cell transplantation to replace diseased organ cells.[18]

The following table portrays biotech patents aggregated by country. U.S. universities account for 85 percent of the Absolute Number of Patents issued in the United States (and 66 percent of gravity-adjusted patents). Universities in smaller countries (in terms of both area and population) such as Austria and Israel, received more U.S. biotech patents than did universities in most large countries.

Number of U.S. Issued Biotech Patents by Country
Ranked by Absolute Number, 2000-2004

Country	Absolute Number of Patents	Gravity Adjusted Number of Patents
United States	5446	5446
Canada	301	602
United Kingdom	134	478
Austria	77	307
Israel	75	283
Japan	45	172
France	45	162
Netherlands	43	154
Belgium	30	108
Switzerland	18	65
Germany	17	62
Singapore	14	56
Korea, Republic of	13	50
Finland	12	44
China	11	42
Ireland (NI+IE)	11	38
Spain	9	32
India	8	31
Hong Kong SAR	5	20
Italy	5	18
Brazil	4	15
Portugal	4	14
Costa Rica	3	10
Mexico	3	10
New Zealand	2	8
South Africa	2	8
Thailand	1	4
Taiwan	1	4
Mali	1	4
Cuba	1	3
World Total	6341	8250

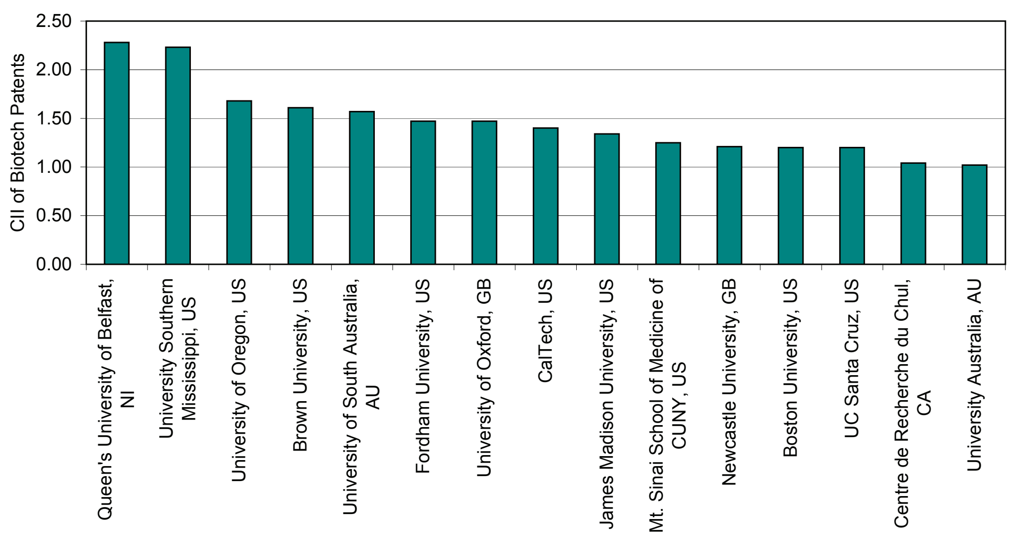
Universities endowed with abundant research funding are able to attract "star-scientists" and top-tier faculty, enhancing their research quality. Therefore, it is no surprise that the Absolute Number of Patents issued is highly correlated with research expenditures. In the United States, the National Institutes of Health and the National Science Foundation are major contributors of funding for research expenditures. Universities have an edge in product commercialization and development if they are able to attract more R&D dollars, have affiliated medical schools and are surrounded by life-science clusters.[19]

While U.S. universities earn the top score in the Absolute Number of Patents measures, non-U.S. universities and government ministries score highest in the three remaining indicators. This suggests that foreign institutions may have fewer incentives to patent in the United States rather than biotech superiority in the United States.

Current Impact Index

Queens University in Belfast, Northern Ireland, which ranks 31st in the overall composite index, scores 100 in the Current Impact Index, a measure of how often the previous five years of a university's biotech patents are cited in the most recent year, relative to all U.S. patents. The university received just six U.S. patents from 2000 to 2004, but its impact on recent patent citations is very high, more than twice the average citation frequency. Other high-ranking universities include the University of Southern Mississippi, which scores a CCI of 97.81 and ranks 86th overall; the University of Oregon, at 73.68 and ranking 91st overall; and Brown University, scoring a CCI of 70.61 and ranking 58th in the overall composite index.

Current Impact Index
Top 15 Institutions, 2000-2004



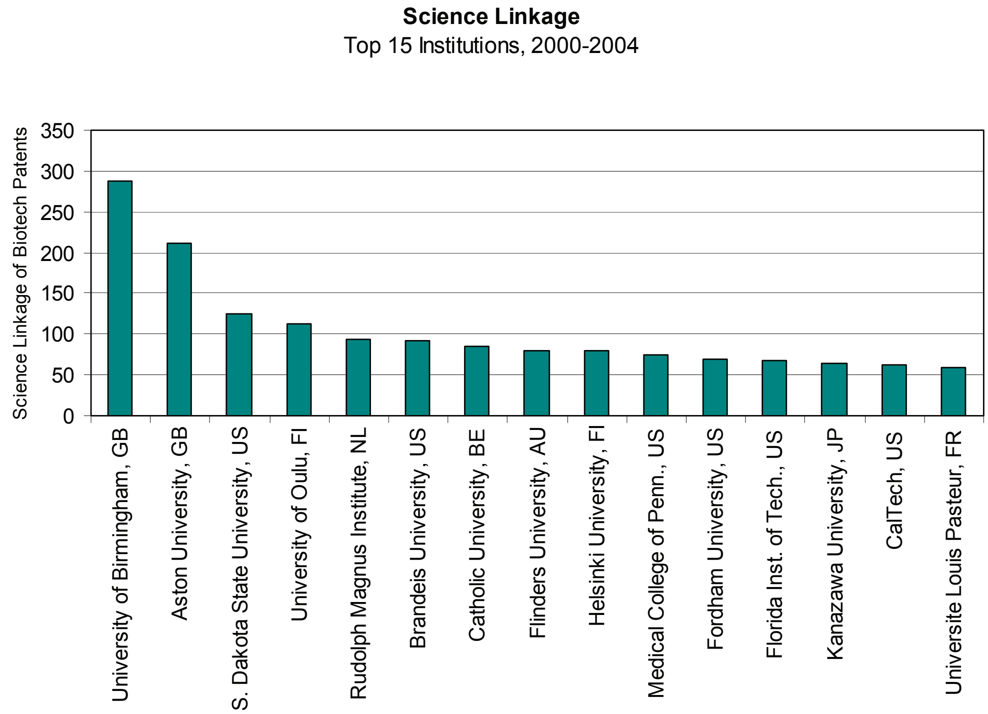
Source: ipIQ

Of the top 15 universities ranked by CII, only five have actually generated more than 10 biotech patents in the past five years (2000 thru 2004): Caltech with 84 patents, scores a CII of 1.4, or 40 percent above the average citation frequency. Other schools generating more than 10 biotech patents in the past five years include: Boston University with 41, Mount Sinai School of Medicine of the City University of New York with 39, the University of Oxford with 19 and Brown University with 16.

It is important to note that one biotech patent alone could yield a high CII. The impacts from a single, groundbreaking patent could be as effective as 10 patents. On the other hand, universities generating multiple biotech patents could be under-represented on CII, since every patent granted may not necessarily reflect the groundbreaking nature of a single innovation. These arguments further support the notion of compiling a composite index incorporating four related yet unique categories.

Science Linkage

As a measure of the average number of science papers cited on the front page of its biotech patents, Science Linkage is an indicator of whether a university is building its technology around the latest research advances.



Source: ipIQ

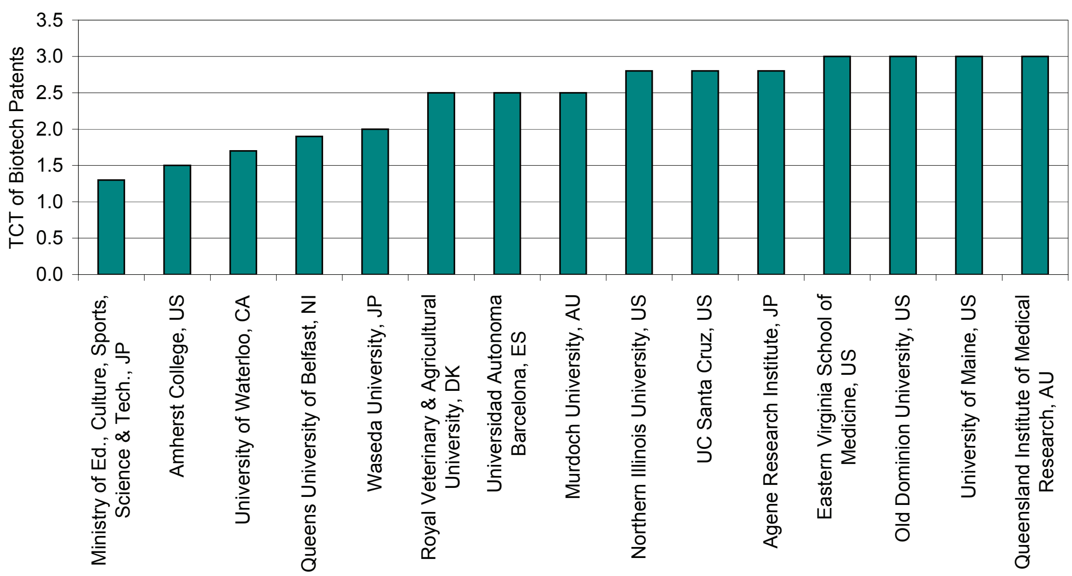
American institutions claim about 72 percent of the top 100 biotech research institutions; however, those located outside the United States cannot be overlooked. The two schools earning the highest Science Linkage scores are both in Great Britain: the University of Birmingham and Aston University in England. This score measures the university's capacity to apply and capitalize on groundbreaking research. With one outstanding patent each, Birmingham and Aston earn SL scores of 100 and 73.6, respectively. Although the University of Birmingham receives a perfect score in the Science Linkage measure, which implies that the university's one biotech patent was most closely linked to scientific research, the university scores a total ranking of only 117 out of 424. A biotechnology exploitation program (BEP) is in place at the university to more fully capitalize on the work done by academics and has witnessed positive results: in 2004, more than $446,000 was generated in licensing income, and $212,000 was funneled toward the creation of spin-offs.[20]

The 15 highest scoring institutions in the Science Linkage category received 123 patents from 2000 to 2004, with 68 percent of them (84 patents) belonging to Caltech, which ranks 14th in this category.

Technology Cycle Time

Universities scoring shorter Technology Cycle Times — the median age of the biotech patents they cite on their own patents are advancing at a faster pace. Citing older patents may be an indication that a university is not formulating its research around the latest advances in science. The importance of TCT lies in the fact that universities able to innovate rapidly increase their probability for commercialization. This measure may vary among industries and among foreign-generated U.S. patents.

Tech Cycle Time
Top 15 Institutions, 2000-2004



Source: ipIQ

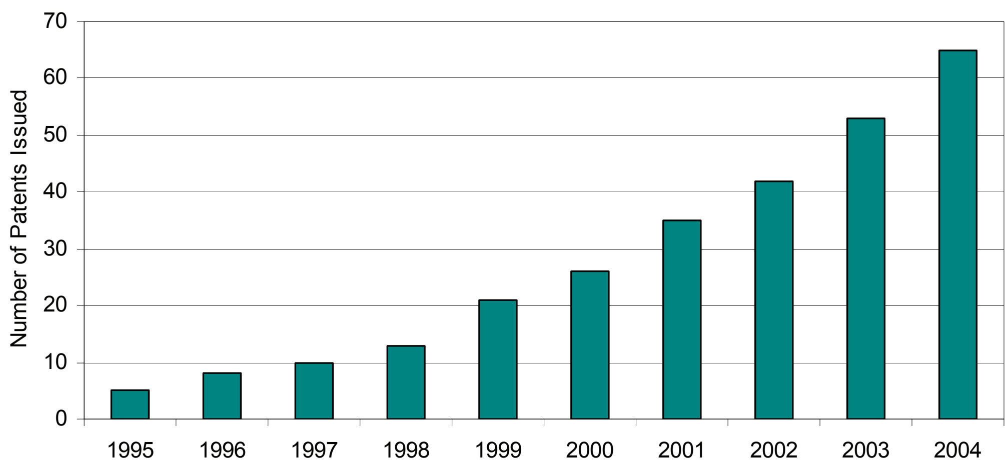
The 100 score in TCT goes to a government ministry rather than a university: the Japanese Ministry of Education, which documented the shortest shelf life for its biotech inventions. (Public university patents in Japan are registered with the Ministry of Education.) The ministry ranks 78th in the overall composite index.

Other high scorers include Amherst College in Massachusetts and the University of Waterloo in Canada. Again, a small number of patents appear to be an advantage when calculating this score: the few patents that have been granted cite very recent sources, and these universities lack patents citing older sources that would increase the Technology Cycle Time average. With six patents, Queens University, Belfast, earns the most patents among the 15 universities with the shortest TCT. All together, the top 15 universities claim 35 patents.

Nanotech Patent Findings

Nanotechnology can be applied to many different industries, but we focus only on its relevance to biotechnology. On a cumulative basis, nanotech patents, stemming from a young but emerging subfield within biotech, grew by 150 percent from 2000 to 2004, or a compound annual growth rate of 25.4 percent. Within the biotechnology area, the USPTO had issued 45 nanotech patents by the end 2004. Of these, only one stems from a foreign source, the University of Delhi.

Cumulative Nanotech (as a Subset of Biotech) Patents Issued
All Universities, 1995-2004



Source: ipIQ

Remarkably, one out of every five nanotech patents belongs to the University of California system. Johns Hopkins and the University of Michigan are also among the leading institutions holding U.S.-issued nanotech patents.

Overall Nanotech* Characteristics: 2000-2004

Category	Statistics
Number of Nanotech Patents	45
Current Impact Index	1.09
Science Linkage	19.95
Tech Cycle Time	6.7

Source: ipIQ

* Captures nanotech subset of biotech

The Current Impact Index of nanotech patents on average suggests a citation frequency of 9 percent greater than the average field. This rate is higher than the overall biotech CII. However, data on nanotech patents should be treated cautiously; the industry's true impact when measuring patent quality may take longer to determine.

Pennsylvania State University and MIT top the list, with nanotech patent CIIs of 2.5 and 1.9, respectively. UC San Francisco scores highest in terms of nanotech patent Science Linkage, i.e., employing the latest advancements to build on its own technology. UC San Diego and UC Santa Barbara score highest in Technology Cycle Time in this subfield.

Section 3: Commercialization Performance

Part 1: Based on AUTM data for the United States and Canada

This section documents how universities perform in the overall commercialization pipeline, including not just biotechnology, but all other research fields. It begins with an examination of research expenditures, then moves on to patent filings and patent-issued performance data, concluding with a summary of their relevance to Licenses Executed, Startups and Licensing Income.

Methodology

Data from the Association of University Technology Managers (AUTM) survey of U.S. and Canadian universities are used to analyze Pipeline Performance Measures to determine which universities are better positioned to capitalize on their innovation assets. Data for individual UC schools were obtained from the UC system web site, as well as their tech transfer offices.

The pipeline is evaluated in three stages:

1. A long-term analysis, using data from 1996 to 2004
2. A short-term analysis, spanning from 2000 to 2004
3. A one-year snapshot, based on data from the 2004 AUTM survey

For each stage, the universities are ranked according to three different scenarios:

1. In absolute terms (data is averaged for the short- and long-term analysis)
2. Normalized by million dollars of research expenditures
3. In terms of productivity (e.g., patents filed per invention disclosure)

We used 17 performance indicators for the short- and long-term analysis of AUTM data and nine for the comparison of AUTM with ASTP information for the one-year, 2004, snapshot. The long-term analysis is not detailed here but is available on our web site, www.milkeninstitute.org.

Assessing these scenarios helps us paint a more accurate picture of how universities perform in the innovation pipeline. The short- and long-term evaluations allow us to reduce the bias of aberrations that might be caused by a stellar or mediocre year in research, licensing and patenting activity.

We developed an overall index of university technology transfer and commercialization based upon the primary exit valves, a weighting system, and absolute and normalized values (relative to research expenditures), using transformed variables from the AUTM data set. Additionally, we compared U.S. and Canadian university performance with pipeline results in Europe, based on 2004 data from the Association of European Science and Technology Transfer Professionals (ASTP) 2006 Survey, conducted by Maastricht Economic Research Institute on Innovation and Technology.

We also spoke with personnel in university technology transfer offices with high Activity rankings, who offer some insight into the processes and environments that shape their tech transfer processes.

Caveats

University participation in the AUTM survey varies from year to year, and data availability and analysis vary by time period. For instance, the 1996–2004 long-term analysis includes 104 U.S. universities and 10 Canadian universities. The number increases to 120 from the United States and 15 from Canada for the 2000–2004 short-term period. The 2004 snapshot includes 157 American and 28 Canadian universities. Some important universities like Yale and Columbia are not included in our rankings because of insufficient participation in the AUTM surveys (Yale, for example, has not responded to the survey since 1999, and Columbia since 2002). Thus, it is not always possible to compare a particular university to another in each time period.

To reduce bias and facilitate comparisons over time, we normalized the data, using research expenditures in order to remove redundancies. However, we urge caution when interpreting normalized data, as they can be misleading.

The UC system includes more than 208,000 students and 120,000 faculty and staff, and is comprised of 10 campuses.[21] Its sheer size lends itself to top rankings in many of the areas we analyzed, even though we include both disaggregated[22] and system-wide data. Skewed results should be taken into consideration when interpreting the aggregate data, relative to individual campuses around the country.

Findings

In this section we present our findings of the innovation pipeline with an emphasis on the 2000–2004 performance. The findings reveal significant differentials between university research expenditures and commercialization success, as measured in terms of Patents Issued, Startup companies formed, Licensing Income received and the overall productivity of the technology transfer office.

The UC system, Johns Hopkins University and MIT top the list of U.S. and Canadian universities with the largest R&D funding for all three periods of the innovation pipeline. Within the UC system, UC Los Angeles received the largest R&D funding, more than $545 million in 2004. Johns Hopkins University, one of the most prestigious universities in the United States, has historically been the recipient of the largest funding grants from the U.S. National Institutes of Health.[23] In fact, with an average of $1.2 billion-plus in research expenditures over the period 1996–2004, John Hopkins took the No. 1 spot in this measure for all three periods of the analysis.

The University of Toronto is Canada's top-ranking university in the short- and long- term periods; it scores 45th among the U.S. and Canadian universities, with roughly $256 million in research expenditures during the 2000–2004 period. In the 2004 "snapshot" ranking, the University of Montreal ($370 million) and McGill University ($280 million) surpass the University of Toronto ($270 million) in research expenditures.

Innovation Pipeline Rankings - Top 10

Research Expenditure Total, 2000-2004

Rank	University	Country	US$ Mill.
1	University of California System	US	$2,488
2	Johns Hopkins University	US	$1,352
3	Massachusetts Inst. of Technology (MIT)	US	$901
4	University of Washington/Wash. Res. Fdn.	US	$727
5	University of Illinois, Chicago, Urbana, Champaign	US	$707
6	W.A.R.F./University of Wisconsin	US	$672
7	University of Michigan	US	$660
8	University of Pennsylvania	US	$627
9	Stanford University	US	$582
10	SUNY Research Foundation	US	$574

Sources: AUTM, Milken Institute

The top universities, in terms of Invention Disclosures for 2000–2004, are shown in the following table. Researchers in the UC system reported an average of 927 invention disclosures in the five-year period, twice as many as the second-ranking MIT. Within the UC system itself, UC San Diego ranks highest, with an average of 260 Invention Disclosures. The University of Toronto, with a 138 Invention Disclosures, is the highest-ranking Canadian university in this measure.

Innovation Pipeline Rankings - Top 10

Invention Disclosures, 2000-2004

Rank	University	Country	Number
1	University of California System	US	927
2	Massachusetts Inst. of Technology (MIT)	US	464
3	California Institute of Technology	US	434
4	Johns Hopkins University	US	356
5	W.A.R.F./University of Wisconsin	US	346
6	Stanford University	US	312
7	University of Pennsylvania	US	296
8	University of California, San Diego	US	260
9	University of Michigan	US	226
10	University of Minnesota	US	225

Sources: AUTM, Milken Institute

California Institute of Technology

Caltech recorded 549 invention disclosures in 2004, more than any other individual U.S. or Canadian university. Karina Edmonds, a licensing associate at the Caltech technology transfer office, explained that "we fully engage the faculty at Caltech and technologists at JPL (the Jet Propulsion Laboratory) in the patenting and licensing process, which builds a great deal of trust between our office and the inventors. We've created a culture where people are aware of the value of intellectual property, making it more likely that they report new inventions to the OTT. At both Caltech and JPL, we are also very active in going out and meeting with the inventors and keeping up with the new technologies."

"The biggest strength is our interdisciplinary research, which combines biotechnology and engineering expertise," said Scott Carter, Caltech's Assistant Director of Licensing. "We don't have a medical school. Therefore we're typically one step removed from the direct pharmaceutical market. For context, the biggest success (in the life sciences) is the invention of DNA sequencing at Caltech, where, to a large extent, revenues from the sale of DNA sequences drive the organization. This is an enabling technology."

Carter noted that biotech accounts for some 20 percent of the university's disclosures, but that probably a higher percentage of patent applications, roughly one-third, are within the life sciences.

The following table, showing Invention Disclosures per Million Dollars in Research Expenditures from 2000 to 2004, is topped by Brigham Young University in Utah, reporting an average of 5.63 inventions for the period. Top BYU research performers in this category include William G. Pitt, Ph.D., and Milton L. Lee, Ph.D., working in the field of chemical engineering. "I've always tried to solve problems, and a lot of the things that I do are in ripe new fields that have not yet been explored in the literature," said Pitt in a May 2006 telephone interview. "Most of my technologies are related to polymers for drug delivery, especially those that use ultrasound as a trigger for targeted drug release."

Three Canadian universities, Simon Fraser University, the University of Calgary and École de Technologie Supérieure (the Higher School of Technology, part of the Université du Québec network), rank among the 10 universities with the highest ratio of Invention Disclosures per million dollars of research expenditures.

Innovation Pipeline Rankings - Top 10

Invention Disclosures Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	Brigham Young University	US	5.63
2	University of Akron	US	1.17
3	Michigan Technological University	US	1.14
4	Simon Fraser University	CANADA	1.13
5	California Institute of Technology	US	1.12
6	East Carolina University	US	1.00
7	UTI Inc./University of Calgary	CANADA	0.99
8	Arizona State University	US	0.94
9	Rice University	US	0.92
10	École de Technologie Supérieure	CANADA	0.83

Sources: AUTM, Milken Institute

In the 2000–2004 period, the UC system filed the most patents, followed by Johns Hopkins University, Caltech, MIT and Stanford. UC San Diego is the highest-ranking UC school, with a five-year average of 172 patents filed.

The University of Pennsylvania, with 536 patents filed, takes the No. 1 spot in the 2004 "snapshot" ranking, outperforming the UC system aggregate,[24] which has 515 filings. "Patenting is a big part of our expenses," said John Zawad, Ph.D., Managing Director of the university's Intellectual Property and Technology Transfer office. "We work to protect our intellectual property as quickly as possible, filing approximately half of all invention disclosures." Patent filings are heavily biased toward the life sciences, he said. The most patents in Canada are filed by the University of British Columbia.

Innovation Pipeline Rankings - Top 10

Patents Filed, 2000-2004

Rank	University	Country	Number
1	University of California System	US	709
2	Johns Hopkins University	US	453
3	California Institute of Technology	US	423
4	Massachusetts Inst. of Technology (MIT)	US	389
5	Stanford University	US	323
6	University of Pennsylvania	US	277
7	Penn State University	US	194
8	University of Florida	US	189
9	W.A.R.F./University of Wisconsin	US	181
10	University of California, San Diego	US	172

Sources: AUTM, Milken Institute

Innovation Pipeline Rankings - Top 10

Patents Filed Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	Rice University	US	1.84
2	Brigham Young University	US	1.78
3	École de Technologie Supérieure	CANADA	1.39
4	Arizona State University	US	1.37
5	California Institute of Technology	US	1.09
6	University of Akron	US	0.93
7	Northeastern University	US	0.80
8	East Carolina University	US	0.77
9	Kent State University	US	0.75
10	University of Maryland, Baltimore County	US	0.72

Sources: AUTM, Milken Institute

The following table, depicting Patents Filed per Invention D isclosure, shows that Rice University in Texas ranks No. 1, with two patents filed per each disclosure. Canada's École de Technologie Supérieure scores second, with a ratio of 1.67. Arizona State University, the University of Hawaii and Johns Hopkins University are in the third, fourth and fifth place.

"We don't consider a high ranking on the number of patents filed per invention disclosure a success," said Jonathan Roberts, a licensing associate in the OTT at the University of Hawaii. "We rely on and file provisional patents on almost anything that comes in the door." Other OTTs may cherry-pick, going through great pains with industrial advisory boards etc., but Roberts said, "We file almost as many patents as disclosures. This is our model. We just don't have the budgetary resources to devote to an in-depth investigative process. We then search the market, following up on any of the inventors' industrial contacts as a first priority. We've found that the best market research is to put it out to industry."

Innovation Pipeline Rankings - Top 10

Patents Filed Per Invention Disclosure, 2000-2004

Rank	University	Country	Ratio
1	Rice University	US	2.01
2	École de Technologie Supérieure	CANADA	1.67
3	Arizona State University	US	1.46
4	University of Hawaii	US	1.35
5	Johns Hopkins University	US	1.27
6	Kent State University	US	1.21
7	University of California, Santa Cruz	US	1.20
8	University of Maryland at Baltimore	US	1.18
9	University of Virginia Patent Fndtn.	US	1.18
10	University of Manitoba	CANADA	1.16

Sources: AUTM, Milken Institute

Generally, Patents Issued provide a good indication of the innovative R&D occurring at a university. Strong patenting Activity is also a reflection of the commercial potential of these innovative ideas. For the period 2000–2004, the UC System, MIT, Caltech, Stanford and Johns Hopkins lead in the number of Patents Issued. According to the annual report published by the University of California Office of Technology Transfer, the UC system leads the world in patents received.[25]

McGill University in Montreal, Québec, with an average of 28 Patents Issued, ranks highest among Canadian universities. "McGill is internationally recognized as a world-class research university in the life sciences," said Michael Avedesian, Interim Director of McGill's OTT.[26] "Our patents come from right across the university: 19 percent from our medical faculty, 25 percent from our three teaching hospitals, 17 percent from our engineering faculty, 14 percent from agriculture and approximately 19 percent from the science faculty. About 60 percent of our patents are in the life sciences, one of McGill's core competencies."

Innovation Pipeline Rankings - Top 10

Patents Issued, 2000-2004

Rank	University	Country	Number
1	University of California System	US	278
2	Massachusetts Inst. of Technology (MIT)	US	152
3	California Institute of Technology	US	131
4	Stanford University	US	101
5	Johns Hopkins University	US	94
6	W.A.R.F./University of Wisconsin	US	88
7	University of California, San Francisco	US	75
8	Cornell Research Fdn., Inc.	US	69
9	University of Michigan	US	67
10	Washington University	US	62

Sources: AUTM, Milken Institute

The University of Akron in Ohio ranks at the top in this measure, with an average of 0.39 Patent Issued per Million Dollars of Research Expenditures (see the following table). Ken Preston, the university's Associate Vice President for Research and Director of Technology Transfer, attributes[27] the score "in large part, to our graduate polymer program, which is the largest in the United States, and to the innovative and productive success of the university's research in thin films, nano-fibers and biomedical products," and noted that his office has established close linkages with industry and developed academic programs with a view to graduating students qualified to meet the employment needs of local businesses.

McGill and Simon Fraser universities rank highest among Canadian institutions, with an average of 0.14 Patent Issued per Million of Research Expenditures for the 2000–2004 period.

Innovation Pipeline Rankings - Top 10

Patents Issued Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	University of Akron	US	0.39
2	California Institute of Technology	US	0.34
3	East Carolina University	US	0.30
4	Brigham Young University	US	0.26
5	Kent State University	US	0.25
6	University of Kentucky Research Fndtn.	US	0.20
7	University of California, Santa Barbara	US	0.18
8	Arizona State University	US	0.18
9	Northeastern University	US	0.18
10	Stanford University	US	0.17

Sources: AUTM, Milken Institute

When considering the average number of Patents Issued per Patents Filed, the top five universities are all located in the United States. The only Canadian university to make the top 10 list, the University of Waterloo, scores an average 0.63 Patent Issued per Patent Filed. Mount Sinai School of Medicine in New York City receives 1.13 Patents per Patent Filed, followed by the University of Kentucky (1.04), Washington University in St. Louis (0.88), Southern Illinois University (0.71) and Michigan State University (0.68).

Innovation Pipeline Rankings - Top 10

Patents Issued Per Patent Filed, 2000-2004

Rank	University	Country	Ratio
1	Mount Sinai School of Medicine of NYU	US	1.13
2	University of Kentucky Research Fndtn.	US	1.04
3	Washington University	US	0.88
4	Southern Illinois University	US	0.71
5	Michigan State University	US	0.68
6	Ohio State University	US	0.66
7	University of Dayton	US	0.65
8	University of Waterloo	CANADA	0.63
9	University of Kansas	US	0.62
10	Wayne State University	US	0.61

Sources: AUTM, Milken Institute

In the 2000–2004 period, the greatest number of Licenses Executed was recorded by the University of California system (256 licenses). Iowa State University takes second place in the ranking, with 213 Licenses Executed. At No. 28, the University of British Columbia is Canada's highest-ranking university in this measure, with 42 Licenses Executed.

Innovation Pipeline Rankings - Top 10

Licenses Executed, 2000-2004

Rank	University	Country	Number
1	University of California System	US	256
2	Iowa State University	US	213
3	W.A.R.F./University of Wisconsin	US	156
4	Stanford University	US	127
5	Massachusetts Inst. of Technology (MIT)	US	118
6	Johns Hopkins University	US	112
7	University of Washington/Wash. Res. Fdn.	US	86
8	University of Southern California	US	80
9	University of Minnesota	US	78
10	University of Illinois, Chicago, Urbana, Champaign	US	77

Sources: AUTM, Milken Institute

Brigham Young University does not appear in the top 10 ranking of Licenses Executed but ranks No. 1 on the normalized basis (per Million dollars of Research Expenditures), with 1.13 Licenses Executed. Iowa State University retains its No. 2 ranking in this measure, as well. Four Canadian universities make the top 10 list. The Université de Sherbrooke leads the way, with 0.56 License Executed per Million Research Expenditures, followed by McMaster University, with a ratio of 0.47.

Innovation Pipeline Rankings - Top 10

Licenses Executed Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	Brigham Young University	US	1.13
2	Iowa State University	US	0.97
3	University of California, Santa Cruz	US	0.75
4	Université de Sherbrooke	CANADA	0.56
5	McMaster University	CANADA	0.47
6	University of California, Santa Barbara	US	0.37
7	Michigan Technological University	US	0.34
8	University of Waterloo	CANADA	0.33
9	University of Western Ontario	CANADA	0.28
10	W.A.R.F./University of Wisconsin	US	0.23

Sources: AUTM, Milken Institute

In terms of Licensing Income for both the 1996–2004 and 2000–2004 periods, the UC system (and UC San Francisco, in particular), New York University (NYU), Florida State University (FSU) and Stanford University lead the list. Most of the Licensing Income generated at these universities came from one or two technologies; in the UC system, this technology was the hepatitis B vaccine licensed by UC San Francisco.[28] At first glance, UCSF would seem to be responsible for nearly three-quarters of UC's Licensing Income in the 2000–2004 period. But while it is true that the campus generates the largest share of the UC licensing income, the 2000–2004 and 1996–2004 averages are skewed by a $200 million lump-sum settlement payment to UCSF by Genentech in 2000.[29]

The biggest contributor to FSU licensing revenues has been Taxol, an anti-cancer drug introduced in 1993 by Bristol-Myers Squibb after the company signed a licensing agreement with the university.[30] The latest data from 2004, however, indicates that FSU is losing its premier position in this measure, the result of the introduction of generics[31] and the drop in Taxol royalties since the drug company stopped using the school's manufacturing process.[32]

The Cohen-Boyer patent, a seminal patent on recombinant DNA, has been the revenue-generating patent for Stanford University. The blockbuster patent expired in 1997, but licensing agreements with major biotech firms, such as Amgen, Genentech, and Eli Lilly,[33] have been responsible for nearly one-third of the school's Licensing Income.[34]

Innovation Pipeline Rankings - Top 10

Licensing Income, 2000-2004

Rank	University	Country	US$ Mill.
1	University of California System	US	$107.8
2	University of California, San Francisco	US	$79.8
3	New York University	US	$58.3
4	Florida State University	US	$45.6
5	Stanford University	US	$45.5
6	Massachusetts Inst. of Technology (MIT)	US	$39.0
7	W.A.R.F./University of Wisconsin	US	$33.4
8	University of Florida	US	$32.4
9	University of Minnesota	US	$30.3
10	Michigan State University	US	$30.0

Sources: AUTM, Milken Institute

In terms of Licensing Income per Million dollars in Research Expenditures, Florida State University (FSU) holds the top position for the 2000–2004 period, as shown in the following table. "It's actually a spike," said Licensing Director Jack Sams. "We had one very significant license for the method of manufacturing Taxol, an important cancer drug. That single license has generated several hundred million dollars, which biases our other data."[35]

Innovation Pipeline Rankings - Top 10

Licensing Income Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	Florida State University	US	$275,136
2	New York University	US	$273,977
3	Université de Sherbrooke	CANADA	$203,310
4	University of California, San Francisco	US	$182,562
5	Brigham Young University	US	$180,658
6	Wake Forest University	US	$151,125
7	Dartmouth College	US	$116,240
8	University of Rochester	US	$113,922
9	Michigan State University	US	$103,240
10	University of Florida	US	$84,520

Sources: AUTM, Milken Institute

The Université de Sherbrooke in the province of Québec had the highest ratio of licensing revenues generated per patent issued for the 2000–2004 period, receiving $9.1 million from licensing deals with an average of two patents issued. Again, a single technology was responsible for the largest share of licensing revenues generated at the Université de Sherbrooke: ACELP (Algebraic Code-Excited Linear Prediction) digital audio compression technology, with wireless and Internet speech-compression capabilities.

Innovation Pipeline Rankings - Top 10

Licensing Income Per Patent Issued, 2000-2004

Rank	University	Country	Ratio
1	Université de Sherbrooke	CANADA	$4,573,377
2	Florida State University	US	$2,920,376
3	New York University	US	$2,428,752
4	Wake Forest University	US	$1,551,250
5	Dartmouth College	US	$1,531,016
6	University of Rochester	US	$1,521,524
7	Tulane University	US	$1,058,474
8	University of California, San Francisco	US	$1,058,204
9	Emory University	US	$718,125
10	Brigham Young University	US	$694,417

Sources: AUTM, Milken Institute

Startups are yet another measure of university technology transfer activities. The leading universities for the 2000–2004 period are shown on the next page. MIT takes the No. 1 spot and scores highest in the "snapshot" 2004 period, as well. However, the UC system, which ranks second for the 2000-2004 period, drops to No. 3 (with five Startups) for the 2004 analysis, behind the University of Illinois (Chicago, Urbana-Champaign campuses), which reports 16 Startups. The University of Toronto is Canada's leading university, in terms of Startups for the 2000–2004 period; the University of Waterloo has the highest ranking among Canadian universities in 2004, with seven Startups. University startups have often played a leading role in the establishment of an industry. One such example is Genentech, a startup that resulted from a joint discovery by professors from Stanford and UCSF, and which is considered the genesis for the biotechnology industry.[36]

MIT ranks consistently high on our overall innovation pipeline measures.[37] These include: Research Expenditures, third place; Invention Disclosures, second place; Patents Filed, fourth place; Patents Issued, second place; Licensing Income, sixth place; and Startups, first place. "Clearly it's the research and the researchers that do it," said Jack Turner, Assistant Director of the MIT technology licensing office. "We have an unusually entrepreneurial faculty that helps identify potential innovation and then brings it to our OTT. It's a culture which has existed here for many years and is aided by our location within the Cambridge/Boston area." Turner's tech transfer responsibilities include coordination with the university's Lincoln Laboratory and the Media Lab. As such, he acknowledged, "MIT has a slight advantage, in that our AUTM survey numbers include the Lincoln lab and the federally funded R&D center data." His office's efforts and accomplishments are measured by the number of licenses and options consummated each year, he said. [38]

Innovation Pipeline Rankings - Top 10

Startups, 2000-2004

Rank	University	Country	Number
1	Massachusetts Inst. of Technology (MIT)	US	24
2	University of California System	US	20
3	California Institute of Technology	US	11
4	Georgia Institute of Technology	US	10
5	Stanford University	US	10
6	University of Michigan	US	9
7	University of Illinois, Chicago, Urbana, Champaign	US	9
8	University of Southern California	US	8
9	University of Pennsylvania	US	7
10	University of Minnesota	US	7

Sources: AUTM, Milken Institute

If startup formation is normalized per million research dollars, then three of the top five ranking universities are Canadian for the period 2000–2004: Simon Fraser University (with 0.194 Startup per Million Research Dollars); École de Technologie Supérieure (with 0.079 Startup per Million); and University of Waterloo (with 0.066 Startup per Million Research Dollars).

Rice University ranks within the top 10 in three of our innovation pipeline measure. It is the top school for patents filed per million dollars of Research Expenditures and patents filed per Invention Disclosure; and ranks ninth, as shown in the table below, for the number of Startups per Million Dollars of Research Expenditures. Nila Bhakuni, Director of Rice University's OTT, attributes the ranking to "the culture and attitude of the managers of this institution who support commercialization, a goal that has been in place since the OTT opened in 1998." She noted that Rice has had "a very large number of filings" in nanotechnology and that the university's business, natural sciences and engineering schools have partnered in the "Rice Alliance for Technology and Entrepreneurship," a program to educate faculty and the Houston business community.[39]

Innovation Pipeline Rankings

Startups Per Million Research Expenditures, 2000-2004

Rank	University	Country	Ratio
1	Simon Fraser University	CANADA	0.194
2	Brigham Young University	US	0.135
3	École de Technologie Supérieure	CANADA	0.080
4	University of Waterloo	CANADA	0.066
5	Kent State University	US	0.054
6	East Carolina University	US	0.053
7	Université de Sherbrooke	CANADA	0.049
8	University of Akron	US	0.048
9	Rice University	US	0.042
10	Arizona State University	US	0.037

Sources: AUTM, Milken Institute

With 1.41 Startups per Patent Issued, Canada's Simon Fraser University earns the highest ranking when measuring Startup companies formed for the period 2000–2004. In fact, six of the top 10 performers shown in the table below are located in Canada. Cyril Gibbons, the Interim Director of Innovations at the University of Toronto, noted that "in 1999, the U of T Innovations Foundation moved away from the more traditional OTT and toward a startup model, which is supported by our 'inventor-owned' IP policy." Biox Corporation, with a market cap exceeding $100 million, is one of the university's startups. But startup revenues tend to decrease over time. "There is tremendous dilution with startups," he said. "We may have a very concentrated equity initially, but as new partners come in and new shares are issued, it dilutes the investment to the initial partners." [40]

Innovation Pipeline Rankings - Top 10

Startups Per Patent Issued, 2000-2004

Rank	University	Country	Ratio
1	Simon Fraser University	CANADA	1.41
2	University of Waterloo	CANADA	1.24
3	Université de Sherbrooke	CANADA	1.10
4	École de Technologie Supérieure	CANADA	1.00
5	University of Montana	US	1.00
6	University of Toronto	CANADA	0.80
7	University of Louisville	US	0.78
8	Brigham Young University	US	0.52
9	Wright State University	US	0.50
10	University of Montreal	CANADA	0.44

Sources: AUTM, Milken Institute

Milken Institute University Technology Transfer and Commercialization Index

While any overall ranking of university technology transfer and commercialization success presents challenges, a comparison is useful for understanding the relative positioning among peers and in identifying best practices. Subtle nuances, due to the unique characteristics of individual universities, lead to divergent strategies toward IP commercialization. A university strong in engineering is likely to implement different strategies than one focused in biotech. We have created an index that encapsulates a systematic approach and measures overall outcome success.

We utilized AUTM survey information in order to have a consistent framework of outcome measures. AUTM doesn't contain some outcome measures — such as employment and market capitalization of firms whose origins were based in university IP — that would improve the comprehensiveness of an overall index. Nonetheless, the primary metrics on the commercialization exit valves from universities are captured. Outcome measure statistics over the 2000–2004 period were used in creating the index.

Our first consideration in developing an overall index is the proper balance between absolute and relative measures of commercialization. For example, holding all other factors constant, a large research university that attracts considerable public funding should have greater commercialization outcomes — such as licensing income and startups — than a smaller university. However, absolute outcome measures don't address the productivity or efficiency of commercialization activity. Thus, we scale the outcome results by research expenditures to gain a relative measure. Nonetheless, absolute measures are important because of the impact of large institutions. Size is significant in assessing the overall influence of research universities. These indicators were filtered for each outcome measure. We give an equal weighting (50 percent) to absolute and relative performance.[41]

Next, we determined the appropriate outcome measures. We chose to focus on primary exit valves, such as licensing income, startups, licenses executed and — to gain some measure of what occurred earlier in the pipeline that could lead to future success — patents granted. Licensing income and startups are the most direct measures of outcome. They give a clear valuation of the quality of university-based intellectual property. Therefore, they received the greatest weights, at 35 percent each. Licenses executed and patents granted were each assigned a weight of 15 percent because they are earlier-stage outcome measures.

These indicators were filtered by taking the natural logarithmic transformations of the absolute and relative measures. This process results in a scoring system that doesn't overly reward an institution for being substantially above its peers on any single measure but does reward for consistent performance across measures. Universities were benchmarked to the highest-scoring institution (top score equals 100) on each of the eight subcomponents comprising the four outcome index measures. Finally, the overall top-scoring university was re-benchmarked to 100.

Milken Institute Technology Transfer Index Methodology Weights

Metric	Absolute	Relative	Overall Composite
Patents Issued	50 %	50 %	15 %
Licenses Granted	50 %	50 %	15 %
Licensing Income	50 %	50 %	35 %
Startups	50 %	50 %	35 %

This methodology results in the Milken Institute University Technology Transfer and Commercialization Index, with the top 25 universities listed in the accompanying table. MIT is the leader on overall outcome measures. It scores first in startups by a wide margin, averaging more than 23 new firms per year — ahead of the entire University of California system (with nine campuses), which reports 20 startups. MIT has been spinning out new firms from its research laboratories for more than 50 years. Academic entrepreneurship was a critical part of the culture long before the process was formalized by the establishment of MIT Technology Licensing Office in the late 1980s.[42] But the university doesn't derive its lofty position from startups alone; it scores 95.2 on patents issued (second to Caltech) and 90.6 on licensing income (out of 100). The university's diverse research strengths in the physical and engineering sciences, in addition to biotechnology, give it unique opportunities for commercialization.

Milken Institute University Technology Transfer and Commercialization Index
2000-2004

Rank	Institution Name	Patents Issued Score	Licenses Executed Score	Licensing Income Score	Startups Score	Overall Score
1	Massachusetts Inst. of Technology (MIT)	95.17	79.89	90.64	100.00	100.00
2	University of California System	97.26	85.25	95.16	83.24	96.59
3	California Institute of Technology	100.00	70.77	87.12	86.60	92.94
4	Stanford University	91.56	84.28	93.76	77.02	92.65
5	University of Florida	84.82	71.41	92.57	69.26	86.11
6	University of Minnesota	78.92	77.46	91.02	69.24	85.55
7	Brigham Young University	66.87	80.60	86.13	77.57	85.41
8	University of British Columbia	74.36	74.09	82.73	77.42	84.23
9	University of Michigan	82.70	72.25	77.98	74.89	82.54
10	New York University	73.68	63.30	100.00	58.16	81.63
11	Georgia Institute of Technology	76.80	60.51	72.79	83.41	80.95
12	University of Pennsylvania	76.41	72.05	83.95	67.15	80.83
13	University of Illinois, Chicago, Urbana-Champaign	72.80	74.55	77.60	72.72	80.35
14	University of Utah	77.08	70.80	81.56	66.01	79.40
15	University of Southern California	70.77	79.81	70.37	75.72	79.28
16	Cornell Research Fdn., Inc.	86.31	75.99	77.99	61.51	78.69
17	University of Virginia Patent Fndtn.	66.53	75.11	79.41	68.48	78.52
18	Harvard University	78.82	76.06	87.54	52.45	77.68
19	University of California, San Francisco	88.60	11.63	99.73	62.39	77.19
20	North Carolina State University	78.41	73.80	74.40	64.77	76.94
21	SUNY Research Foundation	79.51	64.36	84.63	58.01	76.90
22	W.A.R.F./University of Wisconsin	87.59	86.65	90.52	38.99	76.86
23	McGill University	77.47	68.76	72.12	69.24	76.80
24	University of Washington/Wash. Res. Fdn.	75.11	76.10	88.49	50.03	76.54
25	University of North Carolina, Chapel Hill	78.48	76.86	71.14	64.21	76.00

Sources: AUTM, Milken Institute

The UC system scores second on the overall index, at 96.6, recording scores no lower than 82.2 on any of the four composite measures. The UC system is first on the Number of Patents, placing it second on the composite measure, which includes Patents per Million Research Expenditures. Additionally, it is second on the Licensing Income composite and first in the absolute measure subcomponent. UC San Francisco is the highest-scoring individual campus, at 19th. This is remarkable, since the university records a very low score of 11.6 on Licenses Executed, which largely reflects its strategy to focus on licensing IP that is likely to have a substantial impact, principally in biotechnology. That strategy is in turn reflected in total Licensing Income, where UCSF ranks first overall, without the other UC campuses. UC San Diego and UC Berkeley rank in the top 30, as well. Both score high on absolute measures, but not so well when normalized for research expenditures.

Caltech ranks third on the index, with an overall score of 92.9. This is notable for a relatively small institution, but its research quality is very high. Caltech scores first on the Patents composite score by recording strong positions in Absolute Number of Patents and Patents Normalized per Million Research Expenditures. It scores in the upper 80s for both Licensing Income and Startups, and is well positioned in biotechnology research competency. Similar to MIT, Caltech has strengths in engineering and the physical sciences, assisting its aggregate performance.

Ranking fourth, Stanford University displays its entrepreneurial focus. The university scores above 90 on Patents and Licensing Income, where it ranks fourth as well. Stanford's business school has played a key role in developing a culture that encourages and rewards researchers who actively engage in commercialization efforts. Stanford is the final university to score above 90 overall, at 92.7. The University of Florida ranks fifth, perhaps surprising to many, but has seen remarkable success at its office of technology transfer. While Florida's position is assisted by its Gatorade income, it scores relatively high on all four composites. Its weakest area is in Startups, but the university has seen improvement in recent years, led by its OTT head, David Day. Florida focuses on translational, as opposed to basic research, and this is witnessed in its outcome success.

Leading the second tier of the top 10 is the University of Minnesota, at sixth. Minnesota scores high on both absolute Licensing Income and Income Normalized to Research Expenditures. This combination gives it a composite licensing score of 91.0. Startups are its weakest area. Another surprise to some might be Brigham Young University, which is seventh. It is among the national leaders in Licensing Income relative to Research Expenditures and has achieved exceptional performance in the life-sciences area, especially in biotechnology. BYU recorded fairly consistent marks in all four outcome measures.

At eighth, the University of British Columbia is the highest-ranking Canadian university, recording a score of 84.2 overall. Its best score is in Licensing Income; its lowest score is 74.1, in Licenses Executed, thus displaying a consistent performance. The University of Michigan ranks ninth overall. It had consistently high scores, as well, but its best outcome achievement is on Patents. New York University ranks 10th; its position is attributable to its first-place score on Licensing Income. NYU scores second on Licensing Income Relative to Research Expenditures, just behind Florida State University.

Georgia Tech ranks 11th, placing particularly high on Startups. The university has focused efforts on buttressing its ability to form companies from its intellectual property. Penn is 12th, recording its best score on Licensing Income. The University of Illinois, at 13th, owes its position to consistent commercialization outcome scores. Illinois' lowest score is 72.7, and its highest is 77.6. The University of Utah ranks 14th, placing two schools from the state in the top tier. The University of Southern California is 15th, logging outcome scores in the 70s on all measures.

Cornell scores 16th, achieving its highest score in Patents, followed by the University of Virginia, with strong performance in Licensing Income. Harvard is 18th, pulled down by a relative weakness in Startup activity. Its Startups score is a low 52.5, while it has a Licensing Income score of 87.5. This suggests that Harvard creates valuable intellectual property but hasn't established the academic entrepreneurial culture present at its Cambridge-based neighbor, MIT. An average score on Startups would thrust it into the top 10. North Carolina State University is 20th.

SUNY scores 21st, scoring highest on licensing income, but as happened with Harvard, a low Startups score pulls it down. An extreme case of unbalanced technology transfer and commercialization can be found at the University of Wisconsin. A Startups score of 39.0 drops it to 22nd overall. It has a Licensing Income score in the low 90s, and Patents and Licenses Executed in the high 80s. Many of the federally approved stem cell lines were developed by UW researchers. Excluding Startups, the university would rank fifth overall. McGill University ranks 23rd, closely followed by the University of Washington. Rounding out the top 25 is the University of North Carolina, Chapel Hill.

Part 2: Based on ASTP/ AUTM Data for the U.S., Canada and Parts of Europe

This section highlights the relative performance of individual universities from Europe, Canada and the United States in the overall commercialization pipeline.

Methodology

We used data from the Association of European Science and Technology Transfer Professionals (ASTP), as well as AUTM data from the United States and Canada, to analyze the pipeline performance measures that indicate which universities are better positioned to capitalize on their innovation assets. The pipeline is evaluated for a one-year snapshot, based on the latest 2004 data from the ASTP and AUTM surveys. As discussed in Part 1, the universities are ranked according to three concepts: (1) in absolute terms; (2) normalized per million dollars of research expenditures; and (3) in terms of productivity (e.g., patents filed per invention disclosure).

Government and nonprofit research institutes are excluded from the AUTM data analysis throughout this study, except here, in our 2004 snapshot innovation pipeline section. In this section, we include data from seven governmental or nonprofit research institutes in Europe. Because these entities play major roles in shaping technology transfer activities, their exclusion would not adequately reflect the true nature of Europe's performance.

All European numbers in this section are reported in purchasing price parity U.S. dollars (PPP$).

Caveats

We tried to include the maximum number of universities but were limited by the paucity of global comparable data. Additional transparency should be a priority, especially since much research funding comes from public sources. One bright spot in this otherwise arid space is "The 2006 ASTP Survey,"[43] which provides disaggregated data on 23 European public research organizations: 16 individual European universities/university hospitals and seven governmental or nonprofit research institutes.

Findings

The following tables provide a 2004 snapshot of the innovation pipeline for 208 institutions: 23 European, 157 American and 28 Canadian universities. We limited our presentation to the nine innovation pipeline activities that determine the performance of a European research entity.

In Germany, most academic research is conducted in organized research institutes, such as the Max Planck. The following table shows that the Garching Innovation GmbH (the technology transfer company of the Max Planck Society) ranks third for total Research Expenditures in 2004.

Innovation Pipeline Rankings - Top 10

Research Expenditure Total, 2004

Rank	University	Country	US$ Mill.
1	University of California System	US	$2,708
2	Johns Hopkins University	US	$1,547
3	Garching Innovation GmbH (Max Planck Society)	Germany	$1,331
4	Massachusetts Inst. of Technology (MIT)	US	$996
5	University of Washington/Wash. Res. Fdn.	US	$809
6	University of Illinois, Chicago, Urbana, Champaign	US	$789
7	W.A.R.F./University of Wisconsin	US	$741
8	University of Michigan	US	$730
9	SUNY Research Foundation	US	$689
10	Stanford University	US	$673

Sources: AUTM, ASTP, Milken Institute

The Institute Français du Petrole, in France, ranks first in the following two tables for Patents Filed and Patents Issued in 2004. Energy is the focus of research at the institute's three locations — Rueil-Malmaison, the main research center near Paris; Solaize, near Lyon; and Pau.[44]

Innovation Pipeline Rankings - Top 10

Patents Filed, 2004

Rank	University	Country	Number
1	Institute Français du Petrole	France	951
2	University of Pennsylvania	US	536
3	University of California System	US	515
4	Stanford University	US	428
5	California Institute of Technology	US	416
6	Johns Hopkins University	US	402
7	Massachusetts Inst. of Technology (MIT)	US	287
8	Georgia Institute of Technology	US	273
9	University of Florida	US	233
10	University of California, San Diego	US	193

Sources: AUTM, ASTP, Milken Institute

Innovation Pipeline Rankings - Top 10
Patents Issued, 2004

Rank	University	Country	Number
1	Institute Français du Petrole	France	892
2	University of California System	US	270
3	Massachusetts Inst. of Technology (MIT)	US	159
4	California Institute of Technology	US	142
5	W.A.R.F./University of Wisconsin	US	93
6	Johns Hopkins University	US	89
7	Stanford University	US	87
8	Washington University	US	79
9	University of Michigan	US	74
10	University of Illinois, Chicago, Urbana, Champaign	US	59

Sources: AUTM, ASTP, Milken Institute

The Netherlands' Delft University of Technology ranks second in the table below for Patents Issued per Patent Filed in 2004. The university's research schools, institutes and 13 research centers offer a broad range of disciplines, including biotechnology.[45]

The Politechnica University Bucharest in Romania ties in its third-place ranking with the University of North Texas Health Science Center. The Politechnica, which has a reputation of excellence in engineering research,[46] reports two patent applications and four patents granted in 2004.

Innovation Pipeline Rankings - Top 10
Patents Issued Per Patent Filed, 2004

Rank	University	Country	Ratio
1	Brandeis University	US	35.00
2	Delft University of Technology	Netherlands	24.29
3	University of North Texas Health Science Center	US	20.00
4	Politechnica University Bucharest	Romania	20.00
5	University of Texas Southwestern Med. Ctr.	US	12.96
6	University of Arkansas for Medical Sciences	US	12.50
7	University of Central Florida	US	11.82
8	Carnegie Mellon Univervisty	US	10.40
9	East Carolina University	US	10.00
10	Lakehead University	CANADA	10.00

Sources: AUTM, ASTP, Milken Institute

The French Institut National de la Santé et de la Recherche Médical, or INSERM, is "the only French public organization entirely dedicated to biological, medical and public health research."[47] INSERM, one of the seven European government or nonprofit research institutes included in our database, reports in its ASTP survey response 95 invention disclosures and 508 licenses in 2004.

Innovation Pipeline Rankings - Top 10

Licenses Executed, 2004

Rank	University	Country	Number
1	INSERM	France	508
2	University of California System	US	273
3	W.A.R.F./University of Wisconsin	US	203
4	Iowa State University	US	166
5	Massachusetts Inst. of Technology (MIT)	US	134
6	Johns Hopkins University	US	100
7	University of Minnesota	US	100
8	Stanford University	US	89
9	University of Illinois, Chicago, Urbana, Champaign	US	88
10	Purdue Research Foundation	US	87

Sources: AUTM, ASTP, Milken Institute

In the United Kingdom, the publicly funded Medical Research Council works with government agencies, universities, research charities and industry partners on matters of health research.[48] Its tech transfer company, Medical Research Council Technology (MRCT) is located in Oxford and, as shown in the following table, ranks seventh for Licensing Income per Patent Issued in 2004, reporting almost $26 million licensing income and 28 patent applications, with 22 patent grants.

Innovation Pipeline Rankings - Top 10

Licensing Income Per Patent Issued, 2004

Rank	University	Country	Ratio
1	New York University	US	$4,597,932
2	Wake Forest University	US	$3,696,347
3	University de Sherbrooke	CANADA	$2,658,313
4	University of Colorado	US	$1,839,172
5	University of Massachusetts	US	$1,591,926
6	University of Rochester	US	$1,363,532
7	Medical Research Council Technology	UK	$1,169,545
8	University of Minnesota	US	$1,162,743
9	University of Mississippi	US	$1,030,423
10	Emory University	US	$992,832

Sources: AUTM, ASTP, Milken Institute

Three European agencies and/or academic institutions appear on the next table, ranking third (the Medical Research Council Technology in the UK), sixth (Satakunta Polytechnic in Finland) and 10th (the National Network for Technology Transfer, DTU, in Denmark) for Startup companies formed in 2004. Finland and Denmark also appear in the second table below, ranking first and third, respectively, for Startups per Million Dollars of Research Expenditures.

Innovation Pipeline Rankings - Top 10
Startups, 2004

Rank	University	Country	Number
1	Massachusetts Inst. of Technology (MIT)	US	20
2	University of Illinois, Chicago, Urbana, Champaign	US	16
3	Medical Research Council Technology	UK	16
4	Georgia Institute of Technology	US	15
5	California Institute of Technology	US	14
6	Satakunta Polytechnic	Finland	14
7	University of Michigan	US	13
8	Duke University	US	10
9	University of Pittsburgh	US	10
10	National Network for Technology Transfer, DTU	Denmark	10

Sources: AUTM, ASTP, Milken Institute

Innovation Pipeline Rankings - Top 10
Startups Per Million Research Expenditures, 2004

Rank	University	Country	Ratio
1	Satakunta Polytechnic	Finland	2.745
2	Brigham Young University	US	0.212
3	National Netwerk for Technology Transfer, DTU	Denmark	0.121
4	University of Waterloo	CANADA	0.096
5	Simon Fraser University	CANADA	0.086
6	University of North Carolina, Charlotte	US	0.083
7	University of Toledo	US	0.073
8	Rensselaer Polytechnic Inst.	US	0.068
9	University of Notre Dame	US	0.063
10	Michigan Technological University	US	0.058

Sources: AUTM, ASTP, Milken Institute

The Antwerp Innovation Centre in Belgium ranks second for Startups per Patent Issued in 2004, as shown in the following table. It reports two startup companies formed, along with a total of 14 patent applications and one patent grant in the same year. The center is a member of the nonprofit organization FlandersBio, which represents the Flemish life-sciences R&D industry.[49]

Innovation Pipeline Rankings - Top 10

Startups Per Patent Issued, 2004

Rank	University	Country	Ratio
1	University of Montana	US	2.00
2	Antwerp Innovation Centre N.V.	Belgium	2.00
3	University of Vermont	US	1.50
4	University of Toronto	CANADA	1.25
5	Old Dominion University	US	1.00
6	Simon Fraser University	CANADA	1.00
7	Texas Tech University	US	1.00
8	University of Notre Dame	US	1.00
9	Utah State University	US	1.00
10	Brigham Young University	US	0.83

Sources: AUTM, ASTP, Milken Institute

The following table provides a snapshot comparison of U.S., Canadian and European universities overall for 2004. These innovation pipeline measures have been normalized by research expenditures, but benchmark comparisons are fraught with data difficulties. For example, more than half of Research Expenditures reported in the ASTP survey are from research institutes, but they account for less than 10 percent of the AUTM total. With this in mind, we separated universities from non-university research institutes.

Another source of bias is introduced by the higher response rate in the AUTM survey, in which 96 of the top 100 U.S. research universities participated. These universities represent 87 percent of total academic research expenditures. In contrast, while the ASTP sample includes many leading European universities, several top-performing universities did not participate. This suggests that the average European university statistics may be biased downward, relative to their U.S. and Canadian counterparts.

AUTM and ASTP Performance Per Million Research Expenditures

Universities, 2004

	U.S.	Canada	Europe	Ratio	
Average Research Expenditures (US$ Mil.)	*225*	*178*	*100*		
	Per Million Research Expenditures			U.S./Canada	U.S./Eur
Invention Disclosures	0.40	0.14	0.32	2.98	1.25
Patent Applications	0.25	0.06	0.12	4.21	2.06
Patents Granted	0.09	0.01	0.04	6.09	2.38
Licenses Executed	0.11	0.07	0.09	1.58	1.25
Licensing Income (US$)	27,825	12,934	11,988	2.15	2.32
Startups Established	0.01	0.01	0.03	1.74	0.37

Sources: AUTM, ASTP, Milken Institute

The average research expenditures for universities in U.S. dollars totals $225 million for the United States, $178 million for Canada and $100 million for Europe. Even with the exclusion of several top European research universities, the results highlight the Canadian and U.S. advantage in funding. Among universities, the United States leads in Invention Disclosures, Patents Filed and Granted, Licenses Executed and Licensing Income. European universities surpass their U.S. and Canadian counterparts in just one category: Startups established. European universities establish approximately three times as many new firms relative to research expenditures as their counterparts in the United States and Canada. This reflects an emphasis on startup activity as a public-policy priority. However, this higher startup rate says nothing about survival rates and whether startups become publicly traded firms with high levels of employment. The last two columns in the tables show the ratio of U.S. performance relative to Canada and Europe. Wherever the ratio is greater than 1.0, the U.S. performance exceeds that of Canada and Europe.

In 2004 European university performance comes closest to the United States in Invention Disclosures and Licenses Executed. Still, the U.S. performance is 25 percent above Europe on these two measures. In addition, the United States has more than twice as many Patents Filed and Granted, relative to Research Expenditures. This may reflect the greater focus on biotechnology research and the ability to patent genetic material in the United States. For Licensing Income, U.S. universities have $27,825 per Million Research Expenditures, substantially higher than the $11,988 for European universities. This comparison must be made cautiously, as the licensing income is the result of the cumulative investment in research over many years. Nevertheless, it does tend to indicate that U.S. universities rely on a few substantial deals that generate a disproportionate share of income.

AUTM and ASTP Performance Per Million Research Expenditures

Non-University Institutions, 2004

	U.S.	Canada	Europe	Ratio	
Average Research Expenditures (US$ Mil.)	*120*	*25*	*318*		
	Per Million Research Expenditures			U.S./Canada	U.S./Europe
Invention Disclosures	0.44	0.47	0.211	0.94	2.08
Patent Applications	0.25	0.40	0.119	0.63	2.13
Patents Granted	0.10	0.04	0.024	2.43	3.99
Licenses Executed	0.16	0.19	0.135	0.88	1.21
Licensing Income (US$)	81,853	53,172	27,952	1.54	2.93
Startups Established	0.01	0.01	0.003	0.68	2.62

Sources: AUTM, ASTP, Milken Institute

In contrast, European non-university institutions attract far higher research expenditures on average than those in either the United States or Canada; $318 million versus $120 million and $25 million, respectively. Canadian non-university institute performance exceeds that of the United States for Invention Disclosures, Patents Filed, Licenses Executed and Startups established. The U.S. institutes generate more Licensing Income relative to Research Expenditures than do those in either Canada or Europe.

U.S. universities are the world leaders in transferring intellectual property to the private sector. The United States retains a large lead in biotech research at its top universities. Nevertheless, as European, Asian and other governments in the Americas realize how important universities have become in the global innovation race and, indeed, in the race for national competitiveness, the U.S. lead and advantage of absorptive capacity should not be taken for granted. Furthermore, as cultural barriers to university involvement in commercial applications diminish, the American advantage seems likely to dissipate.

An important aspect of the university-based commercialization process that technology transfer office survey data doesn't capture is how many successful large companies grew from startups. The giant Amgens and Genentechs most differentiate the economic impact of U.S. university-based biotechnology commercialization from other technology transfer efforts around the world.

Endnotes:

1. Van Raan, A.F.J. 1998. "In matters of quantitative studies of science the fault of theorists is offering too little and asking too much." *Scientometrics,* 43, pp.129–139.
2. Deutsche Forschungsgemeinschaft (German Research Foundation). 2003. "Funding Ranking 2003 Institutions–Regions–Networks. DFG Approvals and Other Basic Data on Publicly Funded Research." DFG Stifterverband. http://www.dfg.de/en/ranking/index.html.
3. Fractional field counting, as opposed to full address counting, prevents the distortion of the measurable impact of scientific research that may occur when excessive citation behavior results in some publications being cited more frequently.
4. Perkel, Jeffrey M. "The Future of Citations." *The Scientist*. Oct. 24, 2005. p. 24.
5. The recent trend shows that the language bias diminishes as European authors publish more frequently in English. This is particularly true for many scientific fields including biotechnology. See: Van Leeuwen, et al. 2000. "First Evidence of Serious Language-Bias in the Use of Citation Analysis for the Evaluation of National Systems." *Research Evaluation*, 9(2), pp.155-156.
6. Wong, Perry and A. Bedroussian. 2006. *Economic Benefits of Proposed University of Central Florida College of Medicine,* Santa Monica: Milken Institute.
7. It is interesting to note that the April 2006 SSRN (Social Science Research Network) "Top Business School Rankings" lists Harvard Business School as the top U.S. business school and the University of London — London Business School, as the top international business school worldwide.
8. Refers to regular utility patents issued in the U.S. patent system. Other categories of U.S. patents, such as plant patents, design patents, reissues and continuations, are not included. Regular utility patents are considered to be the key category in assessing patent quality.
9. Note, in September 2005, a tenth University of California campus was opened in Merced.
10. DeVol, Ross C., P. Wong, J. Ki, A. Bedroussian and R. Koepp. 2004. *America's Biotech and Life Science Clusters: San Diego's Position and Economic Contribution*, Santa Monica: Milken Institute.
11. http://www.universityofcalifornia.edu/research/biotech.html.
12. http://www8.utsouthwestern.edu/home/research/index.html.
13. http://www.ebdi.org/.
14. http://www.redoxpharm.com/collaboration.asp.
15. Numbers from the Association of American Medical Colleges as reported by *U.S. News & World Report*, cited by DeVol, Ross and R. Koepp with P. Wong and A. Bedroussian. 2003. *The Economic Contributions of Health Care to New England*, Santa Monica: Milken Institute.
16. http://www.news.wisc.edu/packages/stemcells/thomson_bio.html.
17. http://www.wicell.org/news/index.jsp?catid=26.
18. http://www.javelin-ventures.com/kinetique_portfolio.htm.
19. DeVol, Ross C., P. Wong, J. Ki, A. Bedroussian and R. Koepp.
20. http://www.biotech.bham.ac.uk/BTnews47/BEPMercia.htm.
21. http://www.universityofcalifornia.edu/campuses/welcome.html.
22. Data for individual UC schools was obtained from the UC System web site, as well as their tech transfer office.
23. Johns Hopkins Medicine Facts & Figures, 2004–2005. Pps 19, 33. See: http://www.hopkinsmedicine.org/ about/factsfigures05.pdf.
24. The University of California Merced is the 10th campus in the UC system. Because UC Merced opened in Sept. 2005, data analysis of the UC system includes the following nine schools: Berkeley, Davis, Irvine, Los Angeles, Riverside, San Diego, San Francisco, Santa Barbara and Santa Cruz.
25. University of California Technology Transfer Program. Annual Report 2004.
26. Milken Institute telephone interview with Michael Avedesian. June 1, 2006.
27. Milken Institute telephone interview with Kenneth G. Preston, PE, JD. June 6, 2006.
28. http://www.dailycal.org/article.php?id=734.

V. Country Profiles

V. Country Profiles

Introduction

We identify five factors that influence the commercialization of university-based biotech research at all geographic levels — regional, national and sub-national. They include:

1. National innovation policy
2. Funding and venture capital
3. Clusters of biotechnology
4. University technology transfer mechanisms
5. Commercialization success: patents and licensing

1. National Innovation Policy and Culture

The role of national government, the establishment of public policy and the consistent application of intellectual property laws, if they indeed exist, not only vary widely but may also be layered, as is the case with European Union member countries.[1] Governmental agencies and ministries, in combination with private-sector investors and venture capitalists, market and oversee local and national innovation initiatives, such as incentives, access to funding and joint marketing.

It is not the intent of this study to analyze laws pertaining to contracts, patents and licensing, but to raise awareness of the significant variations among the countries we examine and the implications for successful commercialization of university research. Thus, we offer brief discussions of each country's federal policy environment. National governments are involved because of the traditional economic theory of market failure: the inability of market forces alone to research, develop, produce and commercialize the biotech products these governments consider ingredients of national competitiveness. Governments influence such factors as financing universities and university research labs; fiscal policies related to the national rate of savings; entrepreneurship; the protection of IP; income distribution; and sophistication of demand.

Quality human capital is one of the best investments to advance the commercialization of biotech research. Whether or not local governments and community organizations have a direct functional responsibility for the education of their constituents, in many countries, each has a leadership mandate to ensure that colleges and universities achieve excellence in math, science, medicine, finance, IT and management programs.

2. Funding and Venture Capital

Public coffers remain the largest source of university research funding, but recent years have seen exponential growth in industry support from large multinational enterprises, as well as smaller, specialized firms. Access to capital is a primary issue for small businesses and entrepreneurs; and risk capital is a financial engine for product commercialization.

VC firms gravitate toward and cluster around locations of growing success.

Although VC funding slumped after the technology bubble began to burst in 2000, it remains a crucial investment source for knowledge-intensive industries,[2] and because it targets new technologies and dynamic entrepreneurs, it is commonly considered the most influential kind of risk capital funding. VCs are also key to the whole system of early-stage financing; venture capitalists manage and market the businesses spawned by creative intellectual innovators. Successful global firms like Amgen demonstrate that the participation of VCs in mergers, acquisitions and strategic alliances can strengthen and propel a startup into a global success.

VC firms tend to specialize in particular markets or technologies; they gravitate toward and cluster around locations of growing success. Founders of successful firms may themselves become local investors, nurturing creative clusters.[3]

3. Clusters of Biotechnology

Successful biotech clusters depend on the quality of medical and technological research, as well as the availability of research scientists and technicians. Such universities are hotbeds of technological innovation and entrepreneurship, and force new frameworks for our moral values.

When a university seeks potential licensees, it typically begins close to home — working with businesses within the same state or region — because the company often needs access to the inventor (as a consultant to assist in the development process). Increasingly, however, the industry demands of biotech development lend themselves more toward external networking and global geographic dispersion, mitigating the advantages of clustering.

In today's global economy, the basic research, applied science, capital investment, product development, manufacturing, marketing and distribution of biotechnology commonly involve a team of interdisciplinary experts working across multiple industries in many countries. This highly networked activity creates an ideal environment for a global division of labor, using researchers and facilities best suited to the needs of an individual project or program. "Furthermore, geographic proximity of all major researchers in a particular scientific field is unlikely given the opportunity cost that universities face in buying into a single research agenda. Thus, if firms are to have access to the technical knowledge embodied in the top scientists in a field, they will be forced to establish links with researchers outside of their geographic area."[4]

4. University Technology Transfer Mechanisms

Scientific excellence is necessary but, by itself, insufficient for market success. Thus, many universities around the world have established offices to facilitate the transfer of their technology from scientific discovery to industrial development. More specifically, technology transfer offices often identify intellectual property, provide fund-raising assistance to scientists, manage IP protection, and publish and commercialize their research.

Universities engage in technology transfer operations for various reasons, including faculty recruitment and retention, stronger university-industry linkages, enhanced university prestige and, more generally, greater technology transfer for the social and economic benefit of the national or regional economy.[5] No single technology transfer office model/mechanism will ideally suit these multiple objectives. For example, a university may have a single centralized OTT or several offices (serving individual faculty needs). Its tech transfer needs may be handled by an external OTT within a consortium of multiple research entities, public and private.

Technology mining often emanates from the private sector — a pull from the outside rather than a push from within.

National policies may dictate the allocation of university license income — the division between the university and the scientist(s). Huge variations exist among the nations studied, from 100 percent of revenues across Sweden to zero in China. In the United States, while the percentages differ among institutions, net tech transfer revenues are generally divided equally among the researcher(s), the university department(s) and the university's overall budget fund.[6]

One difficulty with scientist incentive plans is that given the time lag between invention and commercialization,[7] rewards to inventors often accrue after their academic input, lessening the effectiveness of incentives. Universities can make projections of likely returns and payments, but this is a risky strategy. Formula-based approaches can be effective for providing incentives, especially when based on gross rather than net returns; and the adoption of equity, as a form of compensation offered by cash-starved startups, is growing.[8]

The majority of OTTs struggle to achieve ambitious goals with very limited resources. Technology mining therefore often emanates from the private sector — a pull from the outside rather than a push from within. Jim Schaeffer, Ph.D., with the West Coast (U.S.) Licensing and External Research Division of Merck Research Labs, explained the company's role: "Merck is actively engaged in the search for university technology with commercialization potential. By 2006, we will have 18 scientific scouts and staff working in locations throughout the world. In 2004 we evaluated nearly 6,000 total opportunities (emanating from all sources) and had approximately 50 major agreements or deals signed."

5. Commercialization Success: Patents and Licensing

Most successful university biotech transfers generate patents. All patents, however, are not created equal, and not every patent sees commercialization. "Ninety-nine percent of patent owners never even bother to file suit to enforce their rights," writes Mark A. Limy in "Rational Ignorance at the Patent Office," a 2000 working paper for the Berkeley Program in Law and Economics. "They spend $4.33 billion per year to obtain patents, but no one seems to know exactly what happens to most of them."

There are no international patents.[9] Rather, patent applications are filed, granted and enforced in each country's relevant patent office where protection is sought. Examples of regional cooperation include the European Patent Office (EPO) and the African Regional Intellectual Property Organization; in addition, one may file an international application under the Contracting State of the Patent Cooperation Treaty. The EPO, the Japan Patent Office (JPO) and the United States Patent and Trademark Office have a trilateral cooperation arrangement on patents.

The current patent process in every corner of the world is cumbersome, expensive and time-consuming. Procedural requirements and fees differ among countries and regions. However burdensome, complicated and imperfect, patents are intended to protect IP. International entrepreneurs wishing to license university research are urged to use caution in considering foreign licensees, especially if the research was government-funded, which may mandate local development, control manufacturing and apply disincentives to global development and/or restrict profit-taking. There are also concerns that strategic alliances with universities allow drug companies to profit from research supported by taxpayers.[10]

Endnotes:

1. EU Commission Regulation EC #240/96 of 31/01/96 on the application of Article 85(3) of the EC Treaty to certain categories of technology transfer agreements. EU O.J. L 31/2 of 09/02/96. See: http://europa.eu.int/eur-lex/en/lif/dat/1996en_396R0240.htm.
2. DeVol et al., 2004. *Biopharmaceutical Industry Contributions to State and U.S. Economies*, Santa Monica: Milken Institute.
3. Wu, Weiping. 2005. "Dynamic Cities and Creative Clusters." World Bank Policy Research WP 3509.
4. Audretsch, D.B. and M. Feldman. 2003. "Small-Firm Strategic Research Partnerships: The Case of Biotechnology." *Technology Analysis & Strategic Management.* 15(2).
5. Thursby, J.G., R. Jensen and M.C. Thursby. 2001. "Objectives, characteristics, and outcomes of university licensing: A survey of major U.S. universities." *Journal of Technology Transfer*. 12.
6. http://www.cogr.edu/docs/BayhDoleQA.htm.
7. An earlier study (1991) by Roger G. Ditzel, "Public Law 96-517 and Risk Capital: The Laboratory-Market Connection," *Journal of the Association of University Technology Managers* III, found that the university licenses that do succeed in bringing a product to market take an average of about eight years to do so.
8. Feldman, Maryann, I. Feller, J. Bercovitz and R. Burton. 2002. "Equity and the Technology Transfer Strategies of American Research Universities." *Management Science*, 48(1).
9. http://www.wipo.int/patentscope/en/patents_faq.html#worldwide_patent.
10. Gerth, J. and S. Stolberg. "Drug Companies Profit from Research Supported by Taxpayers." *New York Times*, April, 23, 2000.

Europe Overview

1. National Innovation Policies

In general, the United Kingdom leads Europe's biotech industry. The government of Margaret Thatcher is credited with spurring the business climate that gave rise to the country's biotech industry.[1] Oxford and Cambridge are renowned for their biotech research.

Germany has achieved a reputation of excellence in the life sciences. But quality basic university research does not automatically lead to successful commercialization. In the Netherlands, for example, universities perform high-quality research, but "the annual number of innovative start-ups is lagging behind in international perspective … and as a result, renovating and innovating abilities in the Dutch economy are limited."[2] In Sweden as well, the universities are productive and research investment is healthy, but neither has resulted in hoped-for commercialization.[3] Public policy in Germany and the UK has targeted biotech development and commercialization. But no single model is applicable across nations, even within the European Union.

In the past decade, innovation policy across Europe has supported the development of high-tech sectors by harmonizing policies. Creating a European Area of Research and Innovation within the European Knowledge Area is a step in the EU's path toward achieving that goal.[4] Even though the responsibility lies within national governments, science is coordinated at the regional level. However, despite harmonization reforms, Europe's regulatory environment is still somewhat fragmented and layered — for example, numerous agencies oversee drug pricing, and trade issues continue to pose barriers.[5]

The 1999 Bologna Declaration brought broad reforms to advanced education in Europe. It was a restructuring commitment taken by 29 participating countries to achieve greater comparability and integration of study programs at higher education institutions across Europe. Overarching commitment is evident in efforts by some 40 countries to create a European Higher Education Area by 2010.[6] However, in 2004, German Finance Minister Hans Eichel warned that Europe was unlikely to reach its targets by 2010.[7] This may be partially due to the fact that some European leaders postponed much-needed reforms. But regulatory advances continue; in November 2005, the European Commission drafted legislation to harmonize marketing of gene therapy, cell therapy and tissue engineering, or "advanced therapy medicinal products."[8]

The European Union as a whole is less involved in basic research funding than is each individual nation but accepts its role in research and technology development. The EU does engage in co-funding innovation initiatives but leaves each unique member-state to deliver its own national programs.

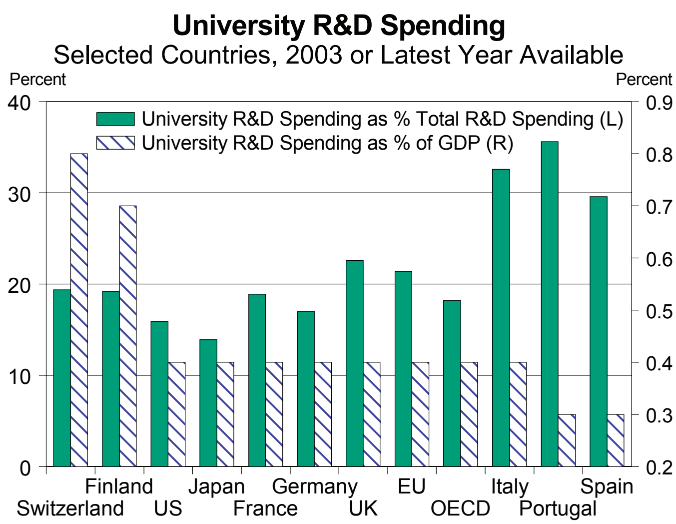
2. Funding and Venture Capital

At the risk of overgeneralization, Europeans are cautious investors. Evidence suggests that risk aversion is the predominant culture of the region. Europeans are still very conservative toward failure — punishment may be evidenced by social exclusions and difficulty obtaining future financing. And, according to EuropaBio, "the financing gap is probably the biggest single barrier to European competitiveness in biotechnology."[9]

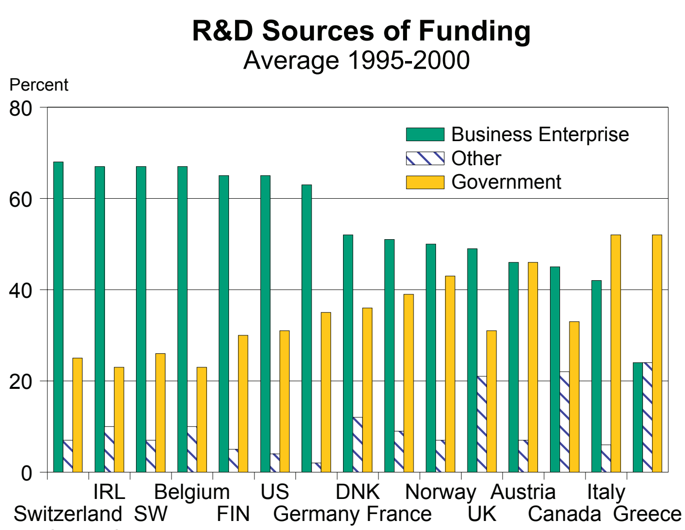
In 2004, Europe's biotech stock indexes outperformed those in the United States, according to a report by Ernst and Young.[10] However, the performance between European and American venture capital funds, in general, is just the opposite. Relative to the United States, the overall profitability of VC returns in Europe is lower, especially at early-stage investing. Further, the European Commission reports that "US funds return cash sooner, indicating that their investments are not only more profitable, but also are realized earlier."[11]

The UK is Europe's leading venture capital market. "The London stock markets, the London Stock Exchange (LSE) and the Alternative Investment Market (AIM) continue to dominate the European IPO scene," although, according to the European Association for Bioindustries, "other exchanges are still seeing large offerings."[12] The European Private Equity and Investment Capital Association promotes venture capital investment.

In 2003, university R&D spending as percent of total R&D spending exceeded 30 percent in Italy and Portugal. Almost 70 percent of Switzerland's R&D expenditures were financed by business enterprises. The Irish, Swedish, Belgian, Finnish, U.S. and German funding structure corresponds to that of Switzerland. In contrast, government funding as a percentage of R&D financed expenditures is particularly high in Italy and Greece.



Source: Ministry of Education, University research, 2003



Source: Science and Technology Indicators 2003

3. Clusters of Biotechnology

The east of England is home to "the highest concentration of biobusiness activity in Europe," according to ScienceCareers.org, citing the Cambridge-MIT Institute.[13] Cambridge, its hub, "is home to over 185 biotech companies, 20 percent of the world's Nobel Prize winners in medicine and chemistry, 17 of the U.K.'s publicly quoted biotech companies and a quarter of the public biotechs in Europe."[14] In Germany, Cologne, Heidelberg and Munich are noteworthy for their clusters.

Greece has expanded its R&D system over the past decades, along with the country's growing participation and support for EU and international R&D programs. Research is conducted by institutes and public universities, including the Aristotelian University, the National and Capodistrian University, as well as the National Technical University (Athens) and the Universities of Patras, Crete,

Thrace and Ioannina. The Bio-Medical Research Foundation of the Academy of Athens conducts research in biology and medicine at the molecular, biochemical and cellular level. The foundation controls seven research centers.[15]

Medicon Valley is a regional cluster that includes Denmark and southern Sweden, and "has grown into one of Europe's three largest regions for the practice of biotechnology and biomedicine. It has also expanded geographically. Originally conceived as a region consisting of areas along the Øresund Sound (including greater Copenhagen and Sweden's southerly Skåne region), it has grown along the coastlines to incorporate Aarhus, Denmark and Göteborg, Sweden."[16]

Eric Poincelet, Director General of BioVision, supports the concept of cross-border clusters, arguing that "the geographical association of transnational regional clusters, which traditionally compete against each other, will facilitate achieving the necessary critical mass enabling Europe to stay in the biotech race."[17] He cites the following four "meta clusters":

European "Meta Clusters"

Meta Clusters	Country
Meta Cluster 1	Northwestern Area of Europe
	Home to the largest number of biotechs, with the highest concentration of posts IPO companies. Suffers from lack of collaboration between the UK and France A "LOXBRIDGE" initiative (London, Oxford and Cambridge) could help together with a better intergration of the Benelux regional clusters.
Meta Cluster 2	The Axis Barcelona-Heidelberg "BioValley"
	Would become reality, if Rhone-Alpes, Switzerland, Bavaria and Lombardy work together.
Meta Cluster 3	Nordic Countries
	Clustered trans-nationally, creating the ScanBalt initiative.
Meta Cluster 4	AG Biotech
	If the new member countries, together with Vienna and Berlin, decide to specialize in the European agriculture sector.

Sources: http://www.teknoscienze.com

4. University Technology Transfer Mechanisms

In the 1990s, academic spin-offs "gained acceptance in Europe as a valid method of technology transfer. Entrepreneurship was also recognized as a key instrument of technology innovation," according to research by Degroof and Roberts (2004), citing the European Commission reports of 1998 and 2000.[18]

But a hindrance to the commercialization of university research remains within the regulatory structure: "the European patent system bars patents on work that has already been publicly disclosed,"[19] including academic publications, meaning that faculty members must file for full protection before they publish articles about their work. In contrast, inventors in the United States may file for patent protection up to a year after any publication.[20] The realignment of patent filing and journal publication time frames is an area for European public policy review consideration in order to protect and capture the full value of intellectual property.

"In the EU, the patent system has been underused because of the lack of harmonization of the legislation for patent protection."[21] Uniform implementation of the Biotechnology Patent Directive in the EU has not been completed in some member states.[22] A number of European countries assign ownership to the research institute. Other countries, including Germany and Denmark, have a principle of "shared benefits" for both scientist and institution. In France, universities bear much of the cost of patent protection, which effectively discourages academic filings.[23]

Many countries in Europe have changed laws or introduced legislation to enable university tech transfers. Germany enacted laws in 2002, and "Finland could make the change in 2006, leaving Italy and Sweden as the only Western Europe countries retaining the professor's privilege," wrote Blumenstyk.[24] The following table summarizes the sharing of intellectual property rights revenues in a number of countries.

Regimes in Europe for Assigning IPRs at Public Research Organizations

Regime	Basic Principle	Countries
1. Scientist is the owner	All revenues to the scientist	Italy, Spain, Finland and Sweden
2. Research organization is the owner	2a. All revenues to the research organization	The Netherlands, France, Ireland, Portugal, Austria and Belgium
	2b. Ownership and revenues are shared between the scientist and the organization	Denmark, Germany and U.K.

Sources: European Commission, EPOHITE, 2003

Spain, for example, has been advancing its science and technologies since the late 1980s. The impact of government subsidies, mainly through external and competitive funding, has been a key instrument in reforming the Spanish public research system. For instance, OTTs were developed under the first national R&D plan (1988–91); by 2002, there were 164 OTTs, 32 percent of which were registered as university OTTs. Spain's Patent Law of 1986 forms the basic regulatory framework for patents issued to public research organizations. Ownership is assigned to the university with inventors (including students), who are granted the right to "fair compensation."

Universities in Spain take an active role in creating joint research-based companies, using their own risk capital. The following table illustrates trends in the direct commercial exploitation of IPR by Spanish universities.

TTOs and University Research-Based Firms
Spain

Research-Based Firms	Firms created in 2001
Total firms created	77
Spin-offs and start-ups	36

Sources: Unidad de Politicas Comparadas (CSIC)
Woring Paper Feb. 26, 2002, Milken Institute

5. Commercialization Success: Patents and Licensing

"Across the whole of Europe, venture capital support for the biotech sector remained relatively robust, with about — 940 million being put to work in 2004."[25] Germany has the most biotech companies in Europe, according to a report by Ernst & Young.[26] At the end of 2003, Europe's biotechnology sector[27] had approximately an equal number of companies as the United States. However, "the US biotechnology industry employs twice as many people, spends approximately three times as much on research and development, raises 3 or 4 times as much venture capital, and has access to 4 times as much debt finance."[28]

The European Commission Biotechnology Innovation Scoreboard (BIS) tracks EU biotech innovation and has created a Best Performance Index as a report card of how countries fare in biotech. In 2002, Belgium scored well in government R&D expenditures; Sweden was recognized for the number of its biotech publications and biotech firms; Switzerland recorded high innovation; and Denmark placed high in terms of U.S.-issued patents and drug approvals. Other EU leaders include Germany (in citation counts, European Patent Office applications and VC funding); the United Kingdom (strength in public spending and publications); and France (based on its high numbers of Ph.D. graduates).[29]

Endnotes

1. Gwynne, Peter and G. Page. 1999. *European Biotechnology.* See: http://www.sciencemag.org/products/ euro2.dtl.
2. Ministry of Economic Affairs. 2003. "Entrepreneurship in the Netherlands — Knowledge transfer: developing high-tech ventures." June.
3. Devrim Göktepe. "Investigation of University Industry Technology Transfer Cases: A Conceptual and Methodological Approach, Part 2."
4. European Commission. 2000. "Towards a European Research Area." *COM (2000),* 6.
5. www.ey.com/global/content.nsf/UK/Media_-_05_06_01_DC_-_Global_biotech.
6. Reichert, Sybille and Christian Tauch. 2005. "EUA (European University Association) Trends IV: European Universities

Implementing Bologna."
7. Schepens, Hugo. 2004. "The New Europe: A Brighter Future for Biotechnology?"
8. Draft of the European Parliament Legislative Resolution. See: http://www.europarl.europa.eu/meetdocs/ 2004_2009/documents/pr/617/617323/617323en.pdf .
9. EuropaBio. 2005. "Biotechnology in Europe: 2005 Comparative study." Lyon: BioVision.
10. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report.* 2005.
11. Rosa, Catarina Dantas Machado and Kristiina Raade. 2006. "Profitability of venture capital investment in Europe and the United States." European Economy, European Commission, DG for Economic and Financial Affairs. Economic paper No. 245, March. See: http://ec.europa.eu/economy_finance/publications/ economic_papers/2006/ecp245en.pdf.
12. EuropaBio. 2005. "Biotechnology in Europe: 2005 Comparative study," Lyon: BioVision. April. See: http://www.europabio.org/events/BioVision/CriticalI%20studyBiotech-Europ.pdf
13. http://sciencecareers.sciencemag.org/advanced_search/results?v:project=ezpubproj&render.function =xml-feed&sources=ezpub&query=east+of+england.
14. http://www.erbi.co.uk/bfora/systems/xmlviewer/default.asp?arg=DS_ERBI_ABOUTART _43/.
15. Laboratory of Political Communication at the U. of Athens. EPOHITE. 2003. See: http://www.cordis.lu/ greece, www.bioacademy.
16. Gwynne, Peter. 2000. "Biotechnology Europe: Leveling the Playing Field," *Science Magazine.* See: http://www.sciencemag.org/products/eurotech.dtl.
17. Poincelet, Eric. 2004. "The European BioClusters: Too Little, Too Many, Too Late: Is the fight over yet?" *Biotechnology in Europe Today*. See: http://www.teknoscienze.com/images/documenti/ supplements/poincelet1.
18. Degroof, Jean-Jacques and Edward B. Roberts. 2004. "Overcoming weak entrepreneurial infrastructures for academic spin-off ventures." WP, MIT Industrial Performance Sector. See: http://web.mit.edu/ipc/ www/pubs/articles/IPC04-005.pdf.
19. Blumenstyk, Goldie. 2005. "Turning Research – Slowly – Into Riches," *The Chronicle of Higher Education*, Oct. 7.
20. Ibid.
21. De Juan, Veronica. 2002. "Comparative Study of Technology Transfer Practices in Europe and the United States," *Journal of the Association of University Technology Managers*, XIV.
22. Thumm, Nikolaus. 2003. Swiss Federal Institute of Intellectual Property.
http://www.ige.ch/E/jurinfo/documents/j10005e.pdf. Thumm's research notes, "Eight member states of the European Union (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands and Sweden) have been taken to the European Court of Justice for their failure to implement the EU directive."
23. www.sciencemag.org/feature/e-market/benchtop/euro2.shl.
24. Blumenstyk, Goldie. 2005.
25. EuropaBio. 2005.
26. As cited in "Science and Technology Overview 2002: Germany." International Trade Canada. See: http://www.infoexport.gc.ca/science/GER_2002-en.htm;jsessionid=AGYKJIBDTNKNCCTHNCACFEQ.
27. The definition of biotech here excludes medical device companies, clinical research organizations and drug companies, which use little biology. Also excluded are consultancies, tech transfer organizations, incubator centers, investors in biotech companies and organizations that are active in biotech firms but which do not have a formal corporate legal identity.
28. The European Association for Bioindustries. *Biotechnology in Europe: 2005 Comparative Study. Critical I comparative study for EuropaBio*. Lyon: BioBision, p.5. http://www.europabio.org/events/BioVision/CriticalI%20studyBiotech-Europ.pdf.
29. Ibid.

Austria

1. National Innovation Policy

It wasn't until 1999 that the Austrian government began to get aggressive in support for its biotechnology industry, with the establishment of its first sector-development program.[1] The following year, the government set forth a second initiative, Life Science Austria, or LISA, as it came to be known; LISA offers seed financing for new ventures, helps startups with business plans, facilitates access to investors around the world and provides funding for the patent process.[2]

The University Act UG of 2002 assists university innovation and tech transfer activities. In particular, the act enables Austria's universities to take up service inventions and directly exploit them. The 2004 uni:invent program provides commercialization support for universities.[3] Also significant is the Austrian Genome Research Programme, GEN-AU.

> Austria's biotech sector focuses on human medicine, environmental biotechnology and biotechnology applications with regard to process development. The sector employs approximately 10,000 employees, with a turnover per year of about € 2.5 billion.

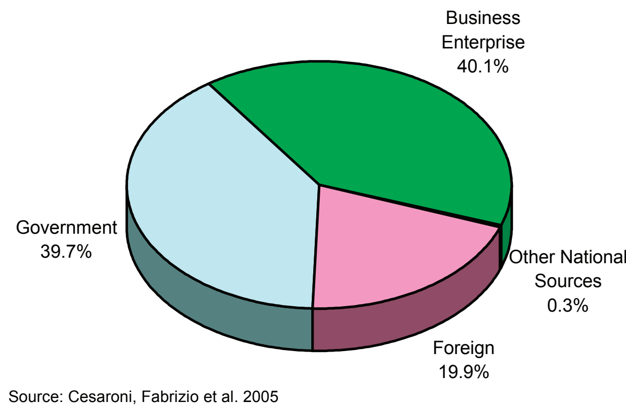
By 2000, Austria had taken steps to remedy another problem that was contributing to slow biotech-sector development: not enough lab space.[4] Government initiatives were expected to "make large amounts of lab space available," according to Till Jelitto, a faculty member at the University of Veterinary Sciences in Vienna and Manager of Corporate Planning at biotech startup Austrian Nordic AG.[5]

Effective 2005, Austria's corporate income tax rate dropped to 25 percent, and additional tax deductions from 25 percent to 35 percent were granted for research. These fiscal incentives make Austria an attractive location for global investors.[6]

2. Funding and Venture Capital

The Industrial Research Promotion Fund (which disburses 59 percent of all public biotech funds) and the Austrian Science Fund are major funding sources, as are the City of Vienna, the Austrian National Bank and the federal state Niederösterreich. Direct contract research from federal ministries plays a minor funding role; however, the Ministry of Economic Affairs, along with the Science and Transport Ministry, is a key player in the public research funding of biotechnology.[7]

The following pie chart shows the percentage shares of R&D funding in Austria.



A report by EPOHITE (Efficiency of Innovation Policies in High Technology Sectors in Europe) states that the availability of venture capital in Austria is generally low, compared to its Western European neighbors.[8]

3. Clusters of Biotechnology

Austrian public research activities are concentrated at universities. Most are located in Vienna, but several biomedical research clusters exist around research institutes in Innsbruck, Graz and Salzburg[9] (10 universities are working on biomedical research in Vienna, Graz, Salzburg and Innsbruck). Austria is home to more than a hundred biotech companies, primarily located in the Vienna Region, Tyrol and Styria.

The Vienna region includes the Campus Vienna Biocenter, Vienna General Hospital, the Novartis Research Institute Campus, the University of Veterinary Medicine and the University of Natural Resources and Applied Life Sciences. Among the global pharmaceutical players are Baxter (European headquarters), Boehringer Ingelheim Austria, Roche Austria, Novartis and Sandoz. Eli Lilly's Eastern European headquarters are located in Vienna.[10] The region's achievements in biotech have generated approximately 80 percent of Austrian startups.[11]

In Lower Austria (Niederösterreich), the following centers, called *technopols*, have emerged: Wiener Neustadt, which focuses on "MIT Modern Industrial Technologies" (life-science links with nanotech and microsystems technology, the MedAustron Project); and Krems (the Centre for Biomedical Technology at Danube University Krems), which emphasizes red biotech.[12]

Danube University Krems

Danube University Krems is the first university in Europe to offer an MBA degree in biotech and pharmaceuticals management focused on business startups.

Tyrol (Tirol) established Life Sciences Tyrol, a portfolio of universities focused on molecular cell biology and neuroscience (Medical University Innsbruck and the University of Innsbruck); biotech companies (e.g., Amynon Biotech, which focuses on tumor diagnostics, and Innovacell, specializing in tissue engineering); and biotech centers and clusters (the Center for Academic Spin-offs, the Competence Center for Medicine Tirol and Health Information Technologies Tirol).[13]

Styria (Steiermark) has announced plans to establish itself as a "human technology" cluster region in medical biotech. The Medical University Graz has preclinical and clinical research in cardiovascular disease, cancer and inflammation. Styria is home to such biotech companies as Oridis Biomed (human tissue bank, gene and protein expression profiling) and Molekulare Biotechnology (high-level protein expression systems).[14]

4. University Technology Transfer Mechanisms

In response to weak biotechnology patent activities, the Austrian government has introduced policy initiatives to enhance university technology transfer: In 1998, the Ministry of Economic Affairs created Technology Marketing Austria, or tecma, a program meant to act as an OTT, to encourage and facilitate the marketing of intellectual property.[15] The following year, the Ministry of Economic Affairs and the Ministry of Science and Transport inaugurated Impulseprogramm Biotechnologie to promote startup companies among researchers by assisting with patenting activities and startup financing.[16]

In addition, the government has supported cooperation among research centers, universities and private entities (competence centers) within the "K plus" collaborative funding programs, which are research centers set up as limited liability companies for the express purpose of enhancing research-business cooperation. The Competence Center for Biomolecular Therapeutics was created with funding from the Ministry for Science and Transport in 2000.[17] Meanwhile, Lower Austria was inaugurating a far-reaching "Technology Offensive," establishing centers of expertise and business clusters. Important areas in research are microsystems technology, nanotechnologies and biomedicine. As stated earlier, the 2002 University Act and the uni: invent program both address issues of university technology transfer.

5. Commercialization Success: Patents and Licensing

From its onset, the uni:invent program instituted a network of innovation scouts at Austrian universities; currently, more than 20 scouts work at fourteen universities.[18] "Already in the first year of the program, some 100 invention reports were processed. About a third of the projects were recommended for patenting and can thus be marketed."[19]

Research Institute of Molecular Pathology (IMP)

IMP is Boehringer Ingelheim's biomedical research institute. Its opening in 1988 laid the foundation for today's Campus Vienna Biocenter. The institute offers an international Ph.D. program, jointly organized with the University of Vienna. The average research output is 80-100 publications in peer-reviewed journals a year. IMP scientists have filed more than 80 patent applications.

Numerous successful biotech companies are based in Vienna. For instance, as of publication time, cancer vaccine specialist Igeneon's leading anti-cancer product was in Phase III clinical trials, while Austrianova (a producer of innovative therapies for pancreatic cancer) emerged as the first Austrian biotech to acquire orphan drug status for a product with Europe's Medical Evaluation Agency, in July 2003.[20]

Intercell AG

Intercell is a 1998 Campus Vienna Biocenter spin-off. The company develops therapies against infectious diseases and cancer. According to CEO Alexander von Gabain, "The ideal conditions provided by Vienna … helped us make the successful transition from very promising research-and-development operation to an international enterprise with a well-rounded product and pipeline portfolio." In 2003, the company raised $50 million of venture capital.

The Vienna Region ranks in the top 10 percent of the official EC regions for biotech patent registrations.[21]

Oridis Biomed

Oridis Biomed, a biotech startup based in Graz, was founded in 2001 by Helmut Denk and Kurt Zatloukal, pathology professors in Graz, together with Peter Swetly (Boehringer Ingelheim, Veterinary University Vienna) and Nikolaus Zacherl (Novartis, IMP Vienna). It emerged from the Medical University Graz and develops treatments against cancer and metabolic diseases of the liver. The company has discovered more than 50 targets for liver disease and is working on lead compounds for drug development.

Endnotes:

1. *Biotechnology in Europe Today*. "Biotech Industry in Austria: Promising white and red applications." See: http://www.teknoscienze.com/images/documenti/supplements/austria1.pdf.
2. Ibid.
3. Bundesministerium für Wirtschaft und Arbeit. 2005. uni:invent. *Patent exploitation for universities*. See: http://www.bmwa.gv.at/NR/rdonlyres/0EA3C613-BF84-490B-9D66-1C35F5E136C8/19704/ Folderuniinvent.pdf.
4. Gwynne, Peter, "Biotechnology Europe: Leveling the Playing Field," *Science*. August 2000. http://www.sciencemag.org/products/eurotech.dtl.
5. Ibid.
6. Austria Knowledge Base. See: http://www.lowtax.net/lowtax/html/offon/austria/austriaspec.html.
7. *Biotechnology in Europe Today*.
8. http://www.epohite.fhg.de/Documents/Wp2_national_reports/NR_Austria_final.pdf.
9. Baier, Barbara, E. Griessler and Renate Martinsen. 2000. "National Case Study of Austria." Project EU-SOE1-CT-1117. European Biotechnology Innovation System, Institut für Höhere Studien, Wien. See: http://www.sussex.ac.uk/spru/documents/austria.pdf.

10. Hoebertz, Astrid. 2005. "Austrian Biotechnology RTD Landscape," *Austria-Russia Science Day*. See: http://www.bit.ac.at/inco/doks/HOEBERTZ_Astrid_1.ppt#3.
11. *Biotechnology in Europe Today.*
12. Lower Austria's Business Portal. See: http://www.niederoesterreich-wirtschaft.at/en/popups/ willkommen.html.
13. Hoebertz, Astrid. 2005. See: http://www.bit.ac.at/inco/doks/ HOEBERTZ_Astrid_1.ppt#27.
14. Hoebertz, Astrid. 2005. See: http://www.bit.ac.at/inco/doks/HOEBERTZ_Astrid_1.ppt#3.
15. *European Trend Chart on Innovation*. "Country Report: Austria, September 2002–August 2003." See: http://trendchart.cordis.lu/Reports/Documents/Austria_CR_September_2003.pdf.
16. http://www.boku.ac.at/iam/ebe/austria.pdf.
17. Baier, Barbara, E.Griessler and Renate Martinsen. 2000.
18. Bundesministerium für Wirtschaft und Arbeit. 2005.
19. Ibid.
20. LISA VR News. Life Science Austria Vienna Region. 2004. "Vienna Region: Austria's Biotech Hub." See: http://www.vienna.lifescienceaustria.at/english/index_e.html.
21. *Biotechnology in Europe Today*.

Belgium

1. National Innovation Policy and Culture

Belgium is made up of three communities (French-, Dutch- and German-speaking) and three regions (Brussels-Capital, Flemish and Walloon, or Wallonia). Each region and community has autonomy for its innovation policy. Regions set policy for specific research and economic development; communities decide on fundamental research and education at universities and other public institutions; and the federal government develops research policies at the national level (i.e., space research), as well as international agreements.[1] This arrangement acts as a double-edged sword; each region and community can create legislation according to its specific needs, but spillover effects do not easily cross borders. Therefore, even though the Inter-ministerial Conference for Science Policy fosters cooperation among the three areas of government,[2] limited cooperation exists, with industry-science links and establishment of technology transfer centers suffering from the delineated policy structure.

The Brussels-Capital region has little experience in innovation policy-making, as the topic has only recently been brought into the political arena. R&D funding had little or no regulation in the 1990s. In early 2002, innovation policy came to everyone's attention when Parliament adopted a framework regulation on the Stimulation and Funding of Scientific Research and Technological Innovation, which redefined R&D funding in the region.[3]

The Flanders region updates its innovation policy annually. Seven broad and general objectives were set for 2000–2004, including the promotion of technical research in both the public and private sectors, and the building up of university and research institute infrastructure.[4]

The Walloon (Wallonia) region has established an "International Elite" program to increase the already high number of foreign researchers (up to 20 percent) in Walloon universities. The program grants scholarships to researchers taking on work sponsored by a company or a Walloon research center.[5]

Belgium has a skilled work force that is one of the most productive in Europe. "About 32 percent of the country's population has a higher education degree. Nineteen percent of the total student population is enrolled in science, applied sciences, health and medical sciences."[6]

2. Funding and Venture Capital

Belgium has benefited from the strong presence of major pharmaceutical firms, which have been the main source of industrial funding.[7] Because Belgium does not allocate R&D funds to the defense sector, government spending on R&D is much lower than for its European neighbors.[8]

Interuniversity Attraction Poles (IAP)

The IAP program is the only public funding program that provides financing to collaborating research teams in both the French- and Dutch-speaking communities. Its annual budget, approximately $504 million, supports nearly 300 researchers and 2,000 publications a year.

In 1999, $223.7 million was spent on R&D in Belgium. Large biotech investments supported university spin-offs in the pharmaceutical industry. In 2001, the federal government accounted for 33 percent of the $1.43 billion R&D budget.[9] Almost 70 percent of R&D funding comes from private sources.[10]

Regional Investment Companies (GIMV in Flanders and SRIW in Wallonia), created by the government in the 1980s, have provided risk capital in life-science R&D. Elsewhere, the Biotech Fund Flanders takes on the role of temporary partner for startups.[11]

As of 2001, Flanders accounted for 42 percent of Belgium's total R&D budget. The Institute for the Promotion of Innovation by Science and Technology in Flanders provides funds and support services to companies, institutes and researchers. Biotech there is also supported through VC funds from Biotech Investment Partners, GIMV Life Sciences and Quest for Growth.

Wallonia has doubled its share of the national R&D budget since 1996 and accounted for 9 percent of the national total in 2001.[12] In 2003, the National Fund for Scientific Research budget totaled $19.4 million.[13] Also providing funds for universities in French Wallonia and Brussels is the Special Research Fund.

Belgium's 2005 spending on R&D is 2 percent of GDP, higher than the EU average.

Banks and security firms increasingly support the nation's biotech sector. "Most banks have special funds for start-up companies. Quest for Growth is such a listed Belgian seed fund specializing in biotech investments."[14]

3. Clusters of Biotechnology

Belgium enjoys one of the most central locations in the European Union. The low cost of real estate, relative to the rest of Europe, helps Belgium's science parks and incubators offer startups a competitive launch pad.[15] The country has three regional biotech clusters: Flanders, Wallonia and Brussels.

The Flanders region leads the nation for cluster development. Flanders Interuniversity Institute for Biotechnology (VIB) is a cluster unto itself, with nine university departments and five labs.[16] The nonprofit FlandersBio includes Flemish biotech companies, research institutes, investors and service industries.[17] The organization works closely with the Flanders Foreign Investment Office and VIB.

Since 2000, the Walloon region has passed two initiatives encouraging and supporting clusters: an economic clusters program (funded by the directorate-general for economy and employment) and a technology clusters program (funded by the directorate-general for research, technology and energy). In 2002, a second call for proposals resulted in 13 applications and five projects chosen, involving 66 partners.[18]

4. University Technology Transfer Mechanisms

University technology transfer offices are a relatively new phenomenon in Belgium, and few specific rules exist to regulate the intellectual property rights of university-created research. Patenting by universities has increased in recent years, especially in the biotech field, attributable to an increase in Belgian universities' propensity to patent, as well as the increasing popularity of biotech.[19] There are 16 universities and research centers active in life sciences in the country.

Flanders Interuniversity Institute for Biotechnology (VIB)

The VIB research institute, with a staff of 850 scientists and a yearly budget of about $70 million, brings together four Flemish Universities (University Gent, K.U. Leuven, University of Antwerp and Free University of Brussels). "Using advanced gene technology, VIB studies the functioning of the human body, plants and microorganisms," according to the institute's web site. " Recent VIB research has led to breakthroughs in molecular and cell biology, developmental biology, genetics, cancer biology and cell death, neurobiology and Alzheimer's disease, plant growth and development," along with advances in other biotech fields. In 2001, VIB registered 29 patents and entered into 22 deals with industry partners.

VIB pursues an active technology transfer policy. Spin-off Ablynx and startup Peakadilly are examples of VIB biopharmaceutical R&D commercialization.

In the Walloon region, funding is provided for experts and legal staff working to interface university research with corporate needs. Guidance and study appointments are available for researchers who wish to create spin-offs. Several seed capital funds, along with public and private risk capital companies, have been formed near major universities.

5. Commercialization Success: Patents and Licensing

A 1991 decree in Flanders and a 1998 decree in Wallonia explained that research results belong to employers (i.e., the university or research center). Because researchers need incentives, the MIT "rule of thirds" was adopted, which means that net proceeds are divided equally among the inventor(s), department(s) and university.[20]

Just as Belgium's regions employ different innovation policies, they also witness varied results. While patent numbers have increased nationwide, patenting increased at a faster rate in the Flemish community. However, when compared to Belgian businesses, the universities have a significantly lower propensity to patent.[21] In 2000, the country ranked first in biopharmaceutical patent applications per million capita. In 2003, the country ranked first in innovation and industry, and second in science, compared to other European nations.[22]

Flanders boasts more than 20,000 employees in the life sciences, with 35 percent working directly in the biotech sector. The region is home to pharmaceutical companies like Jansen Pharmaceuticals, more than 40 biopharma and biotech companies, as well as a number of medical device firms, including Becton Dickinson.[23] In recent years, the Flemish community has experienced success with university-related patents, outperforming the rest of the country.[24]

K.U. Leuven Research and Development

K.U.Leuven R&D is a separate entity within the Katholieke Universiteit Leuven to promote the transfer of knowledge and technology. Some active K.U. Leuven biotech spin-offs include:

- 4 AZA Bioscience, a pharmaceutical company active in drug research in immune pathologies, such as transplantation rejection, rheumatoid arthritis and septic shock
- @mt, which focuses on advanced medical devices and the production of shape-memory alloys.
- AlgoNomics, which develops bioinformatics, with a focus on improving protein properties and lead discovery design
- PharmaDM, a global enabler of drug discovery analytic solutions, based on mining integrated chemical, biological and clinical data
- IriDM, the in-house drug discovery division of PharmaDM
- reMYND, which supports drug discovery in Alzheimer's disease and neurodegeneration.
- Thromb-X, which develops therapies for the prevention and treatment of cardiovascular diseases, as well as improved technologies of embryonic stem cell cultures
- TiGenix, active in tissue engineering and cell-based therapies

As of 2003, the Walloon region accounted for the most biotech companies in Belgium.

Biotechnology in Belgium

	Number of Companies	Revenues US$ Millions	Percent of Total Revenues	Number of Employees	Percent of Total Employees
Brussels	24	123	3.8%	481	6.3%
Flanders	39	456	13.9%	1,912	25.1%
Wallonia	69	2,690	82.3%	5,227	68.6%
Total	132	3,269	100.0%	7,620	100.0%

Source: Biotech en Wallonie Rapport 2005

Endnotes:

1. Nauwelaers, Claire, et al. 2003. "Benchmarking National R&D Policies in Europe: Lessons for Belgium." See: http://www.belspo.be/belspo/stat/rap/nauwelaers.pdf.
2. Belgian Science Policy. 2005. See: http://www.belspo.be/belspo/res/coord/scienpol/savoir/cips_en.stm.
3. "European Trend Chart on Innovation, 2002."
4. "Research and Innovation in Belgium: Science and Technological Innovation Policy in Flanders." See: http://www.cordis.lu/belgium/rd_com_fl.htm.

5. Ibid.
6. Bio 2005. See: http://www.bio.org/events/2005/international/CountryProfiles.pdf#search= 'bio%202005%20country%20profiles'.
8. http://www.exporthotline.com/upload/D865D2AA-2397-40BD-8456-A1D38D01B932.html.
8. Morrison, Mark. 2005. "Sixth Nanoforum Report: European Nanotechnology Infrastructure and Networks," See: http://www.nanoforum.org.
9. http://www.exporthotline.com.
10. http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr111744e.html.
11. http://www.exporthotline.com.
12. Roefmans, Bart. 2004. "Science and Technology Overview 2003: Belgium." See: http:// www.infoexport.gc.ca/science/Belgium_2003-en.htm;jsessionid=DVTRKJ4NZ00OQCTHNCACFEQ.
13. http://www.erch.info/Default.asp?ID=52.
14. http://www.exporthotline.com.
15. Ibid.
16. http://aoi.cordis.lu/article.cfm?article=99.
17. http://www.flandersbio.be/main.asp?lan=1&typ=16.
18. http://trendchart.cordis.lu/tc_datasheet.cfm?ID=8214.
19. Saragossi, Sarina and Bruno van Pottelsberghe de la Potterie. 2003. "What Patent Data Reveal about Universities: The Case of Belgium," *Journal of Technology Transfer,* 49.
20. Morant, Dr. Michel. "Belgian Universities and Intellectual Property." 2003. See: www.european-patent-office.org/epidos/conf/patlib2003/pdf/pres/morant_te.pdf.
21. Saragossi, Sarina and Bruno van Pottelsberghe de la Potterie. 2003.
22. Bio 2005.
23. "Innovation Experience Research Expertise: The Life Sciences Industry in Flanders." Flanders Foreign Investment Office. www.ffio.com. See: http://www.investinflanders.com/en/home/ "Flanders Investment and Trade."
24. Du Plessis, M., B. Van Looy, K. Debackere, T. Magerman. "Assessing Academic Patent Activity: The Case of Flanders."

Czech Republic

1. National Innovation Policy

"The Czech Republic is one of the most stable and prosperous post-Communist states in Central and Eastern Europe," according to the *CIA Fact Book*. The country's well-educated work force and low labor costs are a competitive advantage for attracting firms.

Czech biotechnology is "garnering international acclaim for its breakthroughs in stem cell research, hepatitis and HIV-AIDS treatments, and for cutting-edge biotechnology-nanotechnology processes," according to CzechInvest, an agency of the Czech Ministry of Industry and Trade. In 2003, for instance, researcher Petr Dvorák and his team at the Mendel University of Agriculture and Forestry isolated a new line of human embryonic stem cells, making their lab one of just three in the world at the time to isolate the cells. Dvorák's latest studies "focus on the creation of a mechanism for maintaining the blank state characteristic of unaltered stem cells."[1]

The Czech government recently outlined its R&D goals for the years 2006 to 2011, with applied research a stated top priority. The program, which also plans to direct Czech R&D toward industrial cooperation,[2] outlines an economic development plan to double the R&D share of GDP by 2010. In order to reach its goal of 1.3 percent, the government needs to increase spending by 20 percent to 25 percent annually; Czech scientists are scheduled to receive approximately $767 million for 2006.[3] This program is an application of the Act of 14 March 2002, by which the Czech Parliament amended the law for the support of R&D from public funds.[4]

The implementation of biotechnology goals is divided among several ministries and private organizations. These include the Ministry of Education, Youth and Sports, which is the main agency responsible for R&D policy. Associated with this ministry is the Research and Development Council,[5] an advisory group sponsored by the Czech government; the Ministry of Industry and Trade, which works to support SMEs and carries out its activities through such agencies as CzechInvest,[6] attracting foreign direct investment; and the Ministry of Health, which promotes the public support of health-related R&D. These ministries encourage international cooperation in the spirit of the EU framework. For example, the Ministry of Education financed the Czech Liaison Office for Research and Development, which opened in Brussels in May 2005 to improve research cooperation among European countries.[7]

2. Funding and Venture Capital

The government is working to make Czech R&D comparable with that of other EU nations so that researchers may better compete for EU funding. Public funds for R&D have limits that are synchronized with EU provisions under the new innovation program. Between 50 percent and 75 percent of the costs of applied research, and 25 percent to 50 percent of development costs, are government-financed.[8]

3. Clusters of Biotechnology

Universities and research institutes in the Czech Republic are beginning to strengthen their biotech programs. Currently, universities leading in biotech R&D include Charles University and the Institute of Chemical Technology, both in Prague; Masaryk University in Brno; and Palacký University in Olomouc.

Working alongside the nation's 24 public institutions of higher education,[9] the Czech Republic Academy of Science comprises 57 research institutes that conduct mainly basic research.

Prague is by far the largest center for biotech industry and academia in the country, but the government plans to create a cluster in Brno, the birthplace of the father of genetics, Gregor Mendel. And a new campus at the Brno University of Technology, scheduled for completion in 2006, will concentrate on molecular genetics, genomics and genetic engineering research.[10]

> It is typically difficult to retain post-doctoral students, according to CzechInvest. Many go abroad after completion of their Ph.D. studies. But the country's biotech industry employs about 6,250 people, of whom more than 50 percent are university-educated researchers.

4. University Technology Transfer Mechanisms

The Technology Centre AS CR is the national agency responsible for promoting collaboration between academia and industry through its tech transfer services, aid to small innovative businesses and cooperative efforts with the EU.[11] Members include the Czech Academy of Sciences and the Institutes of Physics, Microbiology, Chemical Process Fundamentals, Plasma Physics and Molecular Genetics, among others. The center is the host and coordinating organization of the Czech Innovation Relay Centre of the IRC consortium, which encourages transnational technology transfers and joint initiatives.[12]

5. Commercialization Success: Patents and Licensing

The Czech Republic fares well in technology transfer, ranking seventh among 79 countries,[13] despite the nation's relatively low rate of patent filings.[14]

Endnotes:

1. http://press.arrivenet.com/hea/article.php/640595.html. See also: http://www.marketwire.com/mw/ release_html_b1?release_id=87147.
2. *European Trend Chart on Innovation: Annual Innovation Policy Report for Czech Republic (FY 2004)*. EC: Innovations/SMEs Programme. See: http://trendchart.cordis.lu/tc_country_list.cfm?ID=22. "Innovation and Innovation Policy in Czech Republic."
3. State Science and Technology Institute. "Weekly Digest," Aug. 15, 2005. See: www.ssti.org/Digest/2005/ 081505.htm#Czech.

4. http://www.msmt.cz/Files/VedaAVyzkum/Legislativa/Act130_2002.htm.
5. Online source for R&D information, sponsored by the Research and Development Council and the Ministry of Education, Youth and Sport. See: http://www.vyzkum.cz/FrontClanek.aspx?idsekce=10117.
6. www.CzechInvest.org.
7. Biotechnology and Business News. See: http://www.biotechnology-pl.com/?lang=en&center =biotechnology.
8. Online source for R&D information, sponsored by the Research and Development Council.
9. Ministry of Education, Youth and Sport. www.msmt.cz/_DOMEK/default.asp?ARI=102097&CAI=3032.
10. Burgermeister, Jane. 2004. "Some success for Czech biotech: An educated work force entices biotech firms, but funding is low and EU money hard to get." *The Scientist*. www.the-scientist.com/news/.
11. Technology Centre AS CR. http://www.tc.cz/about_us/.
12. *European Trend Chart on Innovation*.
13. Porter, Michael E., Klaus Schwab, Xavier Sala-i-Martin and Augusto Lopez-Claros. 2004. *The Global Competitiveness Report*. Geneva: World Economic Forum.
14. *European Trend Chart on Innovation*.

Denmark

1. National Innovation Policy

"Denmark is one of Europe's strongholds for biotechnology," according to Invest in Denmark, a division of the Danish Trade Council within the Ministry of Foreign Affairs. "Best known is Medicon Valley, which is home to more than 60 percent of Scandinavia's pharmaceutical industry and is Europe's fastest-growing biotech cluster, measured by products in development."[1]

"Stem cells and system biotechnology are two specific fields where Denmark plays a leading role in research and development," reports International Trade Canada. "Strong holds also exist in diabetes, immunology, neurosciences, and cancer research."[2] Denmark was the first country in Europe to legislate gene technology (The Environment and Gene Technology Act of 1986). In 2001, the Ministry of Trade and Industry, in conjunction with nine other ministries, launched BIOTIK, a four-year initiative to address gene technology and ethics.[3]

Political responsibility for Denmark's university research and innovation policy resides in the Ministry of Science, Technology and Innovation. In 2002, the Danish government "initiated processes to reform the entire public research and innovation system," according to an OECD survey. "These reforms include The Act on Technology and Innovation, Reform of the Research advisory system and the University Reform [and] … laws governing the Danish National Research Foundation and Government Research Institutions."[4]

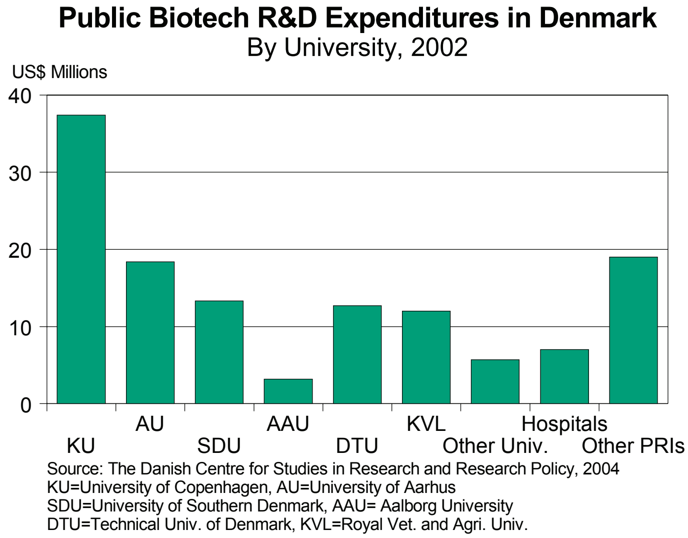
In January 2003, the government submitted a white paper stating its vision for a society that "increasingly produces, attracts, spreads and utilizes knowledge."[5] In 2004, the government "planned the establishment of a 'Future Fund' ensuring greater Danish investment in prosperous high-tech areas such as biotechnology, nanotechnology and information and communications technology."[6]

2. Funding and Venture Capital

Research councils in Denmark are responsible for coordinating the allocation of the research budget. Charities, as funding institutions, are also important.[7]

In 2003, Denmark's expenditure on research totaled $5.5 billion: universities ($1.3 billion); other public research institutes ($400 million); and private firms ($3.8 billion). Denmark spent 2.6 percent of its GDP on research initiatives, which is low by OECD standards.[8] The country aims to increase R&D spending to 3 percent of GDP by 2010, as agreed in the Barcelona Declaration.[9]

Most public biotech R&D is conducted at six universities: the University of Copenhagen (KU), the University of Aarhus (AU), the University of Southern Denmark (SDU), Aalborg University (AAU), the Technical University of Denmark (DTU) and the Royal Veterinary and Agricultural University (KVL). "In all," according to the Danish Centre for Studies in Research and Research Policies, "over 78 percent of biotech R&D in the public sector was conducted at universities, 7 percent in hospitals and the remaining 15 percent in other research institutions and nonprofit organizations."[10]

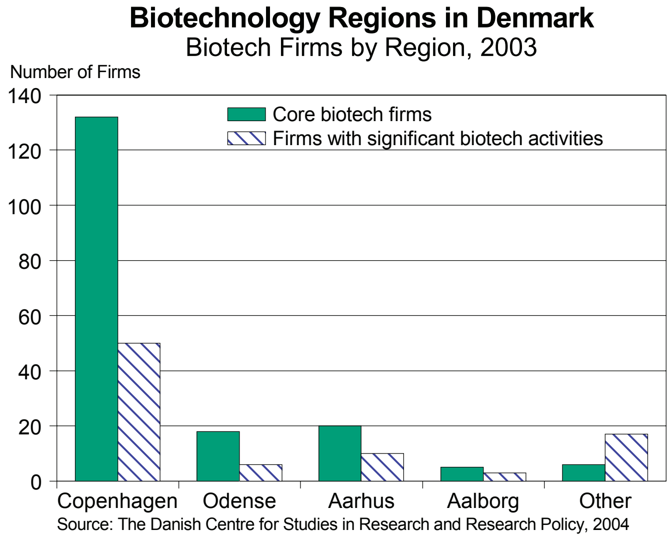


The Medicon Valley Academy, a nonprofit networking association, "works to improve the conditions for science and knowledge production, technology transfer, innovation and for the preconditions for enterprises to exploit this knowledge," and facilitates partnerships between the Medicon Valley research and entrepreneurial communities and others in Denmark, Sweden, Europe and internationally.[11]

3. Clusters of Biotechnology

Biotechnology in Denmark is predominantly associated with Medicon Valley, the third-largest biotech cluster in Europe. Medicon Valley — covering the region of Copenhagen on Denmark's side and Skåne on the Sweden side — is characterized by cross-border partnerships among biotech and pharmaceutical companies, universities, hospitals and investors. Copenhagen is home to several research institutions and universities conducting biotech research, including the University of Copenhagen and the Technical University of Denmark. In addition, Medicon Valley hosts large pharmaceutical companies, including Novo Nordisk, H. Lundbeck, Leo Pharma and Astra Zeneca, as well as many small- and medium-sized biotech companies with strong positions in R&D.

Biotech clusters are also emerging around the other main universities and hospitals near Aarhus, Odense and Aalborg.[12]



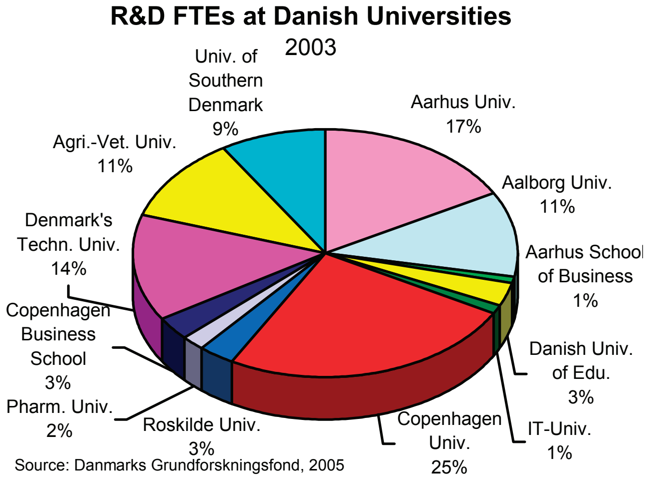
"Denmark has been one of the first European countries to invest unequivocally in nano science and its technological applications," according to the Canadian trade commission, with projects originating from "the national research centre for advanced microtechnologies (MIC) at DTU, the Nano-Science Centre, at Copenhagen U, and the Interdisciplinary Nanoscience Centre at the University of Aarhus, coupled with a cluster of companies related primarily to the optical of health area."[13]

4. University Technology Transfer Mechanisms

Since 1957, university researchers have not had to disclose inventions to their employers. However, beginning in the early 1970s, reports from various committees suggested changes to this policy. But it was not until the 1999 Act on Inventions (similar to the Bayh-Dole Act) that tech transfers became a priority. Before the act, a few government labs had functioning offices of technology transfer (OTTs) dating back to the late 1950s; by the mid-1990s a few hospitals had developed external liaison offices in the direction of OTTs, but this was not a general trend.

Before 1999, only one of the 12 Danish universities — the University of Aalborg — had an office that truly dealt with technology transfers.[14] Subsequent to the 1999 law, invention disclosures increased, doubling from 2000 to 2001, and increasing again in 2002. Biotech accounted for more than 40 percent (53 disclosures) of the total 122 disclosures at universities and university hospitals in 2000–2001.[15]

Denmark currently has a network of OTTs, though they are not necessarily specialized in biotechnology.



The following table shows the number of full-time-employee-equivalent employees (FTEs) engaged in biotech R&D in Denmark.

Total FTEs in Biotech R&D
Denmark, 1997-2001

Sector	1997	1998	1999	2000	2001
Private	3,528	3,648	3,742	3,885	4,028
Public	1,373	1,551	1,729	1,464	1,518
Total	4,901	5,199	5,471	5,349	5,546

Source: The Danish Center for Studies in Research and Research Policy, 2004

In Denmark, a researcher currently is obligated both to publish research results and disclose the invention to his or her employer institution. The institution is then required to determine, within two months, whether it wants to take title to the invention. If so, generally one-third of net income goes to the inventor, one-third to the relevant department and one-third to the institution. An inventor who exploits the invention may receive two-thirds of the net proceeds, with one-third shared by the institution and department. Because each institution determines the actual share, with ministry approval, the allocation of proceeds may vary.[16]

The 2004 Act on Technology Transfer clarifies Denmark's commercialization policy. It also provides additional protection to the research institutions from economic loss and risk of infringement.[17]

The following illustrates the startup phase existing at Copenhagen University, which is typical of many of Denmark's universities.[18]

Office of Technology Transfer at Copenhagen University

1999: Patent office established: one person
2003: OTT office established: five staff for 37 projects in patent portfolio
2005: six staff + one external consultant one day a week (in house) for 20 projects in patent portfolio
Patenting budget:€ 270,000 (also covers commercialization)
"New Concepts for Technology Transfer"
Three-year program (€ 700,000 funding from Ministry)
Three research institutions
The focus on commercialization of IP is through:

- Fast-track program for eighteen selected projects over three years
- Modest PoC (Point of Care) money for each project (€ 13,500 in total per project)
- Best practice workshops with Glasgow University's OTT
- Master classes with external commercial consultant
- Advisory board with Novo Nordisk licensing team and Symbion

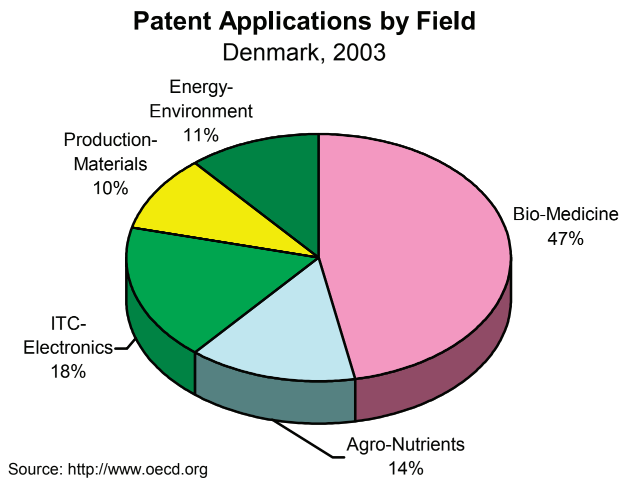
Source: http://www.mva.org/media(1333,1033)/Karen_Laigaard.pdf

Asger Aamund, Chairman of the Board of NeuroSearch and an angel investor, suggests that the Danish government "has not provided the tax breaks on stock options and warrants in order to motivate more academic researchers to make the jump into business."[19]

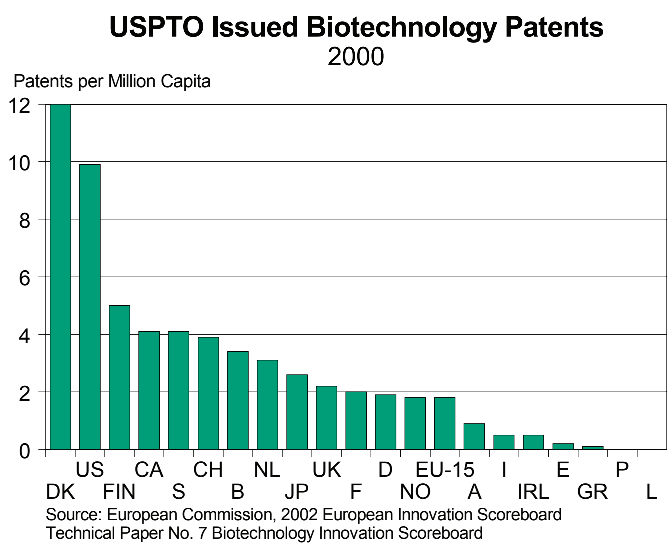
5. Commercialization Success: Patents and Licensing

A 2003 EPOHITE (Effectiveness of Innovation Policies in High Technology Sectors in Europe) report concludes, "Sweden and Denmark do not put as much emphasis as Finland in the exploitation of research results, however the situation is changing."[20] A 2004 publication of the Swedish commercial law firm Delphi & Co. notes that "the relatively low success rate in actually transforming world-class academic research into commercial applications has apparently emphasized the government's need to modify the system."[21] Referring to removal of the teacher's exemption, SwedenBio argues, "Experiences from Denmark show that the transition is unlikely to become profitable in the foreseeable future and might risk the function of an already working system."[22]

More than 50 percent of Denmark's patent activity comes from its life-sciences sector, as illustrated in the following chart.



Analysis of the commercial performance of European Member States,[23] the United States, Japan, Switzerland, Norway and Canada in U.S. biotech patents per million capita reveals that Denmark was the best-performing country in 2000.



1. 7TM Pharma, incorporated in 2000, is a spin-off from the University of Copenhagen by Prof. Thue Schwartz and Christian Elling, Ph.D. The company leverages Schwartz's fundamental research for the development of medicines targeting 7TM receptors (GPCRs). Based in the Scion/DTU Science Park north of Copenhagen, the company's most advanced projects target receptors associated with obesity. Clinical development of the first compound began in June 2005.

2. LiPlasome Pharma, established in 2001, develops and commercializes a novel pro-drug and drug-delivery platform used for anticancer drugs. The spin-off biotech company is located at the Technical University of Denmark. The company's proprietary technology is based on smart lipid-based nanocarriers (LiPlasomes) and permits intravenous transport of high concentrations of anticancer drugs directly to the tumor target, without any prior knowledge of the position and size of the tumor.

Endnotes:

1. Invest in Denmark. http://www.investindk.com/visArtikel.asp?artikel1ID=8121.
2. "Science & Technology in Denmark." April 2005. International Trade Canada. Trade Commissioner Service. See: http://www.infoexport.gc.ca/science/nordics_denmark_report-en.htm.
3. "Biotechnology: Educating the European Public." Final Report. 2002. Coordinator: Prof. Vivian Moses, King's College London. See: http://www2.mpiz-koeln.mpg.de/pr/EBE_FINAL_REPORT.pdf.
4. *OECD Science, Technology and Industry Outlook*. 2004. "Country Response to Policy Questionnaire." See: http://www.oecd.org/dataoecd/31/25/34241948.pdf.
5. Ibid.
6. Ibid.
7. EPOHITE. 2003. "Cross-County Comparison of the Relation between Country Performance and Policy Settings." WP3. See: Danmarks Grundforskningsfond. Danish National Research Foundation. Research and Development in Denmark. 2005. WP. See also "OECD Science, Technology and Industry Outlook 2004. Country Response to Policy Questionnaire."
8. http://www.denmark.dk/portal/page?_pageid=374,520396&_dad=portal&_schema=PORTAL.
9. *OECD Science, Technology and Industry Outlook*. 2004.
10. Bloch, Carter. 2004. The Danish Centre for Studies in Research and Research Policy. "Biotechnology in Denmark: A Preliminary Report." WP. See: http://www.cfa.au.dk/Publikationer/Working_papers/ WP2004_1.pdf.
11. http://www.mva.org/composite-1.htm.
12. *OECD Science, Technology and Industry Outlook. 2004*.
13. "Science & Technology in Denmark." April 2005.
14. Milthers, Sven. 2003. "Changing IPR Regulations for Researchers in Denmark." OECD.
15. Ibid.
16. Ibid.
17. *OECD Science, Technology and Industry Outlook*. 2004.
18. Laigaard, Karen. 2005. "Being a Danish TTO: To commercialise or not to commercialise – that's the question!!" University of Copenhagen.
19. http://www.nature.com/ nbt/journal/v20/n5/full/nbt0502-433.html.
20. EPOHITE. 2003.
21. Rambe, Lars. 2004. "Commericalisation of Inventions from Scandinavian Universities: A Challenge and an Opportunity." See: http://www.delphilaw.com/filearchive/1/111/EBR_Autumn_2004_p34+%20(3).pdf
22. Sweden BIO. 2005. "The Swedish Biotechnology Industry Organization. Abolishment of the Teachers Exemption: Consequences and Position of the Swedish Biotechnology Industry," Stockholm, July.
23. DK=Denmark, US=United States, FIN=Finland, CA=Canada, S=Sweden, CH=Switzerland, B=Belgium, NL=Netherlands, JP=Japan, UK=United Kingdom, F=France, D=Germany, NO=Norway, A=Austria, I=Italy, IRL=Ireland, E=Spain, GR=Greece, P=Portugal, L=Luxemburg.

Finland

1. National Innovation Policy

Finland is one of the world's leading investors in research and development.[1] Its biotech policy got off to a strong start in the mid-1980s, initiated by major programs run by the Academy of Finland, which is similar to the U.S. National Research Council;[2] the National Technology Agency (TEKES), the "main public funding organisation for research and development in Finland"[3]; and the Finnish National Fund for Research and Development (SITRA), which falls under parliamentary oversight.[4]

The Ministry of Education, which oversees Finland's 20 universities and the Academy of Finland, plays an important role in the development of biotechnology, through the universities and six "biocenters," part of a program launched in the 1980s to modernize university structures and graduate training.[5]

Technology policy comes under the purview of the Ministry of Trade and Industry.[6] In addition, the Science and Technology Policy Council of Finland advises the government and its ministries in questions relating to science and technology."[7] TEKES works closely with the council, which is headed by the prime minister and is responsible for the strategic development and coordination of science and technology.[8] Four research councils, organized under the Academy of Finland, are responsible for coordination of the country's research budget.[9]

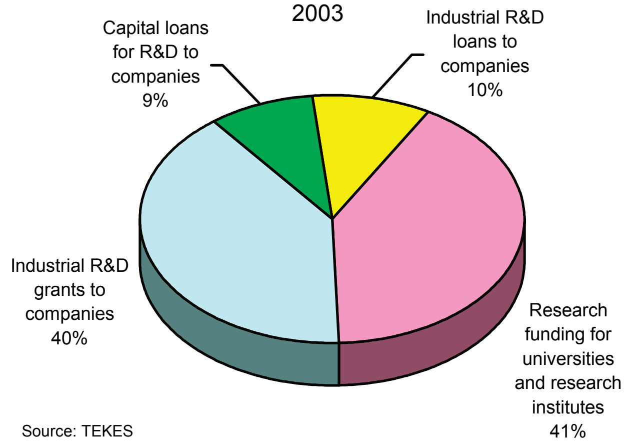
2. Funding and Venture Capital

In 2003, Finland invested approximately 3.5 percent of its GDP in research and development.[10] The funds for TEKES and the Technical Research Centre of Finland (VTT) come from the state budget through the Ministry of Trade and Industry, which also provides direct funding to biotech. TEKES and the Academy of Finland, using a quality-based assessment system, co-fund applications that link basic and applied research.

> "A concern is shortage of funds, leading scientists to apply frequently for relatively small awards, with a consequent waste of effort."
>
> — *Academy of Finland, 2002*

In 2003, chemical and biotechnology R&D allotment accounted for 27 percent of TEKES's overall funding.[11] The following pie chart illustrates the breakdown of 2003 TEKES funding, directed to all fields of technology in both the public and private sectors.

Total TEKES R&D Funding
2003



Source: TEKES

Finland's Ministry of Social Affairs and Health supports biotechnology via specialized institutes, such as the National Public Health Institute (KTL).[12] However, the Ministry of Education, directly or through university budgets and the Academy of Finland, is the biotech sector's main funding agency.

The Ministry of Education distributes earmarked funding chiefly to biocenters and graduate schools, using its own formulas.[13]

University R&D Funding in Finland
Biotechnology Research, 2001

University	Budget Funding in US$
Universities with Biocenters	
University of Helsinki	8,312,827
University of Kuopio	1,890,662
University of Oulu	5,121,439
University of Tampere	2,640,840
University of Turku	3,529,774
Abo Akademi University	1,097,515
Universities without Biocenters	
Helsinki University of Technology	334,805
Tampere University of Technology	398,364
University of Joensuu	26,856
University of Jyväskylä	-
Sources: Academy of Finland, Milken Institute	

In contrast, Academy of Finland funding applications are peer-reviewed; as a consequence, the funding levels are not established in advance, but according to the applications.[14]

In 2001, some 51 venture capital companies operated in Finland, 46 of which were private and five publicly owned; of these, 22 made investments in the life sciences. Public investors constituted 40 percent of the total, while SITRA made up more than 35 percent.[15]

3. Clusters of Biotechnology

Two of the country's six biocenters are in Helsinki: the Institute of Biotechnology and Biocentrum Helsinki, founded in 1989 and 1994, respectively. These two centers house eight centers of excellence specializing in biotech, as well as six biotech graduate schools. Leading biotech research groups, including the Institute of Biotechnology of the University of Helsinki, are located at Helsinki Business and Science Park, which aids patenting and licensing efforts.[16]

The University of Kuopio biocenter is the A.I. Virtanen Institute for Molecular Sciences. In central Finland, Kuopio Science Park is a cooperative venture of the University of Kuopio, the Technology Centre Teknia, Kuopio University Hospital, the Geological Survey Research Centre Neulanen and the Bioteknia complex, which houses a biotech production unit.[17]

Biocenter Oulu is affiliated with the University of Oulu, Finland's second-largest university. The Medipolis Science Park, also located in Oulu, was founded in 1990. Medipolis has spawned nearly 20 biotech companies and works with Oulu University's Faculty of Medicine and Biosciences and the Oulu University Hospital.[18]

The Institute of Medical Technology is situated at the University of Tampere. Finn-Medi, in the Tampere district, consists of a health and biotech network. The Finn-Medi Science Park and Finn-Medi Business Park are located near Tampere University Hospital. Research in molecular and cell biology are carried out at Tampere University's Institute of Medical Technology. The Biomedical Engineering Research Centre, the biomaterials unit of Tampere University of Technology, and biomedical research units of the Technical Research Centre of Finland and Tampere University Hospital are also located there. The Finn-Medi Network employs approximately 12,000 experts.[19]

Turku Science Park fosters alliances among the University of Turku, the Åbo Akademi University, the Turku University Central Hospital and the National Public Health Institute. BioCity Turku sustains more than 90 research groups with more than 600 researchers, graduate students and support personnel.[20]

The National Public Health Institute in Helsinki shows similarities to Finland's Biocenters, although it belongs to the Ministry of Social Affairs and Health, rather than the Ministry of Education.[21]

Finland (unlike Denmark or Sweden) lacks a large array of pharmaceutical companies, but it has traditionally been strong in the production of industrial enzymes. However, the country's framework conditions and governmental support do result in many startups and spin-offs focused on drug discovery and diagnostics.[22]

4. University Technology Transfer Mechanisms

Intellectual property rights supported by public funds in universities and university-affiliated institutes, including biocenters, belong to the inventors. Research facilities not affiliated with universities own all intellectual property rights produced by their employees.

Findings of a 2002 evaluation report conducted by the Academy of Finland suggest that Finland's current hybrid policy has delayed and restricted the development of experienced tech-transfer professionals; prevented OTT employees from acquiring appropriate status within their institutions; hampered effective tech commercialization, perhaps because university researchers lack knowledge of the patenting process; and inhibited the development of strategies for tech transfers from universities and biocenters, as well as methods to exploit specific technologies.

The success of such licensing companies as Licentia Ltd., Finland's largest university-supported "development platform,"[23] will depend on how well they provide services to researchers in universities with which they are associated.

> "The percentage of Finnish patents, in biotech vs. other fields, at the European Patent Office is three-fold lower than the OECD average."
>
> — *Academy of Finland, 2002*

5. Commercialization Success: Patents and Licensing

Technology transfer offices, industrial grants and other financing opportunities exist for university spin-offs and startups with biotech-specific programs. For example, tech transfers and university patenting are supported by SITRA with the creation of profit-oriented OTTs in which universities and SITRA are the shareholders. Moreover, "innovation centers" are present at universities to help university staff and students with tech transfer issues.

> The International Institute for Management Development in Switzerland rated Finland the most competitive economic area with a population under 20 million.

Orion Pharma and Orion Diagnostica are Finland's two leading biotech players, the former having a leading Parkinson's treatment, Comtess, and the latter targeting the global point-of-care market for in-vitro diagnostic products. Orion Pharma collaborates with all the Finnish centers of excellence, but particularly the centers at the universities of Helsinki and Kuopio, the Helsinki Biotechnology Institute and, increasingly, with the universities of Oulu and Tampere. The University of Oulu is Orion Diagnostica's main research partner.[24]

Endnotes:

1. TEKES National Technology Agency of Finland. http://www.tekes.fi/julkaisut/engl_yleise.pdf.
2. Academy of Finland. 2002. *Biotechnology in Finland: Impact of Public Research Funding and Strategies for the Future*. See: http://www.aka.fi/index.asp?id=E12080C439CB48A191E80295F382194F&data=1,URL,http://www.aka.fi/modules/page/show_page.asp?id=A120FE8E911A4CA0841893F46643A8CB&itemtype=00308B787886459385F296A5AFD4FA74.
3. http://www.tekes.fi/eng/.
4. http://www.sitra.fi/en/About+Sitra/sitra.htm.

5. Academy of Finland. 2002. *Biotechnology in Finland*.
6. http://www.tekes.fi/eng/innovation/policy/.
7. http://www.minedu.fi/minedu/research/organisation/sci_tech_council/sci_tech_council.html.
8. TEKES National Technology Agency of Finland. 2004. "World of Technology: Joy of Innovation."
9. http://www.esf.org/esf_genericpage.php?section=8&language=0&genericpage=1972.
10. http://www.tekes.fi/julkaisut/engl_yleise.pdf.
11. http://www.tekes.fi/eng/publications/Annual_Review2003.pdf.
12. Academy of Finland. 2002. *Biotechnology in Finland.*
13. Ibid.
14. Ibid.
15. Ibid.
16. Ministry of Trade and Industry, Invest in Finland. "Biotechnology: A Promising High-Tech Sector in Finland." See: http://www.investinfinland.fi/en_GB/file_centre/_files/11233219940002490/ default/biotechnology.pdf.
17. Ibid.
18. Ibid.
19. Ibid.
20. Ibid.
21. Academy of Finland. 2002. *Biotechnology in Finland*.
22. EPOHITE. 2003. "Cross-County Comparison of the Relation between Country Performance and Policy Settings." WP 3.
23. http://www.oecd.org/dataoecd/11/35/34571089.pdf.
24. Cooke, P. 2004. "Life Sciences Clusters and Regional Science Policy." *Urban Studies*, 41(5/6), May.

France

1. National Innovation Policy and Culture

Layers of complexity characterize France's innovation policy, which falls under the direction of the Ministry of Education, Research and Technology, and the Ministry of the Economy, Finance and Industry. Programs are organized and set at the national level, while implementation is the responsibility of each region. France occupies the "middle road" when it comes to national innovation,[1] performing below the United States, but above most other European nations.

The 1999 Law on Innovation and Research was a catalyst for the creation of biotech enterprises in France. The law allows state-employed researchers and academics to become entrepreneurs without having to forfeit their academic positions. It also simplified the regulations for academic-industrial partnerships; liberalized the financial laws of startup companies and increased the value of research tax credits; and redefined the "simplified joint stock company."[2]

Plan Biotech 2002, whose goal was to raise the country's biotech industry to first place in Europe (from third) by 2007, called for more than $90 million in bank loan guarantees and more than $60 million in seed financing.[3] In 2003, the government established an annual innovation competition to capitalize on the country's wealth of human capital and expand industry participation in R&D. The program launched 466 firms and created nearly 2,800 new jobs; more than 40 percent of winners were from the public sector.[4]

Additional innovation incentives enacted in 2004 include: the *Jeune Entreprise Innovante* [5] (Young Innovating Company), a tax credit for new SMEs whose R&D investment totals at least 15 percent; the SOFARIS Biotech Guarantee,[6] which protects and encourages biotech VC; the creation of *maisons de l'entrepreneuriat* [7] to reinforce an entrepreneurial culture and help bridge the gap between universities and businesses; and the *crédit impôt recherche*, which expanded corporate research tax credits.[8]

Two additional programs facilitate the transfer of life-sciences technology: the National Bio-Startup Fund (with an initial endowment of over $20 million) and the French Federation of Bio-Incubators.[9]

In 2005, then-Prime Minister Jean-Pierre Raffarin created the agency OSEO to promote innovation. Together with the National Research Agency and the Agency for Industrial Innovation, OSEO works to foster business and job creation.[10]

2. Funding and Venture Capital

France, which ranked fifth worldwide in 2005 for R&D spending,[11] has made great progress in terms of government funding for research.

The biotech industry is concentrated in genomics and drug delivery, and shows gains in the production of therapeutic products.[12] "Since the GenHomme network's creation in 2000, the government allocated €25 to €30 million annually to finance 30 to 40 projects," according to an OECD report. "Equal amounts are contributed by the Ministry of Research, and the Ministry of Economy, Finance and Industry. This project attracts €300 million over five years, contributed in equal parts by the government and private sectors."[13]

ANVAR distributes most of the country's R&D funding. It offers interest-free loans that come due once the venture is successful.[14] Local governments are the primary investors in bio-incubators.

France has created nine research charities to increase private R&D funding. Over the five-year period beginning in 2004, the charities are expected to allocate more than $140 million for proposals submitted by universities or research institutions.[15] Also in 2004, the Agence Nationale de la Recherche (ANR) was established. Its $435 million 2005 budget was to be distributed among universities and research organizations for applied research and industry collaboration.[16] The proposed budget for 2006 increased ANR funding by almost $300 million. France's goal is to raise R&D investment to 3 percent of GDP by 2010.[17]

Venture capital funding for biotech is on the rise. The ratio of VC investment to public funding in France's biotech industry in 2001 was approximately 1:3.[18] In 2002, biotech and life sciences received the most VC in the country.[19] The top 15 biotech companies received more than $4 million from VCs in 2003.[20] The French Association of Capital Investors reported that in 2003, investments of about $5 million were made in more than 1,400 French companies, 30 percent of which came from outside France.[21] Some French biotech VC firms include: Apax Partners, Atlas Ventures, Banexi Ventures, Auriga Ventures, Genavent, Sofinnova and Siparex. In December 2004, Paris-based Novexel, newly spun out of sanofi-aventis, raised some $50 million from an international group of investors.[22]

Genset, France's largest biotech firm, was the first biotech to be listed on the French stock exchange. "In June 1996, we had a very successful IPO, raising almost $100 million," noted Chairman and CEO Pascal Brandys in a *Science* magazine interview that year. "There haven't been many IPOs of that size, even in the U.S."[23]

3. Clusters of Biotechnology

Clusters in France are categorized as *poles de competitivité* (competitiveness clusters), *genopoles* (centers that specialize in genomics or post-genomics) and business incubators.

Poles de competitivité are created by the government through competition. In July 2005, the government identified six additional industrial clusters and an additional 67 competitive poles for funding.[24] The competitive clusters receive assistance with R&D funding and relief from some taxes and charges. That year, the French government doubled funding (to almost $2 billion) for the newly chosen *poles de competitivité.*

> The biopark Evry Genopole, created in 1998 by the French government, regional authorities and the French Muscular Dystrophy Association, is the country's "Genetics Valley." About 25 kilometers south of Paris, it is home to a branch of the University of Evry-Val-d'Esonne, 26 research labs and more than 50 biotech companies. Plans include a biomanufacturing center for therapeutic molecules and a hospital center. Researchers at Evry contributed to the 2003 mapping of the human genome.

A 1999 call for proposals resulted in a network of *genopoles* centered around Evry and the National Sequencing Center, as well as the National Genotyping Center, Infobiogen. The network includes *genopoles* located around Lille, Strasbourg, Montpellier, Toulouse, Marseille-Nice, Lyon-Grenoble and Rennes-Nantes. Three sites in Paris — the Institut Pasteur, the Montagne Sainte Geneviève group of laboratories and the Center for Human Genomics of Paris V University — form the Ile de France Region *genopole*, with Evry as its flagship site.[25]

University Joseph Fourier, the Hospital of La Tronche and Commissariat à l'Energie Atomique (CEA) make up the first French nanobiotechnology cluster. NanoBio, located in Grenoble, works closely with the CEA, Minatec and Lyon Biopole. Funded by local authorities with a budget of almost $29 million, the cluster is expected to foster technological and economic development in bioengineering.[26]

In September 2005, the independent think tank Strategic Innovation Council and French scientists announced plans to create the European Institute of Technology of Paris. The goal is to attract some 300 high-level researchers in such fields as nano- and biotech to a 148-acre campus, possibly in southwestern Paris. Funding would come from the French government and elsewhere.

4. University Technology Transfer Mechanisms

INSAVALOR, established in 1988 in Lyon, was one of the first private technology transfer companies in the country, working with the 27 research laboratories at INSA.[27] One example of its commercialization success is *le bistouri à jet d'eau*, a tool of "cutting by a stream of water," the result of collaborative research between laboratory LMP (Team Microsensors Microsystems) and Saphir Medical. It utilizes micromechanics technology for abdominal surgery.[28]

France Innovation Scientifique et Transfert (FIST), an affiliate of the Centre National de la Recherche Scientifique (CNRS) and ANVAR, was established in the early 1990s as an IP licensing subsidiary, working with universities to facilitate commercialization.[29] Since the passage of the Law on Innovation and Research in July 1999, FIST has assisted in creating more than 60 startups.

5. Commercialization Success: Patents and Licensing

While French culture could be described as highly individualistic, a quality that would encourage startups, innovation and private sector investment in research, the country is decidedly risk averse, in part because of high tax rates.[30] Progress is being made: France formerly compared unfavorably with other European countries in the number of its innovative companies, but since 2004, it has ranked very well.[31]

More than two-thirds of France's 300 biotech firms are involved in the health sector. There were 15 biotech startups in France in 1986, 27 created during each of the years 1990 and 1991, and close to 70 established in 2000.[32]

The biopharmaceutical company Endocube at Labege is a spin-off from the Institute of Pharmacology and Structural Biology in Toulouse. Co-founder and Chief Science Officer François Amalric is also Director of the Institute of Pharmacology and Structural Biology, and a professor at the University Paul Sabatier in Toulouse. His research includes work at the California Institute of Technology.

Pierre Bougneres, another Co-founder and the Chief Medical Advisor at the company, teaches pediatrics at University of Paris V and is head of pediatric endocrinology and metabolism at St. Vincent de Paul Hospital in Paris. In addition, he conducted research at Washington University in St. Louis. A third co-founder and Endocube's Chief Science Advisor, Jean-Philippe Girard, is a molecular and cellular biologist at INSERM, the National Institute of Health and Medical Research. He has conducted research at Harvard Medical School.

France ranks No. 3 in Europe in terms of number of biotech firms created. More than 80 percent of its biotech companies opened their doors after 1990, especially after 1997. In 2000, the annual growth rate of French biotech companies was over 25 percent. The sector generates nearly $700 million in revenues and employs more than 4,000 people.[33]

France ranked fourth, behind the United States, Japan and Germany, for European patent applications in 2000. Also in 2000, it was one of five countries (with Japan, Germany, the United Kingdom and the United States) responsible for 83 percent of patents filed with the USPTO, EPO and JPO.[34]

In 2001, France accounted for 6.18 percent (6,804) of European patent applications. Of those, 2,805 were granted, a little over 8 percent of the European total. France filed 5,115 international patent applications, accounting for 4.2 percent of all international patent applications in 2004.[35] That same year, 3,686 of U.S. granted patents were from French inventors, representing a little more than 2 percent of total U.S. patents.[36]

Co-founder of six biotech companies and former president and CEO of Hybrigenics, Professor Arthur Donny Strosberg has patented 24 of his academic discoveries in the United States and Europe, and licensed several of his inventions to such pharmaceutical companies as Abbott, Bristol-Myers-Squibb, Ciba-Geigy, Hoffmann-LaRoche, Janssen Pharmaceutica and Servier.

Hybrigenics is a pathway-based drug discovery firm and a spin-off of the Pasteur Institute, with academic alliances that include Pasteur, Curie, INSERM and CNRS. It has extensive patent assets and strong industry collaborators, including Merck. Stosberg is on leave from his position as chair professor of biochemistry and immunology at the University of Paris VII.

Endnotes:

1. Maastricht Economic Research Institute on Innovation and Technology. 2004. "Annual Innovation Policy Report for France." See: http://www.merit.unimaas.nl/.
2. www.recherche.gouv.fr/technologie/mesur/loi/loigb.pdf.
3. http://www.austrade.gov.au/australia/layout/0,,0_S2-1_-2_-3_PWB1682877-4_-5_-6_-7_,00.html. Dec. 16, 2005.

4. Angelino, Henri and N. Collier. 2004. "Comparison of Innovation Policy and Transfer of Technology from Public Institutions in Japan, France, Germany, and the United Kingdom; Part 1: French and Japanese Case Study." *NII Journal.*
5. http://64.233.179.104/search?q=cache:RCFunddh_xoJ:www.internationallawoffice.com/ ld.cfm%3FNewsletters__Ref%3D7925 +%22Young+Innovating+Company%22&hl=en&gl=us&ct=clnk&cd=1.
6. http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:52000DC0266:EN:HTML.
7. http://www.recherche.gouv.fr/appel/2004/entrepreneuriat.htm.
8. http://www.recherche.gouv.fr/technologie/mesur/cir/.
9. http://ambafrance-ca.org/hyperlab/RECRUTE/_recherche.html.
10. http://www.eubusiness.com/topics/SMEs/france.2005-01-25. See: http://www.oseo.fr/.
11. "Science and Innovation: New Research Bill (November 2005)." British Embassy, France. See: http://www.britishembassy.gov.uk.
12. "Overview of the French Biotechnology Industry." 2005. British Embassy, France.
13. Devlin, Andrew. "An Overview of Biotechnology Statistics in Selected Countries." STI Working Paper 2003/13. Statistical Analysis of Science, Technology and Industry.
14. "Overview of the French Biotechnology Industry." 2005. British Embassy, France.
15. Ibid.
16. "The French Science Budget for 2005." Feb. 21, 2005. British Embassy, France.
17. Sept. 29, 2005. Mission for Science and Technology, French Embassy to the United States. French Research Budget. 2006. See: www.francescience.org/home/page.asp?target=news&ID=408.
18. "Overview of the French Biotechnology Industry." 2005. British Embassy, France.
19. Oggi, Chimica. 2004. "French Biotechnology Industry: Diverse, Young and Promising," *Chemistry Today, International Journal of Chemistry and Biotechnology.*
20. France Biotech. 2004. "The French Biotechnology Industry on the Launchpad: France Biotech Recommends Accelerating Efforts to Allow Takeoff." See: www.france-biotech.org.
21. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report.*
22. Ibid.
23. http://www.sciencemag.org/feature/e-market/benchtop/euro2.shl.
24. "France: Pôles de Compétitivité (Competitiveness Clusters)" 2005, British Embassy, France.
25. "National Genopoles Network." 2003. See: http://www.britishembassy.gov.uk/servlet/Front?pagename= OpenMarket/Xcelerate/ShowPage&c=Page&cid=1115145986769.
26. http://www.news.NanoApex.com.
27. http://translate.google.com/translate?hl=en&sl=fr&u=http://www.insa-lyon.fr/&prev=/ search %3Fq%3Duniversity%2Bof%2Blyon%26hl%3Den%26lr%3D%26rls%3DGGLG,GGLG:2005-37,GGLG:en.
28. www.insa-lyeonj.fr/pg/index.php?Rub=65&L=2.
29. Gering, Thomas. 2004. "Patents and Licensing by Publicly Funded Research Organisations in Europe: An Overview." www.oecd.org/dataoecd/27/14/31857661.pdf.
30. Henriquez, C., I. Verheul, I. van der Knaap and C. Bischoff. 2001. "Determinants of Entrepreneurship in France: Policies, Institutions and Culture." www.spea.indiana.edu/ids/pdfholder/ISSN-01-4.pdf.
31. Brandman, James. 2005. "Venture Capital Turning a Corner in France," *European Venture Capital Journal*. http://www.partechvc.com/newspdfs/EVCJ_May2005.pdf.
32. Devlin, Andrew. "An Overview of Biotechnology Statistics in Selected Countries."
33. "Overview of the French Biotechnology Industry." 2005. British Embassy, France.
34. Devlin, Andrew. "An Overview of Biotechnology Statistics in Selected Countries."
35. World Intellectual Property Organization. 2004. "International Patent System in 2004, Yearly Review of the PCT." http://www.wipo.int/portal/index.html.en.
36. U.S. Patent and Trademark Office. 2005. "Patent Counts by Country/State and Year, All Patents, All Types." www.uspto.gov/.

Germany

1. National Innovation Policy

In Germany, most academic research is conducted in organized research institutes, such as the Max Planck and Fraunhofer Gesellschaft institutes; in specific "scientific universities"; and in the polytechnics (*Fachhochschulen*). There are at least 82 university-level institutions and 124 Fachhochschulen with 50 university biology departments in the country.[1]

German biotech regulation conforms to European Commission directives. The country's 16 federal regions (*Länder*) have sole responsibility for schools, universities and advanced education. Each German *Land* has its own state constitution, with authority for arts (including education). The *Länder* are responsible for financing state departmental research facilities. The Ministry of Education and Research is the federal government agency that funds research.[2]

R&D expenditures in Germany fell by 0.6 percent of GDP between 1989 and 1996.[3] Although this decline was part of a worldwide trend, there were other reasons for concern. In particular, the share of high-tech goods in German exports fell during the early 1990s, and the German economy showed signs of becoming a net importer of technology-intensive products.[4] In response, beginning in 1996 and following a trend in industry and the United States, the German government developed a series of measures geared toward more consistent protection and commercialization of IP:

- In 1997 the government began to reimburse university IP prosecution expenses.[5]
- The Fourth Amendment of the Framework Act for Higher Education was passed in 1998, with the aim of bringing greater flexibility to higher education institutions.[6]
- Lower Saxony established a commission in 1998 to evaluate the performance in the *Länder*'s 12 universities.[7]
- The *Bundestag*'s (federal government's) amendment to the Framework Act mandated university competitions, abolished professorial "immunity" to external evaluation and introduced teaching and research-based financing.[8]
- Germany's version of the U.S. Bayh-Dole Act was implemented in 1999.[9]
- In 2000, the Science Council published a "Theses for the Future Development of the System of Higher Education and Research in Germany" to improve research quality and efficiency in academic institutions.[10]
- Reform of the employment law in higher education and public research in 2002 increased flexibility in employment, salaries and other structural areas.[11]
- In 2004, federal science ministers and the *Länder* reconfirmed their agreement on the primary cornerstones of a program to promote first-class research in Germany in the Bund-Länder Commission for Educational Planning and Research Promotion.[12]

Reform aims to shorten doctoral programs, which previously took six to seven years. With respect to the *Habilitation* (a post-doctoral thesis unique to Germany), the new prerequisite (in effect from 2010) for appointment to a chair will be a junior professorship,[13] and academic institutions may offer B.A. and M.A. courses alongside the Diploma, which is similar to a master's degree.[14]

The Science Council report on higher education and research argued for new forms of cooperation between universities, public research institutes and business enterprises supported through private foundations, such as the Stifterverband.

"Spin-offs and sectoral measures form the focal point of recently modified measures," according to a 2000 CORDIS report.[15]

2. Funding and Venture Capital

Biotech research is not considered a funding priority in Germany, relative to other scientific fields.[16] The federal states (*Länder*) have the primary responsibility for R&D support. Public funding for university research is channeled through state bloc grants, which account for almost two-thirds of university expenditures; capital grants, which the federal government and the *Länder* provide; and "third-party funds," grants and contracts.[17] Major financial support for academic project research comes from the German Research Foundation, an independent nonprofit association.[18] Plans in 2002 called for 58 percent of overall funding to come from the federal government and 42 percent from the federal states. In 2003, more than $220 million was made available for biotech. In the field of nanotechnology, approximately $57 million was to be provided from 2003 up to 2006.[19]

More biotech companies conduct business in Germany than in any other European nation.[20] "There is, however, concern over what will happen to the large number of companies that sprang" from "promotional initiatives" launched in the early 1990s. "To ease the situation, a fund of $566 million, focusing on German high-tech companies, was announced in October 2003.[21] The European Investment Fund (EIF) and the German state each provide 50 percent. The fund is managed by the EIF, only investing in a company if a private professional investor matches the investment. In this way, the German government believes each euro it raises can be leveraged more than six times."[22]

Since 1994, the German Research Foundation has funded an "eight-year centers of excellence" program targeting higher education in the East German regions. Large research centers receive almost $6 million per year.[23]

Pharmaceutical firms pool industrial R&D funding with government allocations.[24] The following public funds support biotech startups: BioRegio, €90 million (since 1999); BioProfile, €50 million (2001–2006); BioFuture, €60 million (since 1998); and BioChance, €100 million public grants plus €150 million projected private funds. Since the early 1990s a number of public, early-stage, venture capital programs, such as Neuer Markt and the Business Angels Network, have been created.

In July 2004, Epigenomics successfully completed its IPO, raising more than $50 million. The company began operations in 1998 with the aim of establishing itself as a leading product company in molecular diagnostics. Early investors included Deutsche Venture Capital, MPM Capital, 3i, Abingworth and the Wellcome Trust. Some of the company's basic technology was developed and licensed from the Max Planck Institute for Molecular Genetics in Berlin. Epigenomics has 144 employees, including 33 at its U.S. branch in Seattle.

3. Clusters of Biotechnology

Munich and its environs, the Rhein/Neckar Triangle (Mannheim, Ludwigshafen, Heidelberg) and Rheinland (Aachen, Koeln, Bonn), are recognized as leading regions for biotech development. These centers of excellence won the BioRegion competition and received grants totaling $87 million in 1995. The BioRegio competition, launched in 1995, promotes the commercialization of university biotech research in Germany.[25] The competition has increased biotech startup formation from 75 companies in 1995 to 279 companies in 1999, and more recently, more than 400.[26] In 1996, the Munich, Rhine-Neckar Triangle and Rhineland regions received €25 million each for a five-year period; the Jena region received $19 million.

The success of the BioRegio competition prompted the government to launch additional initiatives to encourage the growth of Germany's biotech industry. For example, BioChance, targeting high-risk entrepreneurial R&D projects implemented by young SMEs, provided funding of more than €50 million from 1999 to 2002 for 52 startups.[27]

4. University Technology Transfer Mechanisms

Until recently, patents were owned by the inventors: the university scientists and industrial sponsors. Therefore, only in rare cases, such as Karlsruhe and Dresden, did universities in Germany establish patent and license offices.[28] The federal government's Verwertungs-Offensive (Exploitation Offensive) of 2002 resulted in about 20 patent exploitation agencies working primarily for universities.[29]

In 2002, the German Federal Government revised its 1957 Employee Inventions Act, allowing university scientists to avoid disclosure of their inventions to employers. The "university teachers' privilege" *(Hochschullehrerprivileg)* discouraged academic-industry collaboration. This privilege was abolished, accompanied by support for the establishment of a network of patent and exploitation agencies. Inventors receive 30 percent of compensation profits,[30] but institutions hold the intellectual property rights.[31] Research sponsors have four months to claim rights on the invention.

Germany has also established workable structures to enhance and support the commercialization of university research. In 1976, the Ruhr-Universität in Bochum created its Unikontakt office, considered the first technology transfer office in the country. Its success has led to the establishment of OTTs at the majority of universities.[32]

Among the German regions, Bavaria strives to be Europe's renowned center of biotech excellence. The innovation support infrastructure of the BioTech-Region Munich is also very strong. Bayern Innovativ, a region-wide center for tech transfer, and the Eastern and Western Bavarian Technology Transfer Institutes are active in implementing platforms for joint R&D and technology transfers.[33]

5. Commercialization Success: Patents and Licensing

German R&D remains largely concentrated in traditional manufacturing industries, automobiles, machinery, electronic and communication equipment, and industrial chemicals.[34] Therefore, although biotechnology is growing rapidly, patenting has focused in these traditional areas.[35]

The country has a well-established national patent office and has implemented various promotional programs to strengthen IP. Munich is the seat of the European Patent Office (EPO), the German Patent Office and the German Patent Court. Germany implemented AkPat, an Internet platform containing all the competencies in the field of patenting available at centers of higher education with experience in patents, courses of study on patenting, patent-related training and the various services provided by intermediaries. A network of patent information centers offer SMEs access to scientific and technological information essential for innovation management in business.

From 1985 to 1999, the number of biotech patent applications in Germany increased by more than 400 percent, largely owing to an increase in patent cooperation treaty applications. However, the number of biotech applications filed directly at the EPO has declined. In 2000/2001, 747 patents were granted in Germany.[36]

The biopharmaceutical firm vasopharm BIOTECH conducts cerebro- and cardiovascular R&D. The company was founded in July 1998 as a spin-off from the University of Würzburg by Professors Harald Schmidt and Ulrich Walter, the former working in pharmacology and toxicology, the latter in biochemistry and pathobiochemistry. The company specializes in the development of treatments for cerebral and cardiovascular diseases.

Endnotes

1. "Steering and Funding of Research Institutions." Country Report: Germany. http://www.oecd.org/ dataoecd/24/39/2507909.pdf.
2. Lacasa, I.D. and Thomas Reiss. 2003. EPOPHITE. "Effectiveness of Innovation Policies: Biotechnology in Germany (1994-2001)." p 4.
3. http://pubs.acs.org/hotartcl/cenear/981019/7642inter.pdf.
4. *Der Spiegel*. 1998. Projekt Deutschland 2000: Es gilt, einen Schatz zu heben. 35/98. See: Rebecca Harding. 2002. *European Management Journal,* 20(5).
5. OECD. 2003. "Turning Science Into Business: Patenting and Licensing at Public Research Organisations." See: http://www.oecd.org/dataoecd/37/24/30634128.pdf.
6. "Steering and Funding of Research Institutions."
7. Geuna, Aldo and Ben R. Martin. 2001. "University Research Evaluation and Funding: An International Comparison," *SPRU, Science and Technology Policy Research*. WP 71.
8. Geuna, Aldo and Ben R. Martin. 2003. "University Research Evaluation and Funding: An International Comparison." Kluwer, Academic Publishers, Minerva 41. See: http://www.sussex.ac.uk/Users/prff0/ Publications/Geuna&Martin%20University%20research%20evaluation_2003.pdf.
9. OECD. 2003. "Turning Science Into Business."
10. "Steering and Funding of Research Institutions."
11. Ibid.
12. http://www.bmbf.de/en/1321.php.
13. Ibid.
14. Ibid.

15. "European Trend Chart on Innovation." 2000. http://trendcharts.Cordis.lu/annualreports/ trend.Rep.light.pdf.
16. EPOHITE. 2003. "Cross Country Comparison of the Relation between Country Performance and Policy Settings," WP 3.
17. Geuna, Aldo and Ben R. Martin. 2003.
18. "Steering and Funding of Research Institutions, Country Report."
19. BMBF Funding in the Sphere of Biotechnology: BMBF Departments 614/615.
http://www.kompetenznetze.de/Redaktion/Zentralredaktion/Literatur/medien/en/bio-nano-gentec__BMBF-funding-biotechnology,property=pdf.
20. EuropaBio. "Biotechnology in Europe: 2005 Comparative Study." Lyon: BioVision. Note: The German definition for biotech covers all aspects of molecular biology, genetics and genetic engineering. *Gentechnik,* or "gene technology," is divided into *rote* (red) *Gentechnik* and *gruene* (green) *Gentechnik,* and is broadly used in German science, policy, education and industry to define the medical and pharmaceutical aspects of biotech. See Susanne Benner. 2002.
21. SwedenBIO. 2003. "Biotechnology in Sweden. A National Biotech Agenda For Growth." http://www.swedenbio.com/upload/Publications/Reports/.
22. Ibid.
23. "Steering and Funding of Research Institutions."
24. Peterson, Ronald. 2003. *When Venture Capitalists Say "No" — Creative Financing Strategies & Resources.* Bethesda, Md. Comanche Press.
25. Mueller, Christian and T. Fujiwara. 2003. "The entrepreneurial environment for biotech startups in Germany and Japan," *International Journal of Biotechnology,* 5(1).
26. OECD. 2003. "Turning Science Into Business."
27. Ibid.
28. Ibid.
29. Ibid.
30. EPOHITE. 2003.
31. "Steering & Funding of Research Institutions."
32. http://www.ruhr-uni-bochum.de/study-guide/6.htm.
33. Arnold Erik and Jari Kuusisto. 2002. "Government Innovation Support for Commercialization or research, new R&D Performers and R&D Networks," *Technology Review*, 121.
34. Abramson, H.N., J. Encarnacao, P. Ried and U. Schmoch (eds.). 1997. *Technology Transfer Systems in the United States and Germany: Lessons and Perspectives*. Washington, D.C.: National Academy Press.
35. Cantwell, J.A. and R. Harding. 1998. "The internationalization of German R&D," *National Institute Economic Review* 163.
36. OECD. 2003. "Turning Science into Business."

Hungary

1. National Innovation Policy

Hungary is distinguished by a history of innovation and research centered in its universities. And within Central and Eastern Europe, the nation is emerging as a leader in biotechnology.[1]

In January 2005, a new law directing the commercialization of university research — the Act on Research, Development and Technological Innovation — went into effect. "Modeled after the Bayh-Dole Act, the new legal framework has been put into place, but it will take some time until universities learn how to use this opportunity to build up their technology transfer offices," said Erno Duda Jr., President of the Hungarian Biotechnology Association, in a Milken Institute interview. "The whole university commercialization scenario is changing rapidly in Hungary, but they still have a ways to go."

According to the European Federation of Biotechnology in 1999, "There are approximately 100 drug manufacturers located in Hungary, whose combined output represents an estimated 4.2 percent of the country's GDP."[2] Per capita spending on pharmaceuticals reached $152 in 2003.[3]

Hungary's national innovation policies are modeled after those of the European Commission.[4] In addition to legislation, the government has established various boards, committees and funds to help stimulate biotech R&D. These include the Science and Technology Policy Board, headed by the prime minister; the Science and Technology Advisory Committee; the National Office of Research and Technology, supervised by the minister of education and responsible for implementing the government's S&T policy; the Agency for Research Fund Management and Research Exploitation; the Research and Technology Innovation Fund;[5] the Research and Technology Innovation Council;[6] and the Hungarian Academy of Sciences (HAS), an autonomous public body established to promote science and which maintains a special academic research network. The HAS and its institutes are financed by state budgets.

Hungary's comparative advantage in biotechnology, vis-à-vis competing Central and Eastern European nations, is its industrial organization. The Hungarian Biotechnology Association integrates private and public goals, propelling biotech R&D.[7] Created in 2003 by leading biotech firms, the association promotes the sector nationally and internationally, and aids in the commercialization of research. It recently joined EuropaBio, the European Association for Bioindustries.[8]

2. Funding and Venture Capital

Prior to passage of the Act on Research, Development and Technological Innovation, universities and research institutes were prohibited from receiving funding from non-governmental sources.[9]

Gross expenditures on R&D as a portion of Hungary's GDP fell from approximately 2 percent in 1989 to 0.94 percent in 2001, forcing cuts in laboratories nationwide.[10] The Act on Research, Development and Technological Innovation is part of the effort to reverse that trend by permitting research groups to attract private finance, thus establishing a framework for university/business collaboration.[11]

The government allows 100 percent of corporate R&D expenditures to be deducted from profits before taxation for all R&D activities in which the partner is a public or nonprofit research center; companies whose laboratories are located at a university or public research institute benefit from a 300 percent research and technological development tax allowance.[12] Due to these incentives, double-entry bookkeeping in Hungarian companies reporting R&D skyrocketed.[13]

Venture capital in biotechnology remains scarce, despite the promise of business-friendly legislation. Venture capitalists may be cautious because no biotech firms have listed on the Budapest Stock Exchange, though local firms do list on international exchanges.[14]

Incentives to invest in Hungary include the high quality of human capital, coupled with personnel and overhead costs below the European average.[15] In addition, the government has declared biotechnology a national research priority. Beginning in 2005, approximately $213 million annually will be available for applied research grants to universities, research institutes and companies under the Research and Technology Innovation Fund.[16] "Apart from the micro- and small enterprises, every enterprise is obliged to pay at least 0.25% of its turnover into the Fund," according to the National Office for Research and Technology. "The Hungarian government contributes to the Fund with an equivalent amount."[17]

3. Clusters of Biotechnology

As of 2001, about 50 biotechnology companies existed in Central Europe, and about one-third of those were Hungarian companies based in and out of the country.[18] Biotechnology clustering[19] in Hungary is largely centered in Budapest, Szeged, Debrecen and Pécs.[20]

Major research centers include the Agricultural Biotechnology Center; the Bay Zoltán Institute for Biotechnology, based in Szeged;[21] the Biological Research Center of the Hungarian Academy of Sciences, also based in Szeged; the Central Food Research Institute in Budapest; the Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene in Budapest; and the Institute for Small Animal Research in Gödöllõ.

The abundance of intellectual capital in Hungary is marked by the nation's high number of Nobel Prize winners per capita,[22] its high number of scientific articles published per U.S. dollar spent on R&D[23] and its culture of competition, as depicted by its sixth-place ranking of countries able to develop their high-tech industries.[24]

4. University Technology Transfer Mechanisms

Only recently have major universities in Hungary established technology transfer offices. The country's academics, therefore, lack experience and understanding of current intellectual priority rights in the technology transfer process.[25]

One particular initiative is the Biopolis Life Science Consortium, a biotech-related tech transfer institution located in Szeged.[26] In addition, the Hungarian government's Cooperative Research Center program enables companies to initiate the development of a joint infrastructure at major universities, thus emphasizing applied R&D.

5. Commercialization Success: Patents and Licensing

The number of patent applications per $1 million in R&D expenditure in Hungary is internationally competitive, ranking above the United States; but its filing and granting of patent application statistics lags behind Europe.[27] In 2002, there were 962 resident and 91,497 non-resident patent applications filed; 21.7 percent of the resident and 1.3 percent of the non-resident patents were granted.[28] In 1997, by contrast, 744 resident and 29,331 non-resident patent applications were filed, with 46.5 percent of the resident and 2.9 percent of the non-resident patents granted.[29] This marks a major increase of non-Hungarian companies or scientists working within the country.

> "There is a lot of quality academic research in Hungary, but only a small proportion gets commercialized."
>
> — Erno Duda Jr., President, Hungarian Biotechnology Association

Hungary was once responsible for providing Eastern Europe with the majority of its pharmaceuticals.[30] As a new EU member, the country has been unable to export pharmaceuticals to other EU nations where a patent already exists for that product, thus negating its role as a parallel exporter.[31]

Endnotes:

1. http://www.itd.hu/itdh/static/uploaded/document/biotech_HU.pdf.
2. European Federation on Biotechnology, Task Group on Public Perceptions of Biotechnology. Briefing Paper 9. "Biotechnology Legislation in Central and Eastern Europe." June 1999. See: http://www.efb-central.org/images/uploads/LegislationCEE_English.pdf.
3. According to Business Monitor International Ltd.'s "Hungary Pharmaceuticals & Healthcare Report Q4 2004." See: http://www.businessmonitor.com/images/pdfs/pharma/hungarypharma_sample.pdf.
4. European Commission legislation includes EC Directives 90/219 and 90/200. Hungary's biotechnology legislation includes Act No. XXVII of 1998 on Biotechnology Activities, its enacting clauses 1/1999 (I.14.) FVM, 44/1999 (IV.30.) FVM, and Decree No. 1/1999. (I.14.) FVM.
5. The Research and Technology Innovation Fund was established in January 2004.
6. Hungarian Investment and Trade Development Agency. "Biotechnology in Hungary." See: www.csis.org.
7. http://www.hungarianbiotech.org/html_eng/index.htm.
8. Ibid.
9. "Hungary looks into new laws to stimulate innovation," *EU Business*, January 1, 2005. See: http://www. eubusiness.com/topics/Rd/hungary.2005-01-04.
10. http://www.nkth.gov.hu/letolt/k+f/angol_nyelv_statisztika_2001.pdf.
11. http://www.nature.com/news/2004/041229/pf/bioent841_pf.html. Burgermeister, Jane. 2004. "Hungarian Parliament expected to pass a new innovation law," *News@nature.com*, December 30.
12. http://www.nkth.gov.hu/main.php?folderID=891&articleID=3943&ctag=articlelist&iid=1.
13. http://europa.eu.int/comm/research/era/3pct/pdf/rd_investment_snapshot_24sep04.pdf.
14. http://www.nature.com/news/2004/041229/pf/bioent841_pf.html.
15. Hungarian Investment and Trade Development Agency.

16. http://www.nature.com/news/2004/041229/pf/bioent841_pf.html.
17. National Office for Research and Technology. See: http://www.nkth.gov.hu/main.php?folderID=775.
18. Ernst & Young. *Beyond Borders. The Global Biotechnology Report*. 2002, as cited in Sansom, Claire. 2004. "EU Expansion: Enlarged Horizons or False Dawn?" *Nature Biotechnology,* 22(5). http://www.nature.com/nbt/journal/v22/n5/full/nbt0504-501.html.
19. Clusters as defined by the Hungarian Investment and Trade Development Agency. "Biotechnology in Hungary." See: http://www.csis.org/eaac/US_Hungary/Biotechnology.pdf.
20. Hungarian Investment and Trade Development Agency. "Biotechnology in Hungary."
21. The Bay Zoltán Foundation, established in 1992 by the National Committee for Technological Development, carries out applied, technological and scientific R&D. It provides an intellectual basis for developing and emerging SMEs in Hungary. BAYBIO, a subset of the foundation that works in conjunction with other research centers and companies, conducts research on molecular biotechnology, bio-transformational procedures and bioremediation. See: www.bzlogi.hu/WWW/oldalak/BAYLOGIen/ BAYLOGI_honlap/Bemutatkozas/Introduction/index.html.
22. http://www.tcf.org/list.asp?type=NC&pubid=1217.
23. National Science Foundation, Science and Engineering Indicators. 2002. See: http://www.nsf.gov.
Science and Engineering Indicators: 2002.
24. *Financial Times*, 2001, based on OECD's 2001 edition of the *Science, Technology and Industry Scoreboard.* Marsh, Peter. 2001. "A new millennium's winners and losers: How the table was worked out: Competitiveness: The FT has compiled a league table of the countries that are best placed to develop their high-technology industries," *Financial Times*.
25. http://www.nature.com/nbt/journal/v22/n5/full/nbt0504-501.html.
26. Hungarian Investment and Trade Development Agency. "Biotechnology in Hungary." See: http:// www.csis.org/eaac/US Hungary/Biotechnology.pdf.
27. Survey by the Institute for Scientific and Technical Communication. See: http://www.csis.org/eaac/ US_Hungary/Biotechnology.pdf.
28. IP/STAT/2002/B.
29. Ibid.
30. Bio2005. See: http://www.bio.org/events/2005/international/CountryProfiles.pdf.
31. http://www.espicom.com/web.nsf/structure/ph_bksmhungary-or?OpenDocument.

Israel

1. National Innovation Policy

With a multilingual immigrant population, "Israel is well placed to make an impact in interdisciplinary technologies, thanks to the mathematics, physics and computer science training fostered by the universities and the country's specialized military units," according to a report from the Israel Ministry of Foreign Affairs in 2002.[1] The country has a strong scientific network of research in life sciences, bioinformatics, nanotechnologies and pharmaceuticals. More than 22 percent of its Ph.D.s major in the life sciences.[2]

Israel's life-science industry is dominated (51 percent) by medical device companies. The second-largest sector, biotech, accounts for 23 percent of the industry and 129 firms. Of those 129 companies, 38 are revenue-generating. The remaining are either in the seed, preclinical or clinical stages of R&D.[3] Approximately half of Israel's biotech firms have joined the Israeli Biotechnology Organization, which markets Israeli biotech to investors, works with the government to create a climate hospitable to biotech growth and develops ties with life-science industries globally.[4]

> Teva, one of the world's largest generic pharmaceutical companies, is headquartered in Israel and employs 25,000 people worldwide. Sales in 2005 totaled some $5.3 billion. Its recent acquisition of Florida-based IVAX advances the company's strategy for globalization and growth.

The current structure supporting biotechnology is grounded in two laws. The Law for Encouragement of Industrial Research and Development (1984, amended in 1997)[5] requires government-funded R&D to take place in Israel, a mandate that restricts global alliances and market development. The World Economic Forum's 2004–2005 *Global Competitiveness Report* named Israel's inefficient bureaucracy as the most problematic factor for doing business.[6] The industry is further limited because some pension funds and insurance companies, two of the largest investors in the country, choose not to invest in biotech because of these and other government restrictions.[7]

The Law for the Encouragement of Capital Investments (1959) supports private investment through grants and tax incentives favorable to investors and high-tech companies.[8]

The government is committed to developing R&D, as evidenced by its major increase in R&D spending between 1995 and 2002 — from 2.74 percent to 4.72 percent of GDP — a change higher than any other OECD country.[9] Furthermore, in 2004, Israel ranked No. 1 in the world in civilian expenditures on R&D as a proportion of GDP, at 4.6 percent.[10]

Government structures supporting R&D, particularly in biotech, include the Office of the Chief Scientist of the Ministry of Trade and Industry (OCS), which provides financial support ranging from 30 percent to 66 percent, based on a new product's level of innovation, new technology and competitiveness potential, as well as the firm's potential management, production and marketing capabilities. Only if the venture succeeds must OCS grants be repaid, in the form of royalties on sales.[11] Companies are required to pay the OCS royalty payments until full coverage of the grant, similar to LIBOR (London Interbank Offered Rate) loan interest rates. Royalties are usually set at 3 percent for the first three years and increase to 3.5 percent thereafter. Companies that decide to transfer production and manufacturing of OCS-funded products overseas incur greater royalty payments.[12] In 2003, 14 percent of companies receiving OCS grants were in biotech.[13] One of the most important OCS endeavors is the "magnet" program, which finances up to 65 percent of a consortium's budget and currently supports four biotech projects.[14]

In addition, the Technological-Incubator Program provides facilities, management and marketing guidance to scientists and smaller companies in early stages of R&D, up to 85 percent of their approved budgets, between $350,000 and $590,000 for two years.[15] Finally, the Council for Higher Education, and its Planning and Budgeting Committee, allocates about 40 percent of its billion-dollar budget to institutions of higher education for their life sciences programs and R&D.[16]

Despite governmental efforts, the 19th annual Ernst & Young biotechnology report found that Israel's biotech industry was in decline, as measured by the amount of venture capital funding. Yitzchak Forer, Chairman of Kost, Forer, Gabbay and Kasierer, explained that the medical devices sector had received more investment than biotech in 2004. "I believe that in order to bring about a change in biotechnology in Israel," he said, "the state has to intervene, and invest large amounts of money in the industry, if that is indeed a priority for the state."[17]

International cooperation is integral for the expansion of Israeli biotech. An increasing number of Israeli companies outsource their manufacturing and marketing functions because the country lacks the infrastructure required to commercialize on a large scale. Israel has signed agreements with a few EU member nations, as well as with China, Hong Kong and others that encourage R&D cooperation.[18]

2. Funding and Venture Capital

Funding the life-science industry in Israel is divided among various entities, government and private, with the majority of funds split between medical devices and biotech.

Financing Sources for Israeli Life-Science Research

Financing Source	US$ Millions	Percent
Israeli Government	308.0	30.3
Competitive Grants (NIH etc.)	130.0	12.8
Binational Government-Supported Foundations	17.6	1.7
Venture Capital	287.0	28.2
Self-Funding Companies	274.0	27

Sources: ILSI Database, 2004; Industry Reports

The Heznek Fund, another government program, invests alongside private equity in seed-stage companies in return for an equity stake. Riskier developments can be explored without private equity funds bearing the initial burden of risk to secure major capital investments.[19]

Venture capital provides the second-largest source of funding for biotech firms. Approximately 70 venture capital funds exist in Israel.[20] In 2004, VCs invested $287 million in Israeli life sciences companies, a 17.6 percent increase over 2001.[21] Israel's biopharmaceutical industry is the favored investment of European VC firms, which invest up to 85 percent in that sector, and U.S. companies, which invest up to 67 percent.[22] Some universities have created their own VC funds. A group of U.S. investors contributed $8 million to Tel Aviv University's fund and will advise the university on projects in biopharmaceuticals and medical devices.[23]

Industrial R&D constitutes just under one-third of Israel's' life-science funding. Global pharmaceutical clinical trials are often conducted in Israel.[24]

3. Clusters of Biotechnology

Israel's university and research institute system provides the organization for natural clustering. This is propelled by the magnet program, which gives financial incentives for universities and companies to collaborate. The following universities and institutes, which are all within driving distance of each other, play a dominant role in biotech R&D, in collaboration with companies:

- Weizmann Institute of Science in Rehevot pioneered biotechnology in Israel. Included are Kiryat Weizmann Science Park, with Yeda Research and Development serving as its tech-transfer company. The institute ranks third in the world in making money out of technology transfers — $93 million in 2003.[25]
- Hebrew University in Jerusalem; Yissum serves as the university's technology-transfer company.
- Technion, Israel Institute of Technology in Haifa is served by the Technion R&D Foundation, as well as Dimotech, which works on technology transfer.
- Bar Ilan University in Ramat Gan works with the Bar-Ilan R&D Co. on tech transfers.
- Ben Gurion University in the Negev in Be'er Sheva, specifically the Institute of Applied-Life Sciences, with B.G. Negev Technologies & Applications Ltd. works on technology transfer.
- Tel Aviv University, specifically its Department of Microbiology and Biotechnology, uses Ramot as its tech transfer company.[26]

Private-firm concentration mirrors the university system: Twenty-one biotech companies are based in Kiryat Weizmann Science Park; 14 in Jerusalem (Hebrew University); 11 in Haifa (Technion); and five in Ramat Gan (Bar Ilan University). Tel Aviv has two registered biotech companies, and Be'er Sheva none, while Herzliya has five, despite the existence of a major public university. The remainder are spread throughout 29 cities and *kibbutzim*.

The U.S.-Israel Life Sciences Bridge Program joins America's Larta Institute with Israeli partner Atid EDI Ltd.[27] Another enterprise involves Tel Aviv University, which joined the Nano2Life European Network of Excellence in Nanotechnology.[28]

4. University Technology Transfer Mechanisms

In the 2004/2005 *World Competitiveness Report*, Israel ranked 12th in research collaboration between industry and universities, down from ninth the prior year.[29] Higher wages lure many scientists from academic institutions to biotech companies.[30] At Hebrew University and the Weizmann Institute, two universities leading Israel in biotech, along with Tel Aviv University, researchers receive approximately 40 percent of net royalties. Elsewhere, the researcher and university typically receive 40 percent to 60 percent each, while the department usually does not reap any financial rewards.[31]

Israel ranks first in technological readiness and third in the quality of scientific research institutions. However, the nation has a relatively low rate of university research commercialization.[32]

A 2001 study by the Monitor Group of Cambridge, Mass., concluded that Israel's university OTTs were insufficiently funded, inexperienced and inefficient, and that universities lacked uniform standards governing rights and research.

5. Commercialization Success: Patents and Licensing

Israel ranks first worldwide in the proportion of life-science patents to the total number of patents written by Israeli inventors. The country ranks fourth in total number of biopharma patents granted, in terms of patents per capita, and 12th in the absolute number of biopharma patents.[33]

Ranking statistics from 2000 place Israel seventh in its biotech patents as a percentage of the national total submitted to the European Patent Office by Israeli inventors, just over 1 percent of EPO biotech patents in that year. Further, Israel placed 14th in the share of patents granted by the U.S. Patent and Trademark Office and 17th in the number of patent applications to the EPO, both in 2000, according to the residence of the inventors. In terms of absolute numbers, Israel ranked low; relative to its GDP and population, the country ranks high.[34]

Yet Israel's success at generating revenues from these patents is less than stellar. "What will be the added value to the Israeli economy?" asked Shai Aizin, Consul for Economic Affairs with the Israeli Economic Mission in Los Angeles, in a 2005 Milken Institute interview. "Unfortunately, the innovation may begin in Israel, but much of the added value leaves."

"One of the problems is that Israel is far away from the market, the U.S. The VCs are interested in maximizing return on investment for their clients, which sometimes doesn't translate into longevity for the companies they invest in. Instead of supplying product to a U.S. multinational enterprise, what they may end up doing is licensing the IP. So Israel ends up selling just the IP, which doesn't particularly benefit Israel."

"Israel has a good incubator program for startups, but finding a strategic partner willing to be supplied a finished, private-label product is the key. The problem with the incubator program is that it is excellent, but only up to a certain point — getting a prototype and getting the technology developed to a functioning device — often the startup companies are left to fend for themselves with little capital and nowhere to go."

— Jack Tawfik, Managing Director, JANT Pharmacal Corp., Encino, Calif.

Endnotes:

1. Israel Ministry of Foreign Affairs. 2002. "Facets of the Israeli Economy: Biotechnology." See: http:// www.mfa.gov.il/MFA/MFAArchive/2000_2009/2002/11/Facets%20of%20the%20Israeli%20Economy-%20Biotechnology.
2. Bio 2005. http://www.bio.org/events/2005/international/CountryProfiles.pdf.
3. Israel Life Science Industry, 2005. See: http://www.ilsi.org.il/industry_profile.asp. (Accessed March 10, 2006).
4. Manufacturers Association of Israel. 2003. "Biotechnology Branch." See: http://www.industry.org.il/Eng/SubIndex.asp?CategoryID=139.
5. Israeli Industry Center for R&D (Matimop). http://www2.matimop.org.il/1/general/ocs-law.asp.
6. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. *Global Competitiveness Report.* 2004-2005 Geneva: World Economic Forum.
7. Watzman, Haim. 1999. "Israel 'must relax technology transfer law,' " *Nature*, 399(6738).
8. Ministry of Industry, Trade and Labor. "Investment Incentives in the Law for the Encouragement of Capital Investment." See: http://www. moit.gov.il/NR/exeres/9DF4F491-E41C-406F-8903-894F11A502E0.htm.
9. OECD. 2004. "OECD Countries Spend More on Research and Development, Face New Challenges." See: http://www.oecd.org/document/2/0,2340,en_2649_34273_34100162_1_1_1_1,00.html.
10. Klein, Zeev. 2005. "Israel top for R&D spending as a proportion of GDP," *Globes [online] — Israel's Business Arena.* See: http://www.globes.co.il.
11. Innovation Relay Centre. "Biotechnology in Israel: Securing a Prominent Place on World Markets." See: http://www.irc.org.il/biotech/Bio%20in%20Israel.htm.
12. http://www.rotem.co.il/english/services/ocs_eng.htm.
13. PWC Kesselman & Kesselman. See: http://www.ilsi.org.il/industry_financing_history.asp.
14. Innovation Relay Centre.
15. Israel Life Science Industry. 2005.
16. Ibid.
17. Feldman, Batya. 2005. "State must help biotech," *Globes [online] — Israel's Business Arena.* See: http://www.globes.co.il.
18. Israeli Life Science Industry. 2005.
19. Ibid.
20. Bio 2005.
21. Israel Life Science Industry. 2005.
22. Ibid.
23. Thayer, Ann. 2003. "Universities Back Venture Funds," *Chemical and Engineering News*, 81(20).
24. Israel Life Science Industry. 2005.
25. Shai Aizin. Consul for Economic Affairs, Government of Israel Economic Mission, Los Angeles.
26. Israel Relay Centre. "Biotechnology Based on Academic Research."
27. MarketWire. 2004. "Larta Institute Announces Selection of Israeli Companies in US-Israel Life Sciences Bridge Program." See: http://www.marketwire.com/mw/release_html_b1?release_id=65966.
28. Eleasari, Rava. 2005. "Israeli Research Bring Nanotechnology to Life." Israel21c.
29. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004.
30. Revel, Michael. "Biotechnology in Israel," Israel Relay Centre. See: http://www.irc.org.il/biotech/Revel.htm.
31. Dan Schechtman of Technion. See: www.bergforsk.se/bilder/From_lab_to_market_place.pdf.
32. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004.
33. Israel Life Science Industry. 2005.
34. http://www.oecd.org/dataoecd/60/24/8208325.pdf.

Italy

1. National Innovation Policy

Italy has only recently recognized the importance of the biotechnology industry and its wide-ranging potential for economic growth and national competitiveness. In order to realize this potential, the country needs a national innovation policy that supports and promotes the development of biotech companies and the industry as a whole.[1]

During the Silvio Berlusconi government (2001–2006), improving Italy's innovation potential, administrative simplification and university reform was a key priority. The government restructured and merged the ministries responsible for education, universities and research. Today the major bodies responsible for R&D and innovation are the Ministry of Education, University and Research (MIUR); the Ministry of Productive Activities; and the Ministry for Innovation and Technologies.[2]

On the regional level, the Italian government approved a wide range of structural reforms outlined in the National Research Plan (2005–2007), which called for the formation of new industrial districts (11 in all) in selected regions.[3] Each district will focus on a particular field, such as nanotech in the Veneto region and biotech in Milan.[4]

> The health sector accounts for 60 percent of Italy's biotech market, with emphasis in therapeutics and diagnostics.

The Ministry of Education promotes the government's agenda of greater collaboration between public universities and industry. Recent reforms have removed boundaries between public and private institutions so that now professors can hold positions in industry and academia.

The Foundation of Italian Institute of Technology (IIT), established in Genoa in 2003, is developing a number of interdisciplinary research projects. Its Scientific Plan, prepared by the Steering and Regulatory Committee, develops multidisciplinary research emphasizing bio-nanotechnology, neuroscience, automation and robotics. In 2004, the Italian central government allocated $40 million to the IIT Foundation, plus $80 million for each consecutive year from 2005 to 2014.[5]

To promote innovation, the government introduced a number of tax initiatives in its 2004 budget. One of the initiatives, Techno-Tremonti, grants businesses a 10 percent tax deduction for "product and process innovation." The government also instituted short-term, 90 percent income-tax exemptions to attract non-resident researchers.[6]

2. Funding and Venture Capital

Although Italy's is the world's sixth-largest economy,[7] its investment into science and technology R&D is comparatively meager. In 2000, the country invested $10.4 billion in R&D: $4.2 billion from the private sector and $6.2 billion from public funds. The total accounted for only 1.07 percent of Italian GDP, relative to the European average of 1.88 percent.[8] Italian R&D spending declined significantly in the 1990s due to the country's priority of reducing the national debt and its budget deficit. From 1991 to 1995, R&D public funding fell by 6.1 percent.[9]

In 2003, the government proposed taxation of cigarettes as a way to raise funds for research in universities and research institutions.[10] In August 2005, the Ministry of Education announced a competition of $9.8 million for biotech research in the Lombardy region. The money is to be allocated for research and spin-off activity in genomics, proteins and other cutting-edge discoveries.[11] While R&D funding in Italy is on the rise again, it has not yet reached levels attained in the early 1990s.

Italy's universities receive a larger share of total national R&D spending than do universities in the rest of Europe.[12] University R&D spending as percent share of the GDP in 2001 was 0.36 percent, only slightly below the European average of 0.39 percent. In 2002, Italian universities spent nearly $4.5 billion on R&D, reflected as 0.38 percent of GDP, 32.8 percent of total R&D spending and nearly 40 percent of total university funding.[13]

University R&D Funding in Italy

	Values at Current Prices (US$ Thousands)	Percent Share Relative To		
		GDP	Total R&D Spending	Total University Spending
2000	$3,568,294	0.33	31.0	38.0
2001	$3,955,240	0.36	32.6	39.7
2002	$4,530,085	0.38	32.8	39.8

Sources: Italian Ministry of Education, University and Research; Milken Institute

R&D in Italy is funded by the European Union and the Italian government. However, the majority of Italy's competitive life-sciences laboratories rely on EU funding.

Although venture capital and private equity investment have grown considerably, of the $2,290 million invested in 2004, only 2 percent was spent in the biotech sector.[14] Italy lacks seed money for biotech startups. Many investors, domestic and foreign, don't see it as an opportunity for investment. According to a survey conducted by Blossom Associati/Assobiotec, foreign investors are willing to partner with domestic investors but are hesitant to have a 100 percent investment stake in Italian biotechnology firms.[15] GenExtra is a holding company that finances startups in pharmagenomics and nano-biotechnology.[16]

3. Clusters of Biotechnology

Northern Italy is home for about 70 percent of the country's biotech science parks and companies.[17] The region of Lombardy — a leading biotechnology center in Europe and the world — accounts for 50 percent of the nation's biotech industry, with the highest aggregation in the Milan region.[18] The primary strengths of these companies lie in medical applications, diagnostics, therapeutics and agro-alimentary fields.[19] The following map depicts the regional distribution of Italy's biotechnology companies.

Geographic Distribution of Biotechnology Companies in Italy

Source: "Osservatorio sulle Biotecnologie in Italia Biotechnology in Italy," Indagine 2004, Deloitte

Italy has a number of scientific parks specializing in genomics, bioinformatics, biomedicine, diagnostics and nano-biotechnology. San Raffaele Biomedical Science Park in Milan, Canavese Bioindustry Park in Turin, AREA Science Park in Trieste, and CEINGE Advanced Biotechnology Institute in Naples are some of the more significant.[20] These biotech clusters, supported by recent legislative changes that promote R&D, build links between university and industry, and provide opportunities for students.

The San Raffaele Biomedical Science Park

Created in 1992, Milan's San Raffaele Biomedical Science Park concentrates on biomedical and biotechnology R&D and works closely with:

- San Raffaele Hospital, Italy's leading private hospital
- University Vita-Salute San Raffaele, offering degrees in medicine and science
- San Raffaele Scientific Institute for Molecular Medicine (IRCCS), a research hospital affiliated with the University of Milan Medical School
- The science institute DIBIT, Department of Biotechnologies, focusing on basic science research
- A number of pharmaceutical, diagnostic and biotech research groups: Axxam, Bioxell, Bracco, Charles River, Primm and Scherring Plough
- Telethon and Cystic Fibrosis Association foundations
- Molmed and Telbios startups, both a result of research activates of the Park

Also located within the park is the Science Park Raf SpA, the office of biotechnology transfer created in 1995 to support technology transfer activities, innovation, licensing, patenting and commercialization. Its portfolio includes 66 patent applications, 15 licensing contracts, two startups and more than 2,000 R&D contracts.

The Veneto Nanotech cluster, established in 2003, offers facilities and provides seed capital for nanotech application R&D projects, promotes technology transfers and encourages cooperation among universities and industry.[21]

4. University Technology Transfer Mechanisms

Technology transfer is in its nascent phase in Italian universities. In 1989 the University of Bologna was the first Italian university to establish an official technology transfer office. Others followed suit, and within the past few years, more than 20 of Italy's universities have established OTTs. The following table illustrates the timeline of OTT establishment at Italian universities.[22]

Starting Year of Technology Transfer Activities

Fiscal Year	# of Univs.	Fiscal Year	# of Univs.
1989	1	1997	1
1990	0	1998	2
1991	0	1999	0
1992	0	2000	2
1993	0	2001	8
1994	0	2002	8
1995	1	2003	4
1996	0	**Total**	27

Source: Fabrizio Cesaroni et al.

OTT staffs at Italian universities are small but have been increasing in recent years. In addition, a number of tech transfer entities have been established to aid intra-European technology transfers.

In 2001, with the slogan of "inventions to inventors," the government passed legislation (Law 383) that vests patent ownership of publicly funded research with the inventor.[23] Revenue-sharing varies, depending on agreements between the university and inventor. Generally, universities and publicly funded institutes receive from 30 percent to 50 percent of the revenues generated from patent exploitation. Previously borne by universities, patenting fees are now the responsibility of the inventor. However, some universities agree to pay patenting costs for a larger share of proceeds or in exchange for complete ownership.[24]

Italy has seven Innovation Relay Centers (IRCs), which are part of a larger European network comprising 68 centers in 31 countries. These centers offer specialized business-support services to SMEs and help companies establish transnational ventures with universities and companies to better utilize and exploit new and available technologies. Funding for IRCs is partly provided by the EU; their activities are supported by the MIUR. Since 2000, Italian IRCs negotiated 277 technology offers and successfully set up 46 tech transfer agreements.[25]

The Network of Valorization of University Research, established in 2002, includes more than 40 universities. It promotes the use of patenting tools in universities and aims to homogenize management procedures in matters of patenting, tech transfer and establishment of spin-offs.[26]

5. Commercialization Success: Patents and Licensing

Italy's biotechnology industry is characterized by small, innovative businesses that originated as spin-offs or startups. Due to the scarcity of domestic venture capital financing, the number of biotech companies in Italy is small, compared to elsewhere in Europe. However, as Francesco Sinigaglia, the CEO of BioXell, pointed out, "quality is more important than quantity," and Italy's hostile business environment and scarce availability of financing mean that "selection is Darwinian."[27]

The following table summarizes the results of a survey of Italian OTTs. ("N" represents the number of university responses.) Increase in licensing income from 2002 to 2003 is a result of several universities signing high-value contracts. Analysis of the survey results reveals that technology transfer in most Italian universities does not represent a source of valuable monetary returns. In many cases, revenues generated from technology transfer activities do not even compensate for the associated costs.[28]

Italian University OTT Activities

	Italian Patent Applications		USPTO Patent Applications		EPO Patent Applications	
	2003 (N=19)	2002 (N=23)	2003 (N=13)	2002 (N=17)	2003 (N=13)	2002 (N=17)
Total	99	110	23	18	39	31
Average	5.2	4.8	1.8	1.1	2.4	1.8

	IP Protection Expenditures		Number of Licenses or Options Executed		Licensing Income Generated	
	2003 (N=20)	2002 (N=26)	2003 (N=17)	2002 (N=25)	2003 (N=13)	2002 (N=27)
Total	$908,805	$566,975	39	27	$690,706	$345
Average	$45,440	$21,807	2.3	1.1	$53,132	$13

Sources: Fabrizio Cesaroni et al., Milken Institute

Endnotes:

1. "Biotechnology in Europe Today." Supplement to chimica oggi/Chemistry Today. "Italy's Biotech: Only Missed Chances?" See: http://www.mbiolaw.com/pdfs/italy1.pdf.
2. European Trend Chart on Innovation. "Annual Innovation Policy Report for Italy." September 2003–August 2004. See: http://trendchart.cordis.lu/reports/documents/CR_Italy_September2004.pdf.
3. Susan Biggin. 2005. "Universities and Institutes Face Industrial Revolution," *Science,* Vol. 308. 1 April.
4. Programma Nazionale Per la Ricerca 2005–2007. (Ai sensi del D.L. 204/1998, Art. 1, comma 2). See : http://www.governo.it/GovernoInforma/Dossier/pnr05_07/pnr.pdf.
5. http://www.iit.it/.
6. http://www.euractiv.com/29/images/rd_investment_snapshot_24sep04_tcm29-132457.pdf.
7. World Development Indicators database. World Bank. 15 July 2005.
8. http://www.infoexport.gc.ca/science/Italy_2003-en.htm.

9. Ibid.
10. European Trend Chart on Innovation. "Annual Innovation Policy Report for Italy."
11. http://www.riditt.it/page.asp?page=news_nat&idlanguage=it&nmpages=14&action=detail&IDObject =170&IDObjectType=8.
12. http://www.miur.it/ustat/documenti/pub2005/u01.pdf.
13. Ibid.
14. Italian Private Equity and Venture Capital Association. AIFI Yearbook 2005. Graphic per PricewaterhouseCoopers. See: http://www.altassets.com/pdfs/aifi_yearbook2005.pdf.
15. www.blossom-advisory.com/doc/Bio%20World%20Europe.pdf.
16. www.genextra.it.
17. "Osservatorio sulle Biotechnologie in Italia Biotechnology in Italy." Indagine 2004, Deloitte.
18. Ibid.
19. Ibid.
20. http://www.investinitaly.com/UploadDocs/65___Brochure.pdf.
21. http://www.venetonanotech.it/.
22. Cesaroni, Fabrizio et al. 2005. "Technology Transfer Offices (TTO) in Italian universities: What they do and how they do it." Triple Helix Conference, May 15.
23. Anna Meldolesi, 2001. "Bungled law threatens Italian tech transfer," *Nature Biotechnology,* Vol. 19. November. http://biotech.nature.com.
24. Ibid.
25. http://www.cordis.lu/italy/irc.htm.
26. http://www.netval.it/1partners.htm.
27. Anna Meldolesi, 2001.
28. Cesaroni, Fabrizio et al. 2005. The survey was conducted on behalf of the Network per la Valorizzazione della Ricerca Universitaria (University Network for Research Valorisation).

The Netherlands

1. National Innovation Policy

The Dutch government began to focus its efforts on stimulating public policy and biotechnology innovation in 1979.[1] Supported by a well-developed agricultural and food R&D sector, the government's first efforts addressed the establishment of the support infrastructure for basic biotech research. Since then, distinct phases of Dutch public policy evolution can be identified:[2]

- The policy theme for the mid- to late 1980s underscored support of technology transfer collaboration.
- From the late 1980s to mid-1990s, the general technology policy emphasized commercialization and entrepreneurship. Facilitation of the translation of biotech R&D results into commercial products was a central theme in 1994 Dutch biotechnology policy.
- In 1998, the government designated genomics "as an area of strategic technological development."[3] In 2000, the ministers of Economic Affairs and of Education, Culture and Science were presented with the Strategic Actionplan Genomics. Concurrently, Innovation Oriented Research Programme, the IOP Genomics, was initiated by the Ministry of Economic Affairs. The duration of the program is set to eight years, with an approximate budget of approximately $15-$19 million. Furthermore, a program on biomolecular informatics with a budget of at least $9.7 million was designed by the Dutch Organization for Scientific Research.

> Philips, Akzo Nobel, Shell, ASM Lithography, DMS, Unilever and Océ account for 50 percent of business R&D expenditure in the Netherlands, according to an OECD cross-country comparison.

Implemented in 1994, the WBSO Act (Promotion of Research and Development Act) is the largest fiscal incentive initiative and has proved to be cost-effective for motivating commercial R&D, as it reduces the "wage burden" for companies.[4] Under this measure, "the income tax and social contributions for R&D personnel" are also reduced.[5] In 2004, WBSO had a budget of $501 million, which increased to approximately $344 million in 2005. The budget was scheduled to increase, starting in 2006, by an additional $80 million, amounting to approximately $364 million in 2006.[6]

2. Funding and Venture Capital

Since 1990, R&D investment has increased in absolute terms; however, it has declined as a percent share of GDP. The Netherlands is therefore far from reaching the EU goal of 3 percent of GDP investment in R&D.

Dutch R&D Expenditure by Source of Funding

	Absolute (Euro Millions)			As Percent of GDP		
	1990	1995	2001	1990	1995	2001
Government	2,436	2,533	2,925	1.00	0.84	0.68
Companies	2,423	2,761	4,188	1.00	0.91	0.98
Other National Sources	80	153	86	0.03	0.05	0.02
Other Countries	101	560	891	0.04	0.19	0.21
Total	**5,041**	**6,007**	**8,090**	**2.07**	**1.99**	**1.89**

Source: http://eu2004.minocw.nl

"Eight of the 15 universities in the Netherlands are engaged in biotech research shared between the research schools and the Centre for Biomedical Genetics. A number of public research institutes are also active in this field, among them: Wageningen, Utrecht, Groningen, Leiden and Maastrich," according to one report.[7] Funding for university R&D comes from: government grants; the Nederlands Organization for Scientific Research (secondary government funding); and EU nonprofit institutions and industry (third-flow/external funding).

Groningen Biomolecular Sciences and Biotechnology Institute; BioCentre Amsterdam; Experimental Plant Sciences Wageningen; Food Technology, Agrobiotechnology, Nutrition and Health Sciences Wageningen; and Biotechnological Sciences Delft Leiden are among the most influential institutes engaged in biotech R&D.[8]

Several programs, including Biopartner and the TopSpin program of the University of Twente, offer very early support (i.e., before the business plan is written and VC is attracted).[9]

To stimulate public-sector R&D, the Dutch government has instituted several financial incentives. Among these are: the $80 million grants from 2007 onward for structural improvements to R&D worth, investments in the scientific information infrastructure and grants for individual researchers.[10]

The country has a well-developed venture capital market dating back to the 1980s, when a number of U.S. companies, funded by VC seed money, were set up. Today the major players of the Dutch VC market include Atlas Ventures, Euro-ventures, Gilde Investment Fund and Life Sciences Partners.[11]

3. Clusters of Biotechnology

Positioned around the centers of scientific research, the Netherlands' biotech industry is clustered in the "bio-belt" region encompassing Amsterdam, Delft, Eindhoven, Rotterdam, Groningen, Leiden, Maastricht, Nijmegen, Twente, Utrecht and Wageningen. Ten university hospitals are located in the "bio-belt" region, which "accounts for 60 percent of the dedicated life science companies and more than 70 percent of the life-sciences work force in the Netherlands."[12]

The Amsterdam cluster is situated around the University of Amsterdam/Academic Medical Center Hospital; the Netherlands Cancer Institute/Sanquin (Red Cross Laboratory for Blood Research); the Amsterdam Science and Technology Center; and Free (Vrije) University of Amsterdam. Areas of expertise include: bioinformatics, genomics, cell and medical biology, immunology, neurosciences and oncology. Located in the Amsterdam Science & Technology Center, SARA — one of Europe's most advanced computing and networking centers — offers high-performance computing and infrastructural services to the scientific community, educational institutes and industry. Among biotech companies in the Amsterdam cluster are two spin-offs: Am Pharma B.V., of the Free University of Amsterdam; and AMT of Amsterdam Medical Center.[13]

The cities of Delft, Leiden, The Hague and Zoetermeer are part of the West-Holland cluster, considered "one of the largest and most prestigious biotech clusters in Western Europe."[14] The region is home to some of the top universities in the Netherlands: Leiden University, Delft University of Technology; and BIOMAC, an interdisciplinary graduate school specializing in research on structure function relationships of bio-macromolecules.[15] The cluster features 60 biotech companies, such as Astra Zeneca, Centocor, Crucell, Genecor International and Toshiba Medical Systems. Other key institutions include: the Dutch Organization for Applied Scientific Research Institute, Prevention and Health; Leiden/Amsterdam Center for Drug Research; Medical Genetics Center of the Southwest Netherlands; Biotechnological Sciences Delft/Leiden; Leiden BioScience Park; Technopolis; and Delft Tech Park.[16]

At the university level, participation of Dutch students in science subjects is low. The number of Ph.D. holders per 1,000 of the working population is 0.34, compared to 0.56 in the EU, and this proportion is declining by 5 percent per year, according to the Ministry of Economic Affairs (2004).

4. University Technology Transfer Mechanisms

Although the nation's universities perform high-quality research, the transfer of this research to innovative commercial applications is slow — a phenomenon often referred to as the "Dutch paradox."[17]

The university system in the Netherlands allows for institutional autonomy, explaining, in part, why IP ownership differs markedly. In addition, there is no national legal or regulatory obligation to report, disclose or use the IP. In the Netherlands, each university also decides its own tech transfer processes and procedures. Dutch OTTs are generally small, with only one or two full-time-equivalent (FTEs) generalist staff.[18]

TOP (Temporary Entrepreneurial Placements) is one of Europe's "best practice" examples of a university spin-off program. Since its inception in 1984, the TOP program at the University of Twente has assisted in the establishment of hundreds of university startup companies. TOP provides entrepreneurs with advisory services, interest-free loans and training. Assessment studies show that a high percentage of TOP firms survive past their critical early years and remain in the area.

To stimulate the commercial application of university research, the Association of Universities in the Netherlands is developing regulation policy for IP protection and exploitation. Although IP is recognized by the Dutch government as an important policy issue, no formal policy has yet been implemented.[19]

5. Commercialization Success: Patents and Licensing

BioPartner, launched in 2000, is an initiative by the Dutch Ministry of Economic Affairs to promote entrepreneurial activity in academia. Since establishment of the program, nearly 80 new companies have been formed.[20]

> CLEA Technologies is a spin-off from the Delft University of Technology. The company, co-founded by Roger Sheldon, a professor of organic chemistry and catalysis at Delft University, and Luuk van Langen, commercializes a formulation technique for enzymes — the cross-linked enzyme aggregates (CLEAs) — for the fine chemical and pharmaceutical market.

The level of patents filed by Dutch universities is rather modest. Just 19 percent of total university patents (51 percent of patents of public research institutions) have been licensed.[21] The Netherlands' share in biotech patents filed at the European Patent Office represents 3 percent. Furthermore, according to an OECD study, "the share of Dutch biopharmaceutical patents co-invented with an international partner of all Dutch biopharmaceutical patents has been between 25 and 40 percent since 1994."[22]

> Founded in 1575, Leiden University has been working on technology transfer since the early 1980s. Leiden is home to one of the most successful university spin-offs on the continent, the biopharmaceutical Crucell, named by Fortune in May 2005 as one of the 25 "breakout" companies for that year. Crucell, which produces vaccines and antibodies, is located in the university-run BioScience Park; its founder, Dinko Valerio, had been a professor of gene therapy at the university. In 2005, Leiden adopted a new innovation plan for the university that includes loans to professors for startups.

Spin-offs represent approximately 29 percent of all life-science firms created between 1990 and 2002.[23] In 2001, Technische Universiteit Delft had the most patent applications in the country, but Universiteit Twente identified the highest number of spin-offs, 226.[24] In 2003, six of the 17 newly established life sciences companies were founded as university spin-offs.

> LioniX, founded in January 2001, is a spin-off of Twente University. The company provides products based on microsystem technology and MEMS (Micro-Electro-Mechanical-System) for the life sciences. In this case, the university's knowledge is not protected by patents. Instead, LioniX has exclusive, early access to university research and inventions, giving the spin-off lead time to develop products. In addition to this agreement with the TTO, LioniX is building a firm IP position. LioniX owns several research facilities and has a market-based compensation agreement that provides access to university-owned facilities.

Endnotes:

1. "The Dutch Biotechnology Innovation System: An inventory and assessment of the major developments since 1994." S. Kern and C. Enzing. January 2002. See also: http://www.sussex.ac.uk/ spru/documents/netherlandscountryreport.pdf.
2. Ibid.
3. Ibid.
4. http://trendchart.cordis.lu/reports/documents/best_practice_report_2002.pdf.
5. http://www.euractiv.com/29/images/rd_investment_snapshot_24sep04_tcm29-132457.pdf.
6. Van Steen, Jan, Donselaar, P. and Schrijvers, I. (eds.). 2004. "Science, Technology and Innovation in the Netherlands" The Hague, June. See: ftp://ftp.cordis.lu/pub/netherlands/docs/sti_nl_2004.pdf.
7. http://www.optin.nl/ls_uninst.php.
8. http://www.sussex.ac.uk/spru/documents/netherlandscountryreport.pdf.
9. Bekkers, Rudi and M. van der Steen. "IP-based Spin-offs of Public Research Organisations in the Dutch Life Sciences and ICT Sectors," Chapter 17.
10. http://www.minocw.nl/wetenschap/doc/2004/nowt_sum_2003.pdf.
11. http://www.sussex.ac.uk/spru/documents/netherlandscountryreport.pdf.
12. http://www.biopharminternational.com/biopharm/article/articleDetail.jsp?id=132790.
13. www.nfia.com.
14. http://www.area-development.com/Pages/EuropeanClustersEvolve.html.
15. http://www.fwn.leidenuniv.nl/onderzoekscholen/biomac/.
16. www.nfia.com.
17. Ministry of Economic Affairs. 2003. "Entrepreneurship in the Netherlands Knowledge transfer: developing high-tech ventures." June. See: http://www.eim.net/pdf-ez/A200302.pdf.
18. Bekkers, Rudi and M. van der Steen. "IP-based Spin-offs of Public Research Organisations in the Dutch Life Sciences and ICT Sectors."
19. European Trend Chart on Innovation, 2002-2004. "Annual Innovation Policy Report for The Netherlands." September–August.
20. www.hollandbiotechnology.nl. See also: www.europabio.org.
21. Innovation Policy and Performance in the Netherlands.
22. Enzing, C.A., Van der Giessen, S. Kern. 2004. OECD Case Study on Innovation: The Dutch Pharmaceutical and Food Biotechnology Innovation Systems, TNO Strategy, Technology and Policy. 2004 TNO. See: http://www.oecd.org/dataoecd/26/45/31689050.pdf.
23. Bekkers, Rudi and M. van der Steen. "IP-based Spin-offs of Public Research Organisations in the Dutch Life Sciences and ICT Sectors," Chapter 17. See also: Chapter 15.
24. Ibid.

Poland

1. National Innovation Policy

Poland has potential for growth in its biotechnological sectors but needs to implement reforms before it can compete internationally. Poland did not fare well in the 2003/2004 *Global Competitiveness Report*, which identified inefficient bureaucracy, corruption and tax regulations as problematic factors restricting business development in the nation.[1] However, the country remains a leader among the newly admitted EU member states, contributing 45 percent of their "total pharmaceutical market value."[2]

Poland's human capital development is exemplified by the high level of scientific study in universities and research institutes, marked by a shift toward programs taught in English. Twenty-one Polish universities offer master's degree programs in biotechnology (with about 1,700 graduates per year); seven also offer Ph.D. programs in biotech.[3]

Included among the country's academic organizations is the Polish Federation of Biotechnology, founded in 2003 as a sister organization of the European Federation of Biotechnology and a nonprofit association of academic institutions, businesses and individuals.[4] Approximately 60 biotech companies in Poland belong to various networks, including the Center of Biosafety Research and Molecular Biomedicine, the Center of Technology Transfer and the Pomeranian Science and Technology Park, yet there is no unifying national umbrella organization. One possible reason is that many Polish biotech companies are still in the micro-phase, with sometimes just five employees working out of a small laboratory.[5]

The Polish government is working to remedy this situation.[6] The Act of 4 November 2004[7] allows the Ministry of Science and Information Society Technologies — which is responsible for policy and for fostering international support for Polish science and technology — to set the national research framework, as well as standards and policies to consolidate the interests of academia and industry.[8] The ministry also manages government funding for R&D and works with the Council of Science, an advisory body of representatives from various scientific fields.

Meanwhile, responsibility for regional innovation programs falls under the control of the nation's 16 regional *voivodships*, or administrative divisions.

Other government branches active in innovation are the Ministry of Economy, Labor and Social Policy, which includes both the Department of Innovation and the Polish Agency for Enterprise Development; and the Ministry of Education and Sport.[9]

A national development plan (2007–2013) was crafted in 2004 to develop and support business incentives; encourage venture capital and private funding of R&D; reform the current R&D infrastructure; increase coordination between programs to promote commercialization; and build on the educational system.[10]

Poland is party to several international efforts, such as the Biodiversity Convention, Biosafety Protocol and Budapest Treaty.[11] It is also in the process of altering its policies and procedures to mirror those of the European Union.

2. Funding and Venture Capital

Funding for biotechnology is minimal, despite recent government efforts to increase support. In 2003, government expenditures on R&D focused on applied research and experimental development.[12] As part of the national development plan, spending is expected to increase from approximately $24 billion in the years 2004 to 2006 to almost $150 billion for the period 2007–2013, a 162.5 percent increase in per-year spending.

Poland is currently spending 0.65 percent of its GDP on research and technological development, about one-third of the EU-25 average of 1.94 percent.[13] Private sector contributions in Poland make up just 0.2 percent of the total spending, compared to 1.08 percent for the EU-25 average.[14] To comply with the Lisbon Strategy of the European Council, Poland needs to increase its public expenditures as a percentage of GDP to at least 1.0 percent. [15]

Venture capital for biotech and nanotech is also small. Poland lags behind the Czech Republic and Hungary in venture capital availability, placing 74th out of 104 nations in the 2003/2004 *Global Competitiveness Report*.[16] Scientists and institutes are primarily ranked according to the number of publications, and there is little incentive for them to engage in applied research.[17] Other barriers to growth include inadequate networking between business and academia, and a lack of business awareness about university resources.[18]

3. Clusters of Biotechnology

Major centers of biotech and nanotech growth include:

- Hi-Tech Lower Silesia R&D Center, working under the auspices of the Wroclaw University of Technology in conjunction with other academic and research organizations. The center strives to achieve cooperation among scientific, industrial and governmental organizations through its consortium of 27 scientific and industrial partners.[19]
- Hi-Tech R&D Center of Advanced Materials and Technology (CAMAT), coordinated by the Polish Academy of Sciences and various research centers, academies, firms and universities. CAMAT's nanotech research is showing strength.[20]
- The Jagiellonian Center of Innovation, created in 2004 to focus on the biotech and biomedicine sectors, and work in incubation projects from Jagiellonian University.[21]
- Hi-Tech West Pomeranian R&D Center, coordinated by the Szcecin University. The Pomeranian Science and Technology Park is working to establish an environment for collaboration and technology transfer.[22]

4. University Technology Transfer Mechanisms

While most universities are beginning to develop their own offices for technology transfer and incubator programs, the Centre of Technology Transfer, based in Gda[sk, is the nation's leading office of technology transfer. Established in 1996, it is associated with BioMoBiL, which itself was founded in 2003 by the University of Gda[sk andMedical University of Gda[sk "to support the interdisciplinary research of the academic community … of Gda[sk, Gdynia and Sopot."[23] The Centre of

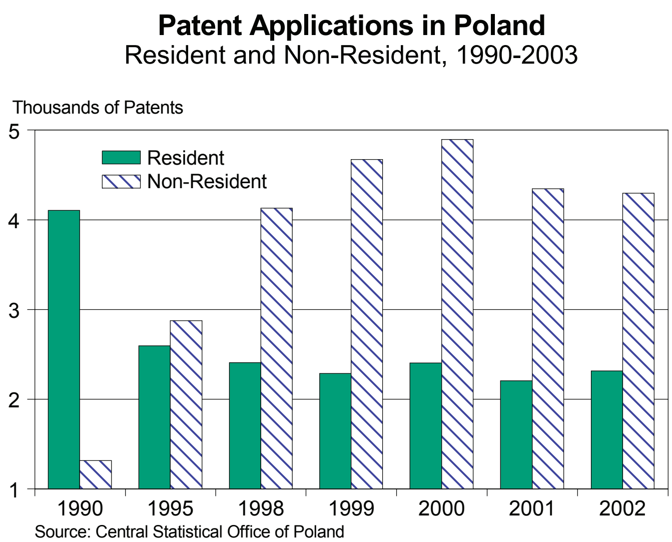
Technology Transfer developed a network of innovation relay centers that work with the OTTs, sometimes serving as the OTT, and functions as an international technology consulting center.[24] Despite its work, tech transfers are not coordinated on a national level.

5. Commercialization Success: Patents and Licensing

In 2003/2004, Poland placed 79th out of 104 countries in its protection for intellectual property, signaling that reform is necessary to create a climate for biotech growth.[25] The national patent office has primary responsibility for enforcing intellectual property rights and has streamlined practices to facilitate cooperation with international patent offices.[26]

"The Polish balance of patents shows a significant deficit," according to *The European Trend Chart on Innovation* (2003–2004). "In recent years the number of patent applications filed by Polish inventors abroad was about 2.5 times lower than the number of patent applications filed at the Patent Office of the Republic of Poland by foreign applicants."[27]

Domestic patent applications filed by Polish residents have been declining since 1990 (see the following chart), while applications filed by non-residents have been on the rise.[28]



Endnotes:

1. Porter, Michael E., Schwab, Klaus, Sala-i-Martin, Xavier, and Lopez-Claros. August 2004. *Global Competitiveness Report*: 2003–2004, Geneva: World Economic Forum.

2. "Pharma/biotech industry more promising in new Member States: report," *EU Business*. February 23, 2005. See: http://www.eubusiness.com/archive/Pharma/biotech.2005-02-23.

3. Bielecki, Stanisław and Twardowski, Tomasz. "Polish Biotechnology." See: http://www.europabio.org/ articles/ article_284_EN.pdf.

4. "Engineering an Industry: Giving Life to Biotechnology in Poland." *Enlargement EU: Life Sciences.* See: http://www.gdspublishing.com/ic_pdf/eeuls/polfedbio.pdf.

5. **Burgermeister**, Jane. 2004. "Biotech budding in Poland: A fledging biotech industry is gaining support from government and EU funding," *The Scientist.* See: http://www.the-scientist.com/news/20040810/01.

6. Niedbalska, Gra[yna. 2005.

7. Journal of Laws. 2004. No. 238, as cited in Niedbalska, Gra[yna 2005.

8. Ibid.

9. *European Trend Chart on Innovation: Annual Innovation Policy Report for Poland (Covering Period: September 2003–August 2004).* European Commission: Innovations/SMEs Programme. http://trendchart.cordis.lu/tc_country_list.cfm?ID=27.

10. Niedbalska, Gra[yna. 2005.

11. Bielecki, Stanisław and T. Twardowski. "Polish Biotechnology."

12. Niedbalska, Gra[yna. 2005.

13. Standke, Klaus-Heinrich. 2005. "R&D in Poland and CEE. International Conference in Warsaw: 'Research Centres for Knowledge Based Society,' " *BerliNews*. May 5. See: www.berlinews.de/archiv-2004/3420.shtml.

14. Ibid.

15. Ibid.

16. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004.

17. Bielecki, Stanisław and T. Twardowski. "Polish Biotechnology."

18. Ibid.

19. http://www.biotechnology-pl.com/?lang=en&center=biotechnology&txt=bio_centers.

20. Ibid.

21. Ibid.

22. Ibid.

23. http://www.scanbalt.org/sw593.asp.

24. International Relay Centre of Western Poland. See: http://www.irc-westpoland.org.pl/en/index.php?d=1.

25. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004.

26. Patent Office of the Republic of Poland. http://www.uprp.pl/English.

27. European Commission. 2004. *European Trend Chart on Innovation Annual Innovation Policy Report for Poland Covering Period: September 2003–August 2004.* See: http://trendchart.cordis.lu/reports/documents/ CR_Poland_September2004.pdf.

28. Niedbalska, Grażyna. 2005. *Main Science and Technology Indicators in Poland in 2000–2003*. Warsaw: Central Statistical Office of Poland. See: http://www.mnii.gov.pl/mniien/index.jsp?place=Menu01&news _cat_id=-1&layout=0.

The Russian Federation

1. National Innovation Policy

Russia's economy has undergone a long transformation as the state-owned model grew into one that is market-driven. The emerging private sector is not yet adequately connected to the primary performers of public R&D. Even now, Russia suffers from institutional inflexibility, as well as "distorted patterns of R&D funding and performance inherited from the Soviet Union," according to the OECD "Observer."[1] Reforms have also led to an exodus of qualified professionals — referred to as the "lost generation of scientists and engineers" — who left the Ministry of Education and universities for more lucrative jobs in the private and informal sectors of the economy.[2] "Russia has to overcome a long legacy of institutional rigidities and dysfunctional institutional arrangements inherited from the Soviet system," noted a World Bank report in 2003.[3]

In 2004, there were 185 students in public universities (per 10,000 population) and 349 students (per 10,000) in private universities, an increase over the record of the former Soviet Union's 220 students per 10,000 of population.[4] But corruption in education remains a problem.

> Most of Russia's research priorities, government programs and lists of crucial technologies result from the lobbying power of science and technology organizations rather than real economic needs and financing capacities, according to a report from the U.N. Development Programme, 2002.

Policies to enhance Russia's international collaboration in science and technology include more participation of Russian scientists in international programs; the Innovation Council on High Technologies, created in 2004 by the U.S. Department of Commerce and the Russian Federation's Ministry of Education and Science to promote high-tech cooperation; intellectual property and tax code revisions that improved conditions for business activities; the 1996 regulation of genetic engineering activity, the most overarching biotech legislation in Central and Eastern Europe;[5] and the Biotechnological Development in Russia in 2006–2015 program, creating an environment for further development of basic and applied biotechnology.[6]

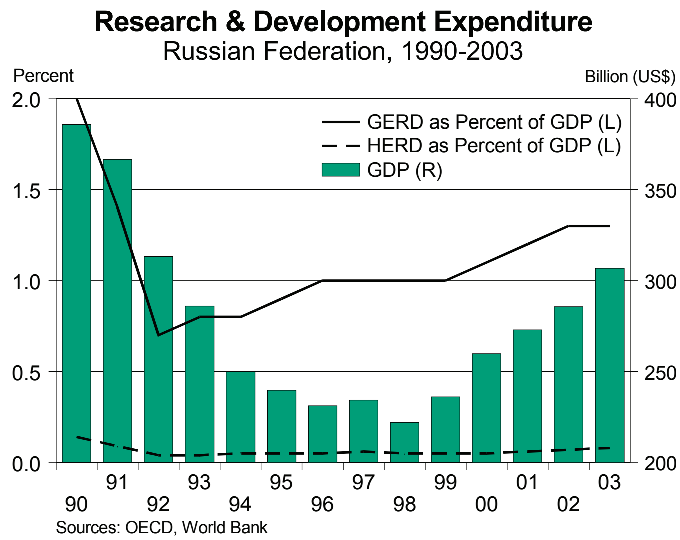
2. Funding and Venture Capital

Prior to the disintegration of the Soviet Union, all research in Russia was government-funded. Government investment in R&D declined dramatically after the dissolution of the Soviet economy, although it still finances a major share (60 percent) of the country's research activities.

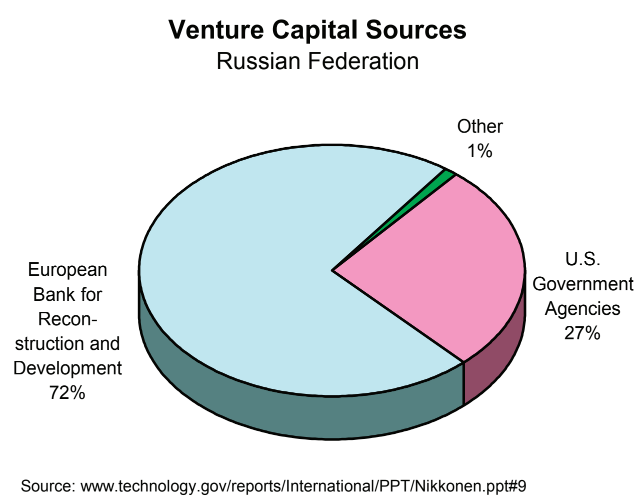
The legacy of the Soviet system is evidenced in the marginal role of universities in R&D; in 1990 more than 77 percent of gross domestic expenditure on R&D, or GERD, was carried out by business enterprises. Although the importance of the business sector as a performer of R&D gradually declined, giving way to government, by 2003 business was responsible for more than 68 percent of Russia's R&D. In 1994, only 2 percent of Russia's GERD came from foreign sources, a share that increased to 9 percent by 2003.

In 1990, GERD accounted for 2.03 percent of Russia's GDP. In 1992, in the midst of the country's socioeconomic restructuring, government support for R&D dwindled to less than 1 percent of GDP. Throughout the mid-1990s and early 2000s, the R&D-to-GDP ratio started to rise; however, by 2003 it still failed to reach 1990 levels. The R&D-to-GDP ratio decline was further exacerbated by the substantial decrease in Russia's GDP.

Monies directed toward higher education expenditures on R&D, or HERD, accounted for a meager 0.14 percent of Russia's GDP in 1990, falling to 0.08 percent of a comparably smaller GDP in 2003. To compensate for the decline, a number of science and technology foundations were formed in the 1990s.[7]



Russia's first venture capital fund, established in 1997, is growing but remains dependent on foreign funds and is primarily oriented toward loans.[8] Established in 2000, Venture Investment Fund is the key element in Russia's venture capital market.



In 2003, the government implemented 12 major innovation projects. Among them was the development of production and introduction of instruments and equipment for nanotech (government support: $13.2 million; funds from other sources: $13.5 million).[9] For biotech programs in 2006–2010, the government has said it plans to allocate $5.25 billion, which includes a public-private biotech VC fund worth $70 million to $140 million, backed by Rosprom, the federal agency for industry.[10]

3. Clusters of Biotechnology

The majority of higher-education institutions, including Russian biotechnology research centers and production facilities, are found in the western third of Russia.[11] Biotech research centers include the network of biological institutes in the Pushchino center of the Russian Academy of Sciences (in the Moscow region); the Moscow Institute of Epidemiology and Microbiology; the State Scientific Center of Virology and Biotechnology at Koltsovo, Novosibirsk (Vektor); and the Moscow State University of Applied Biotechnology.[12] About 20 science-based cities (half the total) are located in or near Moscow.[13]

The most prominent educational institution in Russia, the Lomonosov Moscow State University, has 26 departments (including biology, bioengineering and bioinformatics) and more than 40 research centers and institutes, 40,000 undergraduates, 7,000 postgraduates and more than 9,000 professors and researchers.[14]

The Russian BioConsortium TEMPO (Technology, Education, Marketing, Production and Optimization) brings together 17 biological R&D institutions for commercialization. TEMPO hosted Russia's first Good Laboratory Practices Training Program (for preclinical drug development) at Pushchino in the Moscow region.[15]

International Technopark Pushchino supports small- and medium-sized innovation biotech companies.[16] In 2005 the Russian Ministry of Communications proposed a technopark development concept to encourage the construction of science parks (for research and development) and technoparks (for manufacturing and services) in Moscow, Novosibirsk and Nizhny Novgorod.[17]

The Medical-biotech Center Vector T was established in 2005 as a private medicine and public health company that pursues IP rights and business partnerships for its partners.[18]

4. University Technology Transfer Mechanisms

The Russian Technology Transfer Network (RTTN), established in 2002, listed 35 members in 2005, including innovation technology centers and commercialization offices.[19] Member efforts are directed toward establishing domestic and foreign commercialization partnerships.

The Eurasian Association of Technology Transfer Managers (EATTM) was created in 2005 under the auspices of the U.S. Civilian R&D Foundation. Analogous to the Association of University Technology Managers (AUTM) and the Association of European Science and Technology Transfer Professionals (ASTP), EATTM unites tech-transfer managers and specialists of the Russian Federation and the CIS states. Commercialization in Russia is hampered by the lack of experienced tech-transfer managers. A key mission of EATTM is the development of training programs for them.

The following table summarizes the results of RTTN activity in 2004:

RTTN Activity
2004

Support to Clients	**796**
Companies	493
R&D organizations	303
Prepared TR/TO profiles	**448**
Including "STAR" projects	22
Signed TT Agreements	**11**
Including 1 transnational (French-Russian)	

In the United States and United Kingdom, patenting is commonly outsourced to specialists in law firms. In Russia, patenting is historically conducted in universities. These offices are currently being restored and reorganized into subdivisions of IP and technology transfer with six OTTs: four at universities and two at academic institutes.

Saint Petersburg State University (SPSU)

OTT Model (2003):

- Patent studies and monitoring of 100-120 R&D projects annually
- 100 inventions annually
- 23 percent inventions were adopted in industry annually
- Export of invention-based production (23 countries)
- Foreign patents: 47
- License exports: 7

Commercial Potential (2003):

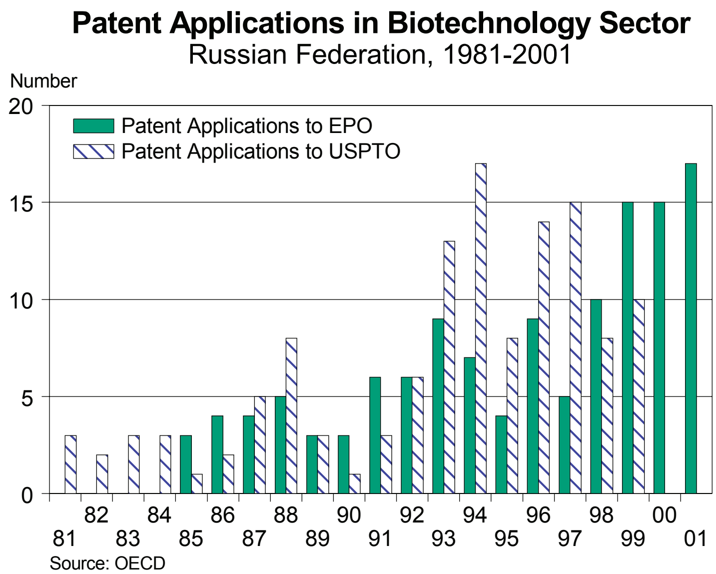
- Technology Portfolio: 27 projects
- Three small innovation enterprises based on IP:
  1. Tercom: State Unitary Enterprise: information technologies
  2. Biotech Ltd.: drugs with immunotropic effect
  3. Koreks Ltd.: laser technology for three-dimensional image formation

Source: http://www.UNIPAT.PU.RU/Russian/projects/rec/presentation.doc

Weak regulation of intellectual property rights is a major impediment for the advancement of Russia's biotech industry. Until the dissolution of the Soviet Union, patents in Russia were government-owned, accessible for public use without the stipulation of permission, royalty or license payments. In 1992, Russian patent law was reformed; the new patent Law granted ownership of government-funded research to the organizations where the research was carried out. Since at the time all organizations were state-owned, the government held all ownership rights. Once those government-owned entities were privatized, the individual researchers became the owners of IP. Unfortunately, the government has since responded with passage of numerous amendments that complicate rather than clarify those IP rights. Although most provisions of Russia's IP legislation are in accord with international treaties, this ambiguity — compounded with co-financed and collaborative international research — makes commercialization troublesome and investments riskier.[20] Patents in Russia are granted to the first to file, as in the EU, rather than the first to invent, as in the United States.[21]

5. Commercialization Success: Patents and Licensing

The following chart illustrates the growth in Russian biotech patent applications filed to the European Patent Office and the U.S. Patent Office.



Poor incentives exist for Russian scientists, due in part to weaknesses in the country's system of IPRs. According to a study from INTAS, the International Association for the Promotion of Co-operation with Scientists from the New Independent States (NIS) of the Former Soviet Union, to some extent, it is evident that "the declining scientific infrastructure … together with uncertainty about prospects for future funding, lead(s) to a tendency among scientists towards quick publication of their results, with little attention paid to questions of ownership and thus commercialization of their research."[22]

> The National Academy of Sciences has observed that "a large gap exists between most research endeavors and successful commercial marketing" in Russia. "Often, commercialization is an afterthought for researchers, occurring only when they realize that unless their products attract customers, they will soon have to abandon their efforts. Few institutes address marketing challenges early in the research cycle, and seldom are research projects willingly abandoned because of marketing risk."

There is a growing demand for Russian bioinformatics, cell-, post-genome- and nano-technologies.[23] The National Nuclear Security Administration redirects Russian weapons scientists to civilian and commercial R&D through nonproliferation programs, including the Initiatives for Proliferation Prevention (IPP) and the Nuclear Cities Initiative (NCI). The IPP creates new jobs through projects that commercialize expertise and products in Russia's scientific institutes involved in weapons technologies. The NCI is converting government jobs of scientists, engineers and technicians with special weapons design knowledge to ones in commercial companies.[24] A RAND study notes, "Since program inception in 1994, IPR — working institute-by-institute and scientist-by-scientist — has engaged over 10,000 Former Soviet Union (FSU) scientists, engineers and technicians."[25]

> Biophysical Laboratory (Biofil) Ltd.
>
> Biofil is a spin-off from the All-Russian Research Institute of Experimental Physics in Sarov. In partnership with the U.S. firm Cyclotec Advanced Medical Studies, Biofil conducts biomedical device R&D. This IPP project, which develops pain-blocking devices that use low-level electrical pulses, won an R&D 100 Award (from *R&D* magazine) for being one of the most important industrial inventions in 2002. Livermore scientists partnered with Cyclotec and Biofil on the device's control module. American biomedical firms have targeted Biofil with more than $350,000 for further biomedical device R&D.
>
> Soliton-NTT
>
> The Institute for Problems of Electrophysics and Soliton-NTT (a spin-off of the Kurchatov Institute) has joined forces with Scientific Utilization of Huntsville, Ala., to develop an alternating-current plasma torch to destroy hazardous and medical waste. The torch is a commercial version of a waste-destruction system used by the Russians for a number of applications, (i.e., destruction of chemical weapons and bioagents).
>
> *Source : www.llnl.gov/str/JanFeb05/Zucca.html*

Endnotes:

1. Cervantes, Mario and Daniel Malkin. OECD. 2001. "Russia's Innovation Gap." See: http:// www.oecdobserver.org/news/fullstory.php/aid/554/Russia%92s_innovation_gap.html.

2. National Academy of Sciences. 2005. "Biological Science and Biotechnology in Russia: Controlling Diseases and Enhancing

Security." See: http://darwin.nap.edu/books/0309097045/html/61.html.
3. Watkins, Alfred. The World Bank. 2003. "From Knowledge to Wealth: Transforming Russian Science and Technology for a Modern Knowledge Economy." WP 2974.
4. Shattock, Michael, E. Kniazev, N. Pelikhov, A. Sandgren and N. Toivonen. 2004. "Entrepreneurialism and transformation of Russian universities." International Institute for Educational Planning. www.unesco.org/iiep.
5. European Federation of Biotechnology. 1999. "Biotechnology Legislation in Central & Eastern Europe." Briefing Paper 9.
6. http://www.ma-rbc.org/event/050618-bio-a.html.
7. See the research of: Dinkin et al, 1999; Mindelli and Pipiia, 1998; MinIndS&T, 2001.
8. Radosevic, Slavo. 2002. "Patterns of Preservation, Restructuring and Survival: Science and Technology Policy in Russia in the Post Soviet Era," University College London. WP 7.
9. OECD. "Science, Technology and Industry Outlook: Country Response to Policy Questionnaire — Russia," 2004.
10. www.nature.com/news/2005/051205/pf/nbt1205-1465_pf.html.
11. Dailey, M. T., V.R. Cardozier. "Higher Education in Russia." WP. See: http://studentorgs.utexas.edu/heaspa/ library/rus.htm.
12. Borodina, Elena. 2002. "Russia's Budding Biotechnology Market." BISNIS Bulletin, August/September. http://www.bisnis.doc.gov/bisnis/bulletin/sept02bull7.htm.
13. "Science-based Cities of Moscow Region." See: http://istina.inion.ru/e_podmos.htm.
14. http://www.msu.ru/en/.
15. The BioIndustry Initiative of the U.S. Department of State. 2005. 2(I). See: http://www.biistate.net/docs/ newsletter/BIINewsletter-Q2.pdf.
16. Biomac innovation. International Technopark Pushchino (Moscow Region). See: http://www.biopark.ru/ ?id=A6E3922E-77BA-4A7E-8C60-1E1F72EFA4F8.
17. Chase, Steve. 2005. "Will Russia Create a Favorable Climate for the ICT Industry?" American Chamber of Commerce in Russia. http://www.amcham.ru.
18. Profile of BioIndustry Initiative-sponsored TEMPO Delegation to SVOD. See: http://bisnis.doc.gov/ bisnis/bisdoc/0510bioevent.pdf.
19. http://www.rttn.ru/about.php.
20. Dezhina, Irina. "Intellectual Property Rights Regulations in Russian Universities: Moving Towards the Best European Practices?" See also: Aolotyky, Natalia. 2003. "Legal Regulation of Protection and Commercialisation of Intellectual Property Created by Russian Public Research Organisations." "Turning Science Into Business: Patenting and Licensing at Public Research Organisations." OECD.
21. http://www.cipr.org/legal_reference/countries/russia/Russia_Patent_ENG_04.pdf.
22. INTAS. 2001. "The Russian science and technology sector: Quo vadis?" http://www.intas.be/documents/ dissemination/OECD-INTAS%20RB%20Input.htm.
23. Luongo, Kenneth, R. Ratta, M. Martellini and Derek Averre. 2004/5. "Rethinking Bio Proliferation Prevention: Security Culture in the NIS." *The Monitor*. 11(1).
24. "S&T Russian Weapon Workers Begin New Commercial Venture." See: http://www.llnl.gov/ str/JanFeb05/ Zucca.html.
25. Wagner, Caroline, I. Brahmakulam, D. Peterson, L. Staheli and A. Wong. 2001. "U.S. Government Funding for Science and Technology Cooperation with Russia," RAND. See: http://www.rand.org/publications/ MR/MR1504/MR1504.pdf.

Sweden

1. National Innovation Policy

Sweden constitutes Europe's "fourth-largest biotech country" and, on a per capita basis, is home to more biotech firms (more than 230) than any other country in the world, according to the nonprofit industry association SwedenBIO, which also notes "an annual growth rate of 10 percent between 1995 and 2003."[1] In 2001-2002, the country's drug development ranked No. 3 in Europe and reported nearly 80 percent growth, according to a survey by Ernst & Young.[2]

Movement toward a national innovation policy was primarily manifested through the Swedish Agency for Innovation Systems (VINNOVA) in 2001. VINNOVA was created under the Ministry of Education and Science not only to promote research competitiveness and regional growth through collaboration with industry and universities, but to fund research, as well.

However, a report released by SwedenBIO outlining a growth agenda notes that the country has not done enough to maintain a competitive global edge or demonstrate a "coherent" strategy for national biotech development. The report also noted that Sweden doesn't invest enough in biotech R&D and offers few tax incentives for private research.[3]

The country "has not yet designed a formal innovation policy."[4] Different government ministries oversee policies for research (the Ministry of Education and Science through VINNOVA and the newly established Swedish Research Council) and for industry (the Ministry of Industry, Employment and Communication). There is little coordination or evidence of clear strategic intent.[5]

As of 2002, the country had 13 universities and 37 university colleges. There are several private educational organizers, such as Chalmers University of Technology AB, the Foundation for the University College of Jönköping and the Stockholm School of Economics.[6] Most public R&D funding is directed toward universities.[7] Nonetheless, public R&D funding is complex: ministries support research activities in their own sectors, with control over individual budgets; and independent authorities initiate their own projects. Thus, the Ministry of Education and Science oversees policy for R&D and VINNOVA.[8]

On a national level, government agencies, including VINNOVA, Invest in Sweden Agency, NUTEK (the Swedish National Board for Industrial and Technical Development) and the Department of Foreign Affairs, are involved in biotech and life sciences. Regionally, many biotech organizations have been created around universities — Medicon Valley, UppsalaBio, Stockholm Bio and MedCoast in Göteborg. In addition, the national Research Forum provides and promotes linkages among academics and investors.[9]

Between 1995 and 2003, R&D spending by the largest Swedish multinational enterprises increased modestly, from $5.1 billion to $5.8 billion, but the share of R&D outside Sweden shot up from 22 percent to 43 percent.

Sweden's laws governing stem cell research, which date from 1991, are uniform across universities and companies, and are among the most permissive in Europe. The country has allowed the acquisition of human embryonic stem cells from discarded embryos and, in 2005, approved the use of stem cells obtained through somatic cell nuclear transfer.[10]

There is a major reorganization under way in the structure of public funding of R&D and support to business and regional development; this includes the examination of R&D tax credits to companies, matching fund initiatives and patent grants.

2. Funding and Venture Capital

Public funds for R&D are distributed either to institutions of higher education or through research councils and sectoral authorities. The Swedish Parliament (via a number of foundations) and private research foundations also finance research.[11]

> Sweden ranks high globally in R&D investments, relative to GDP. The country spent well above 4 percent of its GDP on research in 2004, compared with an EU average of less than 2 percent.

Because Swedish researchers must now compete with other EU academics for funding from Brussels, private investment in the country's R&D has risen since 1995 and may in some cases constitute half of the R&D budget, with the result that "all major universities in Sweden today have strong partnerships with global enterprises."[12]

The government provides investment capital to startups through such agencies as Industrifonden, NUTEK, ALMI and Teknikbrostiftelsen, working in conjunction with private investors. A typical initial investment might range from 30 percent to 50 percent of the budget. Government loans offer favorable interest rates, with deferred or even forgiven repayment.[13] Sweden has a solid VC community, including the Swedish Venture Capital Association and more than 200 VC companies, of which 30 percent have a special interest in biotech.

However, Sweden faces a downturn in financing. "It is expected that the number of venture capital companies will start to decrease as a result of unwise investment, declining market size and lack of capital."[14] This statement is in line with the 2003 findings of Göran Marklund, Director of VINNOVA's analytic division, that "Sweden also lacks very early-stage venture capital. … There is a high risk aversion in Sweden. In connection with this, we have very few business angels walking around with a lot of money who could take such risks."[15]

> "To reach the average level of governmental investment per GDP seen in leading European countries (Germany, France and the U.K.), Sweden would have to invest an additional $31 million annually into biotechnology."
>
> *— SwedenBIO, 2003*

3. Clusters of Biotechnology

Sweden's biotech clusters extend beyond its national borders; its companies, universities and research institutes are involved in international networks and collaborations, especially since construction of a bridge across the Öresund (opened in 2000), connecting Sweden and Denmark. The nonprofit association Swedepark represents and promotes about 30 technology and research parks throughout the country. They include the cross-border Medicon Valley, lying between Copenhagen, Denmark, and Malmö, Sweden. Medicon Valley, the largest in the region, is home to half of Scandinavia's biotech and pharmaceutical firms.[16]

The following table shows the breakdown of Swedish biotechnology companies by cities and industrial sectors in 2001. Most companies are concentrated in Stockholm, with a fair number in Malmö/Lund, Göteborg and Uppsala.

Swedish Companies distributed by Cities and Industrial Sectors in Biotechnology-Related Science, 2001

	Malmö/Lund	Stockholm	Göteborg	Uppsala	Umeå	Other	All
Pharmaceuticals & Medicine	20	32	17	19	2	4	94
Bioproduction	4	2	2	2	2	5	17
Biotech Tools & Supplies	7	15	2	8	1	3	36
Environmental Biotechnology	3	2	2	0	0	1	8
Functional Food & Feed	2	4	1	1	1	1	10
Agrobiotechnology	0	1	0	1	1	4	7
All sectors	36	56	24	31	7	18	172

Sources: VINNOVA 2003, Milken Institute

In the Stockholm-Uppsala region, biotech firms have grown up around the Karolinska Institute and other research centers and hospitals. In western Sweden, two universities — Göteborg University and Chalmers University of Technology — have spawned the creation of three science parks and numerous biotech startups.[17] The country's northern cities of Umeå and Luleå host universities, science parks and clustering biotech businesses.[18]

Lingköping is a relatively small biotech cluster, the result of a strategic life-sciences and biomedicine initiative launched by Lingköping University in 2001 and now comprising a biomedical innovation center and a number of companies working on biosensors and medical imaging.[19]

Karolinska Institutet (KI)

Karolinska Institute is Sweden's largest center for medical training (30 percent) and research (40 percent). The research spans a wide array of topics, from basic science research in molecular biology to public health science. KI offers 19 undergraduate programs (e.g., in 2004, 15 degrees were awarded in biomedical laboratory science and 305 in nursing) and several furthering education and independent courses in medicine.

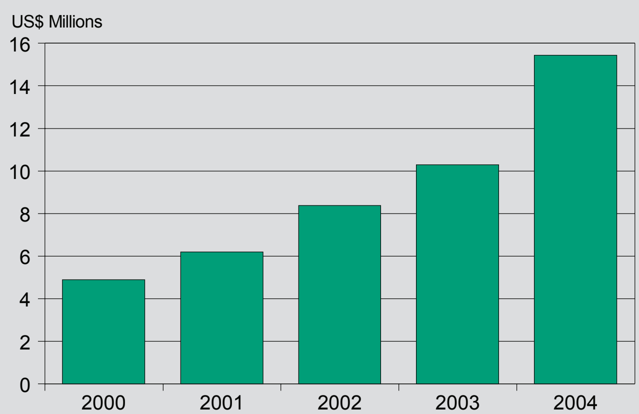
Karolinska Institutet Funding, 2004

Funding Source	US$ Millions
Direct State funding	243
Research Councils	41
Other government agencies	26
Swedish foundations and org.	83
Swedish companies	28
Municipalities and county councils	29
Foreign financiers, including:	46
Companies	18
Foundations and other org.(incl. EU)	28
Financial income	12
Total	508

Sources: Karolinska Institutet Annual Report 2004, Milken Institute

In 2004, KI took part in 164 EU-funded projects and received $15.4 million EU grants. A total of 228 applications were submitted under the Sixth Framework Programme, of which 95 have been approved.

Income from the EU
2000-2004



Sources: Karolinska Institutet Annual Report 2004, Federal Reserve, Milken Institute

4. University Technology Transfer Mechanisms

According to the Third Mission mandate, Swedish universities have to implement their own way of collaboration with industry. Since 1994, and in addition to the establishment of university technology transfer offices, seven broker organizations — technology bridging foundations — have been formed for facilitating tech transfers.

In order to improve the commercialization of research, Sweden is debating whether to replace the Law of University Teacher's Privilege. Since 1949, university scientists have had full entitlement to their research results. Scientists patent their inventions, often with the assistance of public support organizations. In the country's non-university public organizations, the institution retains ownership of IP.

> "Unfortunately, in Sweden, high scientific investments and productivity of universities are not translated into innovative products and processes at the desired levels. This phenomenon has been called the 'Swedish Paradox.' "
>
> *— Devrim Göktepe,*
> *"Investigation of University Industry Technology Transfer Cases: A Conceptual and Methodological Approach"*

Beginning in 1996, universities created holding companies to facilitate tech transfers.[20] Technology link foundations (located at the country's major universities) and the university holding companies (owned by the universities) assist university staff and students in tech transfer activities. The expectation is that university holding companies will become minority owners of university spin-offs.[21]

Reaching beyond the usual university OTT model, MedCoast Scandinavia is a Swedish/Norwegian networking organization that interacts with OTTs to facilitate biomedical commercialization in the Göteborg-Oslo (GO) region. The GO region is made up of Oslo, Akershus and Østfold, in Norway, and Göteborg and Västra Götaland, in Sweden. It is home to almost a quarter of the population of Norway and Sweden, nearly 3 million people. Several science parks are located in the area.

MedCoast is linked to:

- The University of Oslo and the Göteborg University, among the largest universities in Scandinavia, with more than 35,000 students each.
- Chalmers University of Technology, with some 8,000 students.
- IT-University in Göteborg, with 4,000 projected students.
- The Norwegian School of Management BI, with approximately 10,000 students.

5. Commercialization Success: Patents and Licensing

Pharmaceuticals and medicines dominate Sweden's biotech industry, particularly drug discovery and development, the largest sub-sector by number of firms and employees.[22]

SwedenBIO ranks the country ninth internationally for the absolute number of biotech companies. Sweden also scores high in both publications per capita and citations. Since 1997, biotech patents grew at the rate of 9 percent per year. However, "there are reports indicating a decrease of Sweden's academic output and relative quality, mainly due to decreasing public funding in the last decade."[23]

A recent study conducted by SwedenBIO argues that although university tech transfer offices are present at several universities and the OTT-infrastructure at Karolinska Institutet specializes in life sciences, the offices are not capable of shouldering the necessary functions.[24]

> "Sweden's percentage of the world's total publication volume within biotech and applied microbiology increased from 1987 to 1999, reaching a share of just over 2 percent for 1999–2001."
>
> *— OECD, 2003*

"The government's innovation policy is only working in one direction: top-down," said Lena Torell, President of the Royal Swedish Academy of Engineering Sciences (IVA). "Sweden is lacking in 'pull' incentives. We can create as many holding companies, as many technology incubators and whatnot. The problem is how to put incentives in place for individuals at universities to be engaged in technology transfer." The problem in Sweden, she noted, is that "there is no economic growth. Twenty-five to 50 percent of the economic growth in the OECD countries is caused by new technologies and therefore by research, but Sweden, being a top nation in research, fails in commercializing the results."[25]

Sweden's high tax structure, high labor costs and red tape are obstacles to patenting. And because all applications for research grants are by law available to the public, scientific discoveries are potentially exposed early in the research cycle. In a May 2005 interview, Stefan Folster, Chief Economist of the Confederation of Swedish Industries, said, "We aren't seeing as many spin-offs in Swedish industry from research as one would expect. … We don't get enough out of these large investments."[26]

Successful university startups include:

- *Biosynth Svenska AB*, a private company founded by Lund University researchers Dr. David Lecerof and Baruch Yom-Tov. Biosynth works with an active substance used in photodynamic therapy that does not scar or cause discomfort during the application.[27]
- *Aditus Medical AB*, founded in 1997 and which provides devices for intelligent electroporation for research and lab use, in vivo and in vitro. The company is headquartered in Lund. Aditus originated from research projects at Lund University and IDEON Science Park.[28]

- *Aerocrine AB*, a clinically based medical technology company that develops devices for noninvasive monitoring of inflammation through the measurement of gaseous markers. The company was founded in 1997 by scientists from the Karolinska Institute and is headquartered in Stockholm. Aerocrine holds a comprehensive patent portfolio, including 11 patents issued in the United States.[29]
- *Affibody AB*, founded in 1998 by researchers from the Royal Institute of Technology and the Karolinska Institute in Stockholm. Based in Stockholm, the company uses protein engineering technologies for the development of affinity ligands. A key component of its technology is the Affibody molecule, a protein that can be designed to bind to any target protein.[30]

Endnotes:

1. SwedenBIO. See: http://www.swedenbio.com/templates/Page.aspx?id=443.
2. As cited by SwedenBIO. See: http://www.swedenbio.com/upload/About%20Biotech/Swedish% 20Biotech/SwedenBIO_introduction %20swedish%20biotechnology%20industry_5Nov03[1].pdf.
3. SwedenBIO. 2003. "A National Biotech Agenda for Growth."
4. Koch, Per and Oksanen, J. (eds.). "Good Practices in Nordic Innovation Policies, Part 2: Innovation Policy Trends and Rationalities." 2003. STEP, Center for Innovation Research. June 2003. See: http://www.step.no/ reports/Y2003/0703.pdf.
5. Koch, Per and Oksanen, J. (eds.). 2003.
6. "Biotechnology in Sweden." See: http://www.altassets.net/casefor/sectors/2002/nz3292.php. Aug. 19, 2002. Source:Bioseeker Group.
7. Koch, Per and Oksanen, J. (eds.). 2003.
8. http://cordis.europa.eu/sweden/research_sys.htm.
9. The Swedish Research System. See: http://cordis.europa.eu/sweden/research_sys.htm.
10. http://www.medicineandbiotech.com.gpage2.html.
11. Swedish Research. Main Financing Bodies. 2002. See: http://www.kks.se/upload/publikationsfiler/ swedish_research_main_ financing_bodies_2002_publ.pdf.
12. "Biotechnology in Sweden." 2002.
13. Ibid.
14. Ibid.
15. VINNOVA Forum VFI 2003:1. Commercialization of Academic Research Results. See: http://www.vinnova.se/Main. aspx?ID=ca102da6-815e-4eb4-8b2c-e83c495a6f96.
16. "Biotechnology in Sweden." 2002.
17. Ibid.
18. Ibid.
19. Ibid.
20. Ibid.
21. Devrim Göktepe. "Investigation of University Industry Technology Transfer Cases: A Conceptual and Methodological Approach Part 2."
22. http://www.olis.oecd.org/olis/2003doc__.nsf/43bb6130e5e86e5fc12569fa005d004c/ 7524fee7966a86c2c1256de50049f989/$FILE/ JT00154671.PDF.
23. SwedenBIO. 2003.
24. SwedenBIO. 2005. "The Swedish Biotechnology Industry Organization: Abolishment of the Teacher's Exemption: Consequences and Position of the Swedish Biotechnology Industry." July.

25. "Commercialization of Academic Research Results." VINNOVA. 2003. http://www.vinnova.se/upload/EPiStorePDF/vfi-03-01.pdf.
26. European Business. May 2005. See: http://europeanbusiness.eu.com/features/2005/may/RD.html.
27. http://www.biosynth.se/.
28. http://www.aditusmedical.com/.
29. http://www.aerocrine.com/.
30. http://www.affibody.com/.

Switzerland

1. National Innovation Policy

Relative to its population, Switzerland has the highest biotech density worldwide, according to *Swiss Biotech Report 2005*.[1] Many of the country's achievements in biotech are due to the tax environment and banking system (Switzerland is the leading financial center in Europe, with some 340 banks), political stability, renowned universities and a long tradition in pharmaceutical technologies.[2]

> "Switzerland has the second highest number, after Sweden, of independent, dedicated biotechnology firms per inhabitant in Europe."
>
> — *Swiss Federal Institute of Intellectual Property*

Research, education, technology and innovation policies fall under cantonal (state) and federal authority, with federal powers growing in importance.[3] The most comprehensive framework is the federal program paper delivered every four years on education, research and technology (called the "ERT message"), which includes action plans for support and promotion.[4] University biotech research is enhanced by the Priority Program Biotechnology of the Swiss National Science Foundation.[5] The Innovation Promotion Agency, or CTI, targets results-oriented transfers of knowledge and technology.[6]

The country boasts two federal institutes of technology, 10 cantonal universities and seven universities of applied sciences under cantonal or inter-cantonal authority. Swiss universities are autonomous.[7]

Switzerland is not a member of the European Union, but many of its laws are in line with EU directives. It is a signatory to the World Intellectual Property Organization Convention, which preserves the worldwide protection of intellectual property. The Swiss Federal Institute of Intellectual Property regulates IP matters.[8] The ownership rules for IP may be modified through other regulations in the higher education sector. A recent CEST (Center for Science and Technology Studies) survey notes that IP from research in Switzerland generally belongs to the organization.[9]

2. Funding and Venture Capital

Since 2004, when Switzerland became associated with the Sixth EU Framework Programme for research and technology development, the country has contributed CHF 200-220 million each year to the program. In return, the European Commission provides direct funding to Swiss researchers and small and medium-sized enterprises.[10]

The federal state and cantons fund about 70 percent of higher-education R&D expenditures. The Swiss National Science Foundation funds another 10 percent, and the remaining 20 percent is funded by external sources, including private investment, funding for joint applied research, co-funding by the Commission for Technology and Innovation, and other federal offices.[11]

The government agency CTI funds salaries for about 1,000 academic researchers each year. In addition, CTI Start-up supports the establishment of high-potential growth companies. CTI funding stands at approximately CHF 400 million for the period 2004 through 2007.[12]

Switzerland ranked third in Europe in 2003 and 2004 for venture capital influx: $168.1 million and $194 million, respectively.[13] It has more than 40 venture capital firms and biotech-specific investment funds, including Adamant Biomedical Investment; Aventic AG; BB Biotech Ventures; Clariden Biotechnology Equity Fund; and UBS Equity Fund, Biotech.[14]

"Switzerland makes more than €20 million available each year for research in nanotechnology."[15]

3. Clusters of Biotechnology

Four major biotech clusters, along with the Swiss Exchange and Swiss Biotech Association, have formed the marketing alliance SwissBiotech, consisting of more than 800 life-sciences and biotech companies in the country.[16] BioValley Basel is one of the most important pharmaceutical and biotech clusters in the world and home to multinationals Novartis, Roche, Serono and Syngenta.[17] Other clusters include Biopolo Ticino, a biotech platform for tech transfers and business development; Bio Alps, with science parks and incubators; and the greater Zürich area, with more than 200 biotech firms and the highest density of biotech companies worldwide by population size. The ETH Zürich and University of Zürich are epicenters of scientific research in the area.[18]

The Federal Institute of Technology in Zürich, the University of Basel and the University of Zürich are collaborating to create a "center of competence" in systems biology, said to be the first of its kind in Europe.[19]

Established in 1971, the Biozentrum institute is integrated as a department at the University of Basel. Research areas include biochemistry, microbiology, structural biology, cell biology, pharmacology and neurobiology, as well as the newer fields of genomics, proteomics and nanosciences. Its scientists publish approximately 200 papers a year. About 25 doctoral students graduate each year, with about the same number carrying out their Ph.D. work at Basel institutions, working with Biozentrum scientists.[20]

Zurich MedNet is a web-based information resource and business development network comprising more than 400 companies, universities, institutes, foundations, hospitals and labs. It has teamed up with the University of Minnesota's MBBNet (a web portal to the state's virtual biomedical and bioscience community) to offer links to more than 1,300 organizations.

Seven cantonal universities — the universities of Basel, Berne, Fribourg (G.F), Geneva, Lausanne, Neuchâtel and Zürich — and the ETH Zürich offer studies in biotechnology.[21] The University of Basel, the oldest in Switzerland, is top-ranked in worldwide research.[22]

4. University Technology Transfer Mechanisms

"Around 20 full-time-equivalents are engaged in technology transfer for the Swiss universities," states a 2003 CEST report, "whose staff ranges from virtually zero to four full-time-equivalents."[23] Recent changes allow more flexibility for faculty partnerships and consulting work.[24]

Federally controlled tech transfer activities are based on decentralized decision-making. Most OTTs are less than 10 years old and generally deal with IP management for their home institutions. In contrast, cantonal universities have several institutional solutions.

The Swiss Network for Innovation, created in 1999, supports tech transfer activities at tertiary education organizations.[25] The Swiss Technology Transfer Association, or swiTT, was created in 2003 by 32 founding members responsible for technology transfer at 20 public research institutions.[26]

Numerous institutions in the Greater Zürich Area manage tech transfers, including:[27] CTI, an initiative of the Federal Office for Professional Education and Technology; ETH transfer, the technology transfer institution of ETH Zürich; and the Transfer Center for Technology Management, part of the Institute for Technology Management at the University of St. Gallen.

Technology transfers for the University of Basel are controlled by the rector's office, while the universities of Geneva and Lausanne have internal OTTs.[28] BioteCHnet, a partnership of the Swiss Universities of Applied Sciences, is an active biotech transfer institution.

Swiss universities have established a number of tech transfer principles.[29] University innovations are owned by the universities; collaboration results are stipulated via contracts; and universities are entitled to a financial share of the revenues generated by the cooperative partner through commercialization of the IP. On average, 50 percent of gross income goes to the research group or scientist's department, and the remainder is divided among the OTT, the inventor(s) and the organization.[30]

Unitectra, the OTT for the universities of Bern and Zürich, has managed more than 2,000 transfer projects involving more than 1,500 agreements. In 2004, Unitectra dealt with 650 new transfer cases, an increase of more than 50 percent over the previous year. The majority were in the life-sciences industry. In addition, the OTT disclosed some 60 inventions, licensed 30 technologies (about two-thirds of which were granted to SMEs) and recorded six spin-offs (one from the University of Bern, five from the University of Zürich).

5. Commercialization Success: Patents and Licensing

The 2005 *World Competitiveness Yearbook* ranks Switzerland in the following Top 10 listings: Nobel Prizes per resident (second); active patents per resident (second); private research expenditures (sixth); R&D expenditures per resident (sixth); and R&D employees per resident (eighth); and eighth overall among the 60 nations studied..[31]

"Accounting for 79 of the 465 European products in the pipeline, the Swiss biotech industry ranks an impressive second in Europe in terms of revenue and market capitalisation," according to the 2005 *Swiss Biotech Report*. At the end of 2004, the country's biotech industry consisted of 223 companies (133 research-oriented firms and 90 direct supplier companies).[32]

In 2000–2001, 112 U.S. patents were granted in Switzerland.[33] In 2001, OTTs generated 241 invention disclosures and 132 patent applications, primarily in health, pharmaceuticals and medical technology (including biotech), as well as IT, electronics and instruments. In that period, institutions of higher education were granted 59 new patents, and 157 non-disclosure or confidentiality agreements and 60 material tranfer agreements were issued.

Nearly two-thirds of all spin-offs come from the two federal institutes of technology, and 20 percent from the cantonal universities. "Overall, higher education institutions have a portfolio of more than 900 active patents, and one has a portfolio of several hundred," states one report.[34] "In 2001, higher education institutions negotiated 200 licenses, only a small portion of which were linked to active patents. Many are based on copyrighted materials (81), patent-pending inventions (33) or non-patented inventions (27)."

About half of the licensed patents generate income totalling more than CHF 8 million. Licensing-in is not very common.[35] In 2000, the average revenue per license in Switzerland was €45,000.[36]

Founded in 1998, ESBATech is a spin-off from the University of Zürich that specializes in the identification of disease-relevant genes and screenings for lead compounds in cell-based assays for drug discovery. The company develops therapeutic single-chain fragment antibodies. In 2005, ESBATech announced an agreement with Novartis for receptor tyrosine kinase inhibitors. ESBATech received BioValley Basel's 2004 Life Sciences Prize 2004 and was a 2005 recipient of the Red Herring 100 Europe, a list of innovative companies.

In 2001 the country had more than 400 spin-offs, most of which are still active. The rate of formation is now estimated at 50 new firms a year. The two federal institutes of technology constitute about two-thirds of these spin-offs, while cantonal universities are responsible for approximately 20 percent.[37]

Molecular Partners is a spin-off founded by Prof. Andreas Plückthun and his team from the Biochemistry Institute of the University of Zürich. The company develops novel binding proteins for applications in biotechnology, diagnostics and therapeutics, based on proprietary technology. In 2005, Molecular Partners won a W.A. De Vigier Award ($75,000) for entrepreneurship in Switzerland. The company also won the 2005 Swiss Technology Award.

Endnotes:

1. *Swiss Biotech Report 2005*. http://www.standortschweiz.ch/imperia/md/content/seco/ deutsch/ organisation/11.pdf.
2. Ibid.
3. Vock, Patrick and Urte Hinrichs. 2004. "Swiss Science and Innovation Policies: Recent developments 2002-2003." CEST.
4. Ibid.
5. *Biotechnology in Europe Today*, a supplement to *Chemistry Today.* March/April 2005. "SwissBiotech: A nation as biotech cluster." http://www.teknoscienze.com/images/documenti/supplements/switzerland1.pdf.
6. *Swiss Biotech Report 2005*.
7. Vock, Patrick. 2003. "University Technology Transfer in Switzerland, Organization, Legal Framework, Policy and Performance." CEST.
8. http://www.ige.ch/E/institut/i1.shtm.
9. Vock, Patrick, E. Sultanian and U. Hinrichs. 2002. Technologietransferaktivitaten 2002. Umfrage bei Hochschulen und offentlich finanzierten Forschungsorganisationen. CEST 2004/3.
10. Vock, Patrick and Urte Hinrichs. 2004.
11. Vock, Patrick. 2003.
12. *Swiss Biotech Report 2005*. See also: http://www.swissbiotech.org/finance_instr/priv_equity/index.html.
13. Ibid.
14. Ibid.
15. http://www.researchandmarkets.com/reports/37898/.
16. *Biotechnology in Europe Today*.
17. Basel Area. Business Development. http://www.baselarea.org/e_informationen_geografie.cfm##.
18. http://www.greaterzuricharea.ch/default_en.asp.
19. *Swiss Biotech Report 2005*.
20. The Biozentrum of the University of Basel. http://www.biozentrum.unibas.ch/ataglance.html.
21. *Swiss Biotech Report 2005*.
22. The Biozentrum of the University of Basel.
23. Vock, Patrick. 2003.
24. *Biotechnology in Europe Today.*
25. Vock, Patrick. 2003.
26. http://www.greaterzuricharea.ch/default_en.asp.
27. Greater Zürich Area. http://www.zurichmednet.org/default_en.asp.
28. Vock, Patrick. 2003.
29. EPFL Technology Transfer. 2005. http://sri.epfl.ch/en/page1260.html.
30. Vock, Patrick. 2003.
31. http://www.greaterzuricharea.ch/default_en.asp.
32. *Swiss Biotech Report 2005*. See also: www.swissbiotech.org.
33. OECD. 2003. "Turning Science into Business: Patenting and Licensing at Public Research Organisations."
34. Vock, Patrick. 2003.
35. Ibid.
36. OECD. 2003.
37. Vock, Patrick. 2003.

United Kingdom

1. National Innovation Policy

The United Kingdom leads the European market in biotechnology.[1] Its pharmaceutical industry covers 12 percent of the global market, ranking fourth worldwide, with strengths in therapeutics and gene therapy, as well as stem cell and drug-discovery research. [2]

The country became the world's cloning leader after the research debacle in the Republic of Korea. While British scientists have cloned a human embryo, they have not yet derived a line of stem cells from such an embryo.[3] Embryologist Ian Wilmut, the man behind Dolly the sheep and the first director of Edinburgh University's new Centre for Regenerative Medicine, is an advocate for stem cell therapy in the treatment of degenerative and terminal illnesses.[4]

The UK has a stable and efficient regulatory environment, and participates in EU efforts to simplify and harmonize administrative provisions.[5] In the early 1990s, the government emphasized technology transfers, particularly for university spin-offs.

The secretary of state for trade and industry has overall responsibility for the government's science policy. Most day-to-day functions (including health, education, industry, rural affairs and transport) have been decentralized to England, Northern Ireland, Scotland and Wales. The Office of Science and Technology allocates the science budget (more than $4 billion per year) to research councils.[6]

The Medicines and Healthcare products Regulatory Agency provides regulatory review of medical devices and drugs. This department and the Ministry of Science work with the Cabinet Office's biotech committee to oversee the biotechnology sector.[7]

In 2000, the government announced tax credits for small businesses and, in 2002, extended the credit to large companies.[8] In 2005, university startups also saw relief with the announcement that income taxes could be deferred until the companies become profitable; under previous regulations, taxes were levied at the time the IP was transferred.[9]

Britain's December 2005 Pre Budget Report doubled funding for stem cell research, to £100 million over the following two years, and called for new initiatives in support of innovation and science. The report also recommends the creation of a National Institute for Health Research to support 10 new university-based centers for excellence in medical research, some 250 academic fellowships and 100 clinical lecture training opportunities each year. Also listed in the budget is the creation of a UK–China University Partnership Scheme, with scholarships, academic exchanges and collaboration. To encourage in-migration of young foreign scientists and technologists, the government proposed a plan that would permit graduating foreign students to work in the UK for up to a year.[10]

Katy Lawrence, Assistant Director of the Micro and Nanotechnology Innovation Group, DTI, described how the country's Micro and Nanotechnology Network was created in partnership with the regional development agencies. "Investments of £60 million (for industry-facing capital infrastructure in nanomedicine, nanomaterials and nanofabrication) and £40 million (for applied research in micro- and nanotechnology) have been made,'' she told the Milken Institute. ''The Nanotechnology Issues Dialogue Group, chaired by the Office of Science and Technology, oversees . . . activities in nanotechnology health and safety, toxicology and risk assessment. The Department of Trade and Industry . . . formulated the Technology Strategy Board, which provides a business-led framework for identifying and supporting emerging technologies in the UK.''[11]

2. Funding and Venture Capital

Most government research funding is delivered to universities through two systems.[12] The first, known as Quality Related funding, supports university research through four funding councils: the Higher Education Funding Council for England; the Scottish Higher Education Funding Council; the Higher Education Funding Council for Wales; and the Department for Employment and Learning in Northern Ireland.

Quality-related funding pays research salaries and training costs, builds research capabilities and offers the freedom to pursue so-called ''blue-skies'' research. Bloc grants enable universities to shape overall research strategy. Funding councils invest approximately $2.6 billion annually in scientific research.

- Six UK biotech firms went public in 2004.
- Total revenues from public companies were €1.8 billion, with a net loss of €186 million.
- Public companies invested €560 million in research and development.
- UK firms have 165 new products in the pipeline, of which 30 are in Phase III clinical trials.

Source: http://www.ey.com/global/content/nsf/UK

A second funding stream comes from eight research councils and consists of project grants by the Office of Science and Technology allocated by a peer review process. Research Councils U.K., established in 2002, encourages collaboration. The Biotechnology and Biological Sciences Research Council is the country's top funding agency for academic research and training in the non-clinical life sciences, and promotes the commercialization of university research.[13]

Research charities invest some $1.2 billion in the country's science base — around $900 million in universities.[14] In 2004, the medical research charity Wellcome Trust spent nearly $700 million (less than approximately $840 million in 2003), according to its web site. The British Heart Foundation spent more than $95 million on research in 2003/2004. The foundation's goal is to create ''centers of excellence'' around foundation-funded professors at 16 universities.

A funding stream to support university knowledge transfer in England was established in 1999. Third-stream funding was also introduced in Wales, Scotland and Northern Ireland. Between 1997 and 2004, the UK government invested approximately $750 million in plans to increase knowledge transfer and interaction among universities and businesses.[15]

From 1981 to1999, the UK was the only country, compared with its competitors, to experience a significant decline in total R&D spending as a share of GDP. In 1981, the country's spending on R&D, as a proportion of GDP, was second only to

Germany among the G7 nations; but by 1999, it had dropped behind the United States, France and Japan, and only just maintained its position vis-à-vis Canada. Although some of the decline in spending can be traced to weak support by the public-sector, the majority was due to a lack of support by business.[16]

The White Rose Technology Seedcorn Fund was founded in 1999 with winnings from the University Challenge Competition. Current funding exceeds $10 million and is provided by the Office of Science and Technology, the Wellcome Trust, the Gatsby Foundation and the Regional Development Agency for Yorkshire and the Humber. The fund invests in technologies emerging from the universities of York, Leeds and Sheffield.

Industrial R&D as a percentage of GDP declined in the UK but rose elsewhere, and often substantially. Compared with other OECD countries, the UK scores poorly in average annual growth in business R&D, as measured by purchasing power parities. Business R&D intensity also lags behind that of many other developed economies. "The UK's business research base is both narrow and fragile," according to the 2003 *Lambert Review of Business-University Collaboration*, "and is heavily dependent on the investment decisions of a dozen large companies mainly involved in pharmaceuticals and defence."[17]

Some universities have relationships with VCs and angel investors. According to Jo Taylor, Chairman of the British Venture Capital Association (which has some 170 members), the UK private equity and VC sectors are by far the largest in Europe, and second only to the United States. Arakis, founded in March 2000 and based at Chesterford Research Park, south of Cambridge, raised more than £49 million in three private equity funding rounds.[18] Domantis, a company specializing in antibody molecules, was founded in 2000. It raised $54 million, attracting $33 million in Series B venture financing in February 2004.[19]

The investment company IP2IPO recently struck a number of deals with UK universities to set up partnerships for commercializing their IP. In May 2005, IP2IPO announced a 44.3 percent acquisition stake in Oxford NanoLabs Ltd., a spin-off from the University of Oxford.

Oxford NanoLabs is developing technology for biosensing, and plans to develop a series of products from its platform technology, initially hand-held diagnostic devices for medical testing with longer-term applications in counter-bioterrorism and gene sequencing. Its underlying science was developed in the research groups of Hagan Bayley, Ph.D., an expert in membrane protein engineering and stochastic sensing.

IP2IPO's stake in ONL consists of a 5.3 percent interest received as a result of its partnership with Oxford's chemistry department and 39 percent of a direct investment of over $800,000. The formation of Oxford NanoLabs was assisted by ISIS Innovation, the technology transfer company of the University of Oxford.

3. Clusters of Biotechnology

The UK boasts multiple regional biotech clusters, including: Edinburgh, Dundee and Aberdeen in Scotland; the northwest of England; Cambridge; Oxford; and the greater London area. Niche centers of excellence exist in Northern Ireland, Wales and the northeast of England.[20] Oxford and Cambridge are the most spectacular examples.

The Cambridge cluster includes not only the university but also Addenbrooke's Hospital, the Medical Research Council Laboratory of Molecular Biology, the Sangre Centre, the Babraham Institute, the European Bioinformatics Institute and more than 250 biotech firms. An entrepreneurship center, attached to the university's graduate school of business, offers such degrees as a master's in bioscience enterprise and classes like "Basics of Building a Business." VC firms are also located in the area. An "angel initiative," the Cambridge Enterprise Accelerator, provides funding for companies linked to academic research.[21]

In Cambridge, the formation of biotech clusters has led to the development of incubators. The Babraham Incubator offers lab and office space, networking opportunities, and access to financial and marketing advice. In addition, more than a hundred incubators have joined the UK Business Incubation National Incubator Organization; nine are in Oxfordshire, managed by Oxford Innovation Ltd., Oxfordshire BiotechNet and the Oxford Science Park.[22] The MerseysideBIO incubator, established with government grants (including the EU), provides research and office space to some 15 startups, and networks with Liverpool University and Liverpool John Moore's University.[23] All UK science parks are located at or near universities.[24]

In December 2004, the government announced a plan to transform Manchester, Newcastle and York into "science cities," with $183 million in funding to be divided among the regional development agencies Yorkshire Forward, One NorthEast and the North West Development Agency.

4. University Technology Transfer Mechanisms

Most universities in the United Kingdom have OTTs. Their staff numbers are rising, as are investments in and revenues from university research. There is no single model for tech transfer offices.

The annual *U.K. University Commercialisaiton Survey* reports that by the end of 2004, more than 79 percent of the responding institutions had at least two full-time-equivalent employees at each technology transfer office. In the same year, an average of 10 FTEs per institution was employed in tech transfer and commercialization, reflecting an increase from 2002 and 2001, when on average six and five FTEs were employed, respectively. The number of FTEs at each institution, however, varies. For example, during 2003, one institution had no FTEs, while four employed more than 30. The maximum number of FTEs at a single university in 2003 was 48.[25]

According to the *Lambert Review of Business–University Collaboration*, "when a research project is financed with public funds, there is no question of business owning any resulting IP." Conversely, companies usually retain ownership of industrial sponsored research. In public/private collaborations, individual universities negotiate the IP rights.

The London Technology Network, launched in 2002, works with academic institutions to facilitate technology transfer in computer, life and physical sciences. The company, formed by the London Business School and University College London, is funded through the Department of Trade and Industry and other government agencies. Approximately 20 universities have partnered with the network, which has access to more than 4,000 researchers.

According to the Lambert Review of Business-University Collaboration, "A senior manager of a global R&D company summarized LTN's value to industry: 'There are some 40 universities in London and they do all kinds of research. Trawling over all of them would take forever, but this way we can go along to a meeting, get together with other companies and have direct contact with the researchers.' "

The majority of universities adopt a formula-based approach to the allocation of returns from the licensing and sale of IP. Although somewhat varied, most embody these common themes:

- There is a three-way split among the university, department and inventor(s).
- Revenues are usually net of patenting costs (and sometimes the cost of IP managers' time), enabling the university to recoup some of its initial outlay.
- The inventor's share falls and the university rises as net returns increase. Individuals can be substantially rewarded relative to their salaries.
- Although interdisciplinary and international collaboration are increasingly necessary in cutting-edge biotech research, UK revenue sharing, when there are multiple inventors, is unclear.[26]

"My research discoveries in France led me towards more commercially relevant research. Unfortunately, venture funding in France was very low," said Dr. Simon Ward, Founding Director of Molecular SkinCare, a spin-out from the University of Sheffield. "This led me to relocate back to the U.K., and ultimately Sheffield, where there is a very strong university research presence with an appreciation of commercial translation."

Molecular SkinCare develops products for the treatment of skin diseases, such as eczema, psoriasis, dermatitis and skin cancer. Funding for the company was led by Sitka Health Care Venture Capital Trust ($2.16 million). Further investors include: Cambridge Research & Innovation, Catalyst Biomedica, the University of Sheffield, Avlar BioVentures, regional development agencies, the chamber of commerce and the South Yorkshire Bioscience Network.

5. Commercialization Success: Patents and Licensing

"The U.K.'s relatively poor record in commercializing basic research has long been a subject of concern," according to the 2003 *Lambert Review of Business-University Collaboration*. "The Paris Exhibition of 1867, when Great Britain was awarded the palm of excellence in only ten of the ninety departments, was regarded as something of a national disaster."[27] In response, the UK "moved to create civic universities with the strong support of British industry." More recently, as positive results remain elusive, "these worries have taken on a new intensity."[28]

UK science ranks high in terms of papers and citations, yet according to the government's 2002 spending review, until recently, Britons have fewer patents and startups than some of their competitors.[29] Universities generate only a small share of annual patents; universities in Scotland, at approximately 10 percent, account for the highest proportion.[30]

The UK University Companies Association, or UNICO, administers an annual "U.K. University Commercialisation Survey." The following summarizes the most recent aggregate results.

- University research invention disclosures rose from 14 on average per institution in 2001 to 28 in 2004. In all, 2,871 inventions were disclosed by 82 responding institutions.
- In 2003, the majority of patents issued to UK institutions were from outside of the country: 15 percent from the United States and 68 percent from other countries. During 2004, 885 new patent applications were filed (an average of 9 per institution) down marginally from the prior year.
- Licensing activity increased significantly from 2001 to 2004. During 2003, more than 80 percent of the institutions participating in the UNICO survey had 775 licenses, options and agreements yielding over $51 million. Licensing income from higher education institutions rose from more than $26 million in 2003 to some $34 million in 2004.
- The commercialization strengths among universities vary. For example, of the UNICO respondents for 2004, a fifth reported no new invention disclosures, while 17 percent reported more than 60; a quarter filed no new patent applications, while 4 percent filed more than 40 new applications; 29 percent (up from 17 percent in 2003) earned no licensing income, while 27 percent earned up to $92,000. Although 60 institutions created 229 spin-off companies in 2004, more than 43 percent formed no startups.

The majority of university spin-offs, which tend to be in pharmaceuticals, bioscience and new technologies sectors, are unsustainable. The emphasis on startup formation, driven by the availability of University Challenge Funds and the government's vision of these companies as a source of job creation,[31] needs to be re-examined. The Library House Spin-out Monitor identified some 200 technology life-science spin-offs in 2004.[32] There were nine IPOs by companies formed from UK universities in 2004, with a combined value of over $1.1 billion.[33]

Endnotes:

1. Critical I Ltd. 2005. *Comparative Statistics for the UK, European and US Biotechnology Sectors: Analysis Year 2003*. February.
2. BIO 2005. http://www.bio.org/events/2005/international/CountryProfiles.pdf.
3. Naik, Gautam. 2006. "How U.K. Took Cloning Lead," *Wall Street Journal*, Jan. 17.
4. http://news.scotsman.com/dec05.
5. See: Wallace, Lorna H. 2000. "Foreign Direct Investment Into the USA: A Subnational Investigation," in John H. Dunning (ed.) *Regions, Globalization, and the Knowledge-Based Economy*. Oxford University Press, for a discussion of "regulatory environment," a key determinant of competitiveness.
6. http://www.ost.gov.uk/about_ost/index.htm.
7. "Biotechnology: Educating the Public, Final Report," Feb. 1, 2000. See: http://europa.eu.int/ comm/research/biosociety/pdf/ebe_report_300603_ec.pdf.
8. http://www.hmrc.gov.uk/ria/spin-out.pdf. See also: *Lambert Review of Business-University Collaboration*, 2003. See: http://www.hm-treasury.gov.uk/media/DDE/65/lambert_review_final_450.pdf
9. http://www.mms.co.uk/html/article.asp?articleID=389.
10. www.hm-treasury.gov.uk/pre_budget_report/prebud_pbr05/prebud_pbr05_index.cfm. See also: www.ssti.org.
11. Katy Lawrence, Assistant Director, Micro and Nanotechnology Innovation Group, DTI, UK.
12. *Lambert Review of Business-University Collaboration*. 2003.
13. http://www.bbsrc.ac.uk/about/Welcome.html.
14. http://www.hm-treasury.gov.uk/media/33A/AB/spend04_sciencedoc_1_090704.pdf.
15. *Lambert Review of Business-University Collaboration*. 2003. See also: European Commission. *Trend Chart: Innovation Policy in Europe 2004,* Publications DG Enterprise and Industry.
16. *Lambert Review of Business-University Collaboration*. 2003.
17. http://www.ost.gov.uk/policy/science_strategy.pdf. See also: *Lambert Review of Business-University Collaboration*, 2003.
18. http://www.arakis.com/overview2.htm.
19. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report.*
20. BIO 2005.
21. Ibid.
22. Bradstock, P. 2001. *Entrepreneurship and Innovation in Europe October-November 2000.* Oxford Trust.
23. http://www.2020network.ca/index.php/Technology_Developments_in_England.
24. Seigel, Donald, P. Westhead and M. Wright. 2003. "Assessing the Impact of University Science Parks On Research Productivity: Exploratory Firm-Level Evidence From the United Kingdom," *International Journal of Industrial Organization*.
25. *UK University Commercialisation Survey: Financial Year 2003.* See also: http://www.unico.org.uk/ prerelease.htm.
26. http://www.ost.gov.uk/policy/science_strategy.pdf.
27. *Lambert Review of Business-University Collaboration,* 2003, which concluded that the UK was strong in research, but less effective at translating its products into social and economic benefits.
28. *Lambert Review of Business-University Collaboration*. 2003.
29. http://nextwave.sciencemag.org/cgi/content/full/2003/08/27/4.
30. *Higher Education Business Interaction Survey 2000-01*, HEFCE, 2003 and *Patent Office Annual Facts and Figures 2000-01,* Patent Office, 2001.
31. *Lambert Review of Business-University Collaboration*. 2003.
32. "Creating Success from University Spin-outs." 2005. Review conducted by Library House on behalf of the BVCA, Nov. See: http://www.liverpoolventures.com/pressfolder/ict_trends06.html.
33. http://www.hmrc.gov.uk/ria/spin-out.pdf. Note: Library House reports 12 IPOs.

Asia

Australia

1. National Innovation Policy

Australia is the leading biotechnology location in the Asia-Pacific and, according to The Economist Intelligence Unit, the top location to conduct pharmaceutical clinical trials.[1] The country's openness to cross-border partnerships is reflected in its large number of international biotech alliances: 72 percent of announced life-science partnerships in 2004. Biotech R&D constitutes more than 3 percent of global medical research.[2]

As of year-end 2004, the biotech industry employed about 6,100 people, 46 percent of whom were working at companies specializing in human therapeutics, 16 percent in agribiotech and 15 percent in diagnostics. About 28 percent of employees were R&D staff.[3]

In July 2000, Australia introduced a National Biotechnology Strategy to provide a framework for intergovernmental collaboration.[4] Other initiatives include Backing Australia's Ability (BAA), passed in 2001, and Backing Australia's Ability II (BAA II), in 2004.[5] But the country's policy framework and culture of innovation continue to be limited by the lack of financial support for biotech innovation projects. For years, innovation and the commercialization of R&D have taken a back seat to economic policy that focused instead on deficit reduction, lowering taxes and reducing interest rates.[6] References to innovation and R&D in the nation's budgets have been rare since the late 1990s.[7]

In September 2005, however, the Ministry for Education, Science and Training released a study aimed at overcoming this deficiency. The study, *Research Quality Framework: Assessing the quality and impact of research in Australia*, provides the government with the basis for redistributing research funding toward areas with the highest-quality research potential.[8]

Under Australia's current innovation policy, federal and state governments offer grants — but not projects — to companies. Thus, when a university research project runs out of funding from traditional sources, research teams commonly start a company. This new company may then receive a research grant to facilitate continued research. But now the research team is burdened with the added complexity of managing a firm. When the grant runs out, the team often seeks venture capital. But because this tends to happen at an early stage of the project or product life cycle, VCs are hesitant to invest.[9] Many biotech companies go public prematurely, without adequate access to capital.

2. Funding and Venture Capital

In its 2005 benchmarking study, the Economist Intelligence Unit ranked Australia sixth for R&D spending when compared with Germany, India, Japan, Singapore, the United Kingdom and the United States.

Biotechnology in Australia is largely funded by the National Health and Medical Research Centre, within the Department of Health and Aged Care. Government support of the National Biotechnology Strategy was initially close to $16 million, spanning three years (2001–2004). In January 2001, the Strategy received another $34 million from the BAA Initiative, the Biotechnology Centre of Excellence and the Biotechnology Innovation Fund.[10] Australia's state, territory and commonwealth governments also commit substantial resources.[11]

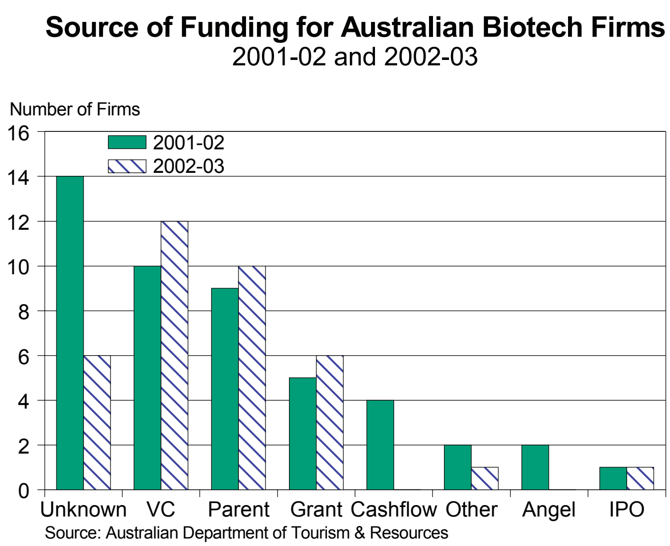
Through the BAA initiatives, the Australian government made a commitment by 2004 to more than $8 billion in funding for the 10 years from 2001 to 2011.[12] As part of BAA II, the "Commercial Ready" fund allocated an additional $740 million to biotech R&D. With this, the government underwrites pre- and post-IPO companies, as well as startups.[13]

Australian business spending on R&D in the medical, health and biological sciences amounted to $418 million in 2002–2003, approximately 10 percent of all business spending on R&D.[14]

"Between 1996 and 2003, the total amount of Australian venture capital invested in biotechnology was about [US $80] million," notes a report by Spruson & Ferguson, a law firm with offices in Australia and New Zealand. "By comparison, the average amount of venture capital invested in each U.S. biotech company that listed in 2003 received US$94 million. So roughly speaking, the average U.S. biotech had as much venture capital invested in it as the money raised by all Australian biotechnology companies over the last seven years."[15]

The *Economist Intelligence Report* notes, "During 2003–04, the health-care sector, including biotechnology, continued as the most attractive industry for Australian venture capital, in terms of capital invested, number of companies receiving capital, and the number of investment transactions."[16] In terms of VC availability, Australia ranks eighth globally (among 104 participating countries), with an average score of 4.7 on a 7.0 scale.[17] Investors in Australia are wary of innovative but risky projects. On the Australian Stock Exchange, there are more than 100 biotech companies listed.[18]

The following figure illustrates the sources of funding for new Australian biotech firms (as of 2005).[19] Australia's capital markets are becoming more comfortable about investing in biotech; however, the amount of funding remains limited. It could be advantageous for the country to explore other "potential avenues for funding, such as superannuation funds," notes the Spruson & Ferguson report. [20]



As of 2003, more than $65 million per year was invested in nanotechnology, which is receiving support from state governments. Nanotechnology Victoria (NanoVic) was formed in 2003 with almost $8 million from the Victorian government and matched by member institutes. It brought together Monash University, Swinburne University of Technology, RMIT University and CSIRO. NanoVic drives nanotechnology with a focus on market pull.[21]

3. Clusters of Biotechnology

"Approximately 20 universities are directly involved in pharmaceutical-related research and/or alliances, with one-third being located in each of Victoria and New South Wales," according to the *Economist Intelligence Report.*[22]

There are seven main biotechnology clusters in Australia: Melbourne, Adelaide, Perth, Brisbane, Sydney, Canberra and Hobart/Launceston. These are located in capital cities with proximity to leading universities. Most biotech companies are spin-offs from universities and maintain links with the public research sector.[23] The following table summarizes key universities within each of these clusters, as well as their corresponding states. These clusters house research institutes that have affiliations with major public hospitals, universities and health-related Cooperative Research Centres.[24]

Key Universities in Biotech Clusters

Cluster	State	Universities
Melbourne	Victoria	University of Melbourne Monash University
Sydney	New South Wales	AGSM Macquarie University
Brisbane	Queensland	Queensland University of Technology Griffith University
Perth	Western Australia	University of Western Australia Curtin University Murdoch University
Adelaide	South Australia	University of Adelaide
Canberra	Australian Capital Territory	Australian National University University of Canberra
Hobart/Launceston	Tasmania	Australian Maritime College University of Tasmania

Source: www.bio.org/events/2005/International/CountryProfiles

Victoria is Australia's biotech capital, home to around 40 percent of the industry's firms and employees.[25] The state has the highest number (68) of newly established biotech companies set up between 2000 and 2002, followed by 41 in New South Wales.[26] The aggregate capitalization of its listed life-sciences sector is valued at more than $7.7 billion. In 2003, the largest share (37 percent) of VC investment targeted Victorian companies.[27] Sales in 2004, from the state's life-science companies, generated approximately $3.5 billion, a 140 percent increase over 2003. Victoria is also Australia's leading generator of U.S.-granted biotech patents.[28] The proportion of public sector R&D spending dedicated to biotech is highest in Victoria of all Australian states and territories, with 40 percent of total National Health and Medial Research Council funding in 2005.[29]

In a 2005 Milken Institute interview, Nicholas Kotsiras, Member of Parliament for Bulleen, said, "An office of chief scientist, Victoria, needs to be established to aid the development and direction of policy specific to innovations developed in the state. Currently, there is no single individual who advises all ministers with matters relating to innovation. The chief scientist will focus on the areas that Victoria is good in, such as the biomedical, manufacturing and information communication technology industries." Kotsiras sees the role of chief scientist as an independent member of the state government's Innovation Economy Advisory Board, having close cooperation with the commonwealth's chief scientist to help drive integrated national programs and ensure that Victoria is in a position to influence and benefit from Commonwealth policies.

4. University Technology Transfer Mechanisms

Respondents to Australia's "National Survey of Research Commercialisation 2001 and 2002"[30] reported employing around 500 full-time-equivalent commercialization staff in 2002. Of these, 194 were at universities. Although the number of OTT staff grew significantly (by 40 percent) between 2000 and 2002, nine universities did not report employing any commercialization staff.

Australia occupies 18th position worldwide, in terms of university–industry collaboration.

The Spruson & Ferguson report shows a shortage of human capital with the requisite skills and experience in commercialization activities. Many universities spend very little on IP commercialization.[31] In September 2005, the Australian Graduate School of Management and the Faculty of Medicine at the University of Sydney announced their intention to offer a combined MBA/MBBS for medical students to better equip them with the management and leadership skills required in the increasingly complex biotechnology industry.[32]

Baby Wallaby Bone Development

Human bone development is becoming less of a mystery as Melbourne researchers engage in a new study involving three-dimensional synchrotron images of baby wallabies. According to John Brumby, the Minister for Innovation, "This information could lead to the isolation of proteins for later use in the treatment of poor bone development in premature babies and in the treatment of osteoporosis."

5. Commercialization Success: Patents and Licensing

Respondents to the national research commercialization survey reported 841 invention disclosures in 2002. Of these, 521 were in universities and 167 in medical research institutes. In 2002, three universities accounted for almost half of all university disclosures, with 11 universities not reporting any invention disclosures.[33] Respondents also reported filing a total of 820 patent applications (new and continuations): 319 issued worldwide, including 146 in Australia and 70 in the United States. In total, only six universities accounted for more than 60 percent of all university (Australian and U.S.) patent applications during 2002. Results from the 45 organizations responding in each of the years 2000 to 2002 show declines in both the number of patent applications made and the number of patents issued.

The survey results reflect a common global trend: Licensing income in Australia was heavily concentrated. In 2002, three universities accounted for more than 80 percent of total university adjusted gross income from licenses. Almost half of all licenses originated from the biological sciences. In 2002, six universities were responsible for 72 percent of licenses executed, and 16 universities did not report executing any license. The number of licenses executed fluctuated slightly down in 2001 from 2000 and up in 2002, with 37 percent of all licenses executed exclusively. Respondents reported $81 million gross income from licenses in 2001, increasing to $86 million the following year. However, among the 45 respondents to the 2000, 2001 and 2002 surveys, there was an overall decline in adjusted gross licensing income between 2000 and 2002, reflecting a 32 percent decline in income received from 2000 to 2001, then a relative leveling off in income received across the total respondent population. The majority of this decline reflects a 45 percent reduction in license income to universities over that period, mainly attributable to a single, large, one-off payment in 2000. Once this payment is adjusted for, income received is relatively stable across the period.

In 2001, 33 percent of license income came from running royalties, increasing to 44 percent in 2002. In both years, 5 percent was cashed-in equity. The 45 consistently reporting institutions showed an increase in the proportion of income received from running royalties between 2000 and 2002. The country's licensing income, as a proportion of research expenditures, was higher for medical research institutes (6 percent) than for the publicly funded research sector as a whole (1.7 percent).

The formation of new biotech firms in Australia peaked at 71 in 2001, declining in both 2002 (67 startups) and 2003 (30). In the period 2001–2002, more than half of new firm formations were spin-offs from research centers or universities, reaching 66 percent in 2003.[34] In 2004, this figure fell to 50 percent.[35] The country is home to almost 400 core biotech companies.[36]

As of 2004, Victoria had a total of 84 patents, with research and investment partnerships totaling $120 million.[37] University research commercialization case studies follow.[38]

- *Colony Stimulating Factors*: Prominent among Victoria's contributions to biotech and medicine are colony stimulating factors (CSFs), now in worldwide use for protecting cancer patients from bone marrow damage caused by high-dose chemotherapy. Melbourne's AMRAD Pharmaceuticals markets its G-CSF products as Granocyte. G-CSF and GM-CSF were discovered by Professor Donand Metcalf and his team at Melbourne's Walter and Eliza Hall Institute of Medical Research. Professor Metcalf received the Victoria Prize for scientific R&D by the Victorian Government in August 2000.

- *Bionic Ear Technology*: An Australian company is the global leader in "bionic ear" (cochlear implant) technology. The "bionic ear" helps people who gain little or no benefit from hearing aids. The technology originated from the work of Professor Graeme Clark and his team at the University of Melbourne in the 1970s. Further work continues at the Bionic Ear Institute and the Cooperative Research Centre for Cochlear Implant and Hearing Aid Innovation.

- *Relenza*: Relenza, an inhaled treatment, is used to treat influenza. Research conducted by the Biomolecular Research Institute (affiliated with the Commonwealth Scientific and Industrial Research Organisation) in Melbourne solved the crystal structure of the influenza enzyme. Subsequent complementary work at Monash University's Victorian College of Pharmacy achieved chemical synthesis of neuraminidase inhibitors. Biota Holdings Ltd., established in 1985 to fund human pharmaceutial R&D, provided funding to the project. In 1990, Biota made an agreement with Glaxo Wellcome (now GlaxoSmithKline) to develop Relenza. The first manufacturing facility for Relenza opened in Melbourne. Relenza, launched in Australia, received EC and USFDA regulatory approval in 1999.

Australia has also been successful in the development of clinical trial research. A 2004 KPMG report, "Competitive Alternative," ranks Australia third worldwide in terms of cost of conducting clinical trials.[39] The country ranks as more cost-effective for biomedical R&D than the United Kingdom, the United States and Germany, especially for salaries, utilities and income tax.[40]

Endnotes:

1. Ranked against Germany, India, Japan, Singapore, the U.K. and the U.S. Economist Intelligence Unit. September 2005. *Benchmarking Study of the Characteristics of the Australian and International Pharmaceuticals Industries,* a study undertaken for the Australian Department of Industry, Tourism and Resources, Invest Australia and the Victorian Government Department of Innovation, Industry and Regional Development.
2. Bio 2005 Country Profiles. See: www.bio.org/events/2005/international/CountryProfiles.
3. Hopper, Kelvin and Lyndal Thorburn. "2005 Bio-Industry Review," Innovation Dynamics Pty. Ltd.
4. Biotechnology Australia. 2004. "Industry and Research."
5. AusIndustry. An Australian Government Initiative. See: http://www.ausindustry.gov.au.
6. The Allen Consulting Group. 2003. "The Economic Impact of the Commercialisation of Publicly Funded R&D in Australia," prepared on behalf of the Australian Institute for Commercialisation. See also: Ramussen, Bruce. 2004. "The Biomedical Sectors in Australia and Canada: Comparative Policy Analysis." Pharmaceutical Industry Project WP.
7. Ramussen, Bruce. 2004. "The Biomedical Sectors in Australia and Canada: Comparative Policy Analysis." Pharmaceutical Industry Project WP.
8. http://www.biofirst.nsw.gov.au/.
9. Spruson and Ferguson (2005, May 10). *Building a Stronger Biotech Sector*.
10. Biotechnology Australia. 2004. "Industry and Research."
11. http://www.biotechnology.gov.au/content/controlfiles/.
12. Backing Australia's Ability. An Australian Government Initiative. See: http://backingaus.innovation .gov.au.
13. Australian Government. Department of Industry Tourism and Resources. "Global Partners." Australia Biotechnology 2004.
14. Australian Bureau of Statistics. Catalogue No. 8112.0.
15. Spruson and Ferguson. 2005.
16. Economist Intelligence Unit. 2005.
17. Porter, Michael, K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004. "The Global Competitiveness Report 2004-2005," World Economic Forum.
18. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report.*
19. Australian Government. Department of Industry Tourism and Resources.
20. Spruson and Ferguson. 2005.
21. Bio 2005. "Biotech Down Under," Invest Australia.
22. Economist Intelligence Unit. 2005.
23. Australian Government. Department of Industry, Tourism and Resources.
24. Bio 2005.
25. www.biotechnology.vic.gov.au/news/article.asp?id=234 See also: Hopper and Thorburn. 2003. "Bio-Industry Review: Australia and New Zealand."
26. State Government of Victoria. Department of Innovation, Industry and Regional Development. 2004. *Biotechnology. Strategic Development Plan for 2004.*
27. Ibid.
28. Hopper and Thorburn. 2003.

29. www.biotechnology.vic.gov.au/news/article.asp?id=234.
30. A web-based AUTM-style questionnaire by Australia's Department of Education, Science and Training. 2004.
31. Spruson and Ferguson. 2005.
32. http://www2.agsm.edu.au/agsm/web.nsf/Content/News-MediaReleases-AGSM-USYDLaunchDualMBA-MBBS.
33. Australian Department of Education, Science and Training. 2004.
34. Hopper, Kelvin and Lyndal Thorburn. *2005*.
35. Economist Intelligence Unit. 2005.
36. Bio 2005.
37. State Government of Victoria. Department of Innovation, Industry and Regional Development. 2004. *Biotechnology: Strategic Development Plan for 2004*.
38. http://www.business.vic.gov.au/BUSVIC/STANDARD/PC_50848.html. See also: http://www.science.org.au/nova/013/013key.htm; http://www.bionicear.org/bei/overview.html; and http://www.monash.edu.au/.
39. BioInnovationSA. Industry Alternatives. http://www.bioinnovationsa.com.au/research_capabilities.htm.
40. http://www.bio.org/events/2005/international/CountryProfiles.

China

1. National Innovation Policy

China's innovation policy has its roots in the Russian system, where R&D was efficient and state-driven. Science and technology outputs were freely transferred from public institutions to state-owned enterprises, resulting in few market incentives to push R&D beyond the status quo. Structural reforms initiated in 1985 introduced changes to open the economy.[1] In this regard, China has made considerable progress.

In the early 1980s, China initiated a national biotechnology program.[2] Development of nanotech began in 1990, with a 10-year project to support nanomaterial research[3] several years before the U.S. Nanotech Initiative in 2000.[4]

The country's patent system was inaugurated in 1978, and a national patent office was created in 1980.[5] China enacted its first patent law in 1985 and has revised it twice to adapt to market changes, such as permitting the patenting of pharmaceuticals.[6] Also in 1985, China introduced its first National Biotechnology Development Policy for the five-year plan beginning in 1986, under the Ministry of Science and Technology (MOST), the State Development and Planning Commission (SDPC) and State Economic Commission.[7]

The Natural Science Foundation of China, established in 1986, supports basic research.[8] It comprises seven academic departments, four bureaus and one administrative office, with the Department of Life Sciences the largest.[9] Also in 1986, the High Technology Research and Development Plan (863 Plan) was approved, with an allocation of 10 billion RMB spanning 15 years to promote high-tech R&D.[10] The development plan received a total biotechnology budget of about 1.5 billion RMB from 1986 to 2000.[11] The program continued after 2000 and, as of 2002, had produced 1,408 graduates, 3,228 published papers and 657 patents applied for in biotech and agriculture.[12] However, these outputs have not placed Chinese universities high in global biotech rankings. The foundation's first biotech project got under way in 2000, with $14.5 million in funding.[13]

The National Basic Sciences Initiative was introduced in 1997, with a total budget of $302 million in the five-year period 1997–2002. The plan prioritized biotechnology and complemented the 863 Plan, as well as other national initiatives.[14]

In its Ninth Five-Year Plan (1996–2000), China provided financial and policy support to build institutions and research in health biotech, implementing in 1999 the Special Project on Biotechnology.[15] In 2001, the State Council, capitalizing on its longstanding strength in agriculture,[16] passed a new Agricultural Science and Technology Development Compendium, leading to a proposal for further increases in the biotech R&D budget for the Tenth Five-Year Plan (2001-2005), exceeding previous budgets since 1985.[17]

Following China's accession to the WTO in 2001, the country has worked to implement the Trade-Related Aspects of Intellectual Property Rights agreement[18] and increase IP protection. In April 2002, in a bid to address international concerns, a guideline list for foreign investment was issued to prohibit genetically modified organisms as a "prohibited area for foreign investment."[19]

Enforcement of China's Patent Law has led to a growth in patent applications. As of March 2004, China's general patent filing volume exceeded 2 million.[20] Biotech patents granted increased by about 20 percent each year from 1992, to more than 3,000 in 2002. Overall, the growth rate of foreign filings was higher than the rate for domestic filing,[21] suggesting the increasing international recognition of China's market.

In less than two decades, China initiated the decentralization of authority, introduced market competition and boosted scientific innovation through market-based incentives. But universities remain highly centralized, with hampering bureaucracies and little incentive to promote research and commercialization of biotechnology.[22]

China's large patient population is seen as a means of outsourcing clinical trials.

Inter-organizational linkages are inadequate to facilitate effective university tech transfers because of weak IP protection.[23] As such, universities may implement new technologies on their own, despite lower potential returns, instead of commercializing them. This is aggravated by China's long history of centralized and functional institutional makeup.[24] It also may explain the lack of global recognition of biotech R&D in China, since innovations are less likely to be publicized and commercialized widely.

Change is under way. The country's State Food and Drug Administration, modeled after those in the United States and Europe, is consolidating the industry to improve quality standards "by requiring Chinese manufactures to obtain Good Manufacturing Practice certifications, and wholesalers and retailers to obtain Good Supply Practice certifications."[25] Reform efforts are allowing universities to pursue revenue-generating activities besides education. Since the early 1990s, the Ministry of Education has promoted masters, graduate and post-graduate programs at many universities.[26]

2. Funding and Venture Capital

Since its establishment in 1986, the National Science Foundation has seen its budget increase to more than $1.5 billion by 2000. Between 1996 and 1999, the Department of Life Sciences funding totaled $1.23 billion.[27] More recently, from 2001 to 2004, university life-sciences support increased annually, from $24.7 million in 2001 for 1,154 projects to more than $56 million in 2004 for almost 2,400 projects.[28]

Despite annual increases, biotech R&D in China is limited by a lack of comparable funding to the United States. The scientific research outlay of China was half that of the U.S. National Institutes of Health's $27 billion in 2003. In the same year, China's expenditure in life-sciences basic research accounted for just 0.02 percent of GDP, compared to 0.3 percent in the United States. China also lacks industrial and private foundation funding.[29]

Biotech research at universities and public research institutes is growing. But according to an article in *Nature Biotechnology*, "the government's growing interest in the field has not translated into boundless opportunities for biotech entrepreneurs." State-owned firms and VCs lack experience judging potential investments and remain reluctant to support risky startups.[30] Venture capital funding in China tends to be low, averaging $1.2 million per project as of 2004,[31] and favors traditional sectors.[32] There are also difficulties for funds syndication — "funds financed by a given district cannot syndicate with funds that will be invested in a company located in another district," according to the article.[33]

> The China Venture Capital Association has 50 VC companies, with a total of $40 billion, under management. It looks to Chinese universities for technology to launch spin-offs. The prestigious Tsinghua University provides both technology and some investment funds.

The 2005 UNCTAD *World Investment Report* finds that investments by private equity and VC funds, especially from the United States, are important sources of foreign investment in China. "There are large differences in countries' capabilities to innovate and benefit from the R&D internationalization process," notes the report. "According to a new measure of national innovation capabilities . . . the differences appear to be growing over time. . . . Developed countries fall into the high capability group, as do Taiwan Province of China, the Republic of Korea and Singapore."[34] Beijing, Shanghai, Guangzhou and Shenzhen account for 85 percent of all R&D units set up by foreign companies, mainly because they are close to local universities and research institutions.[35] "China is the destination mentioned by the largest number of respondents for future R&D expansion, followed by the United States," the report states.

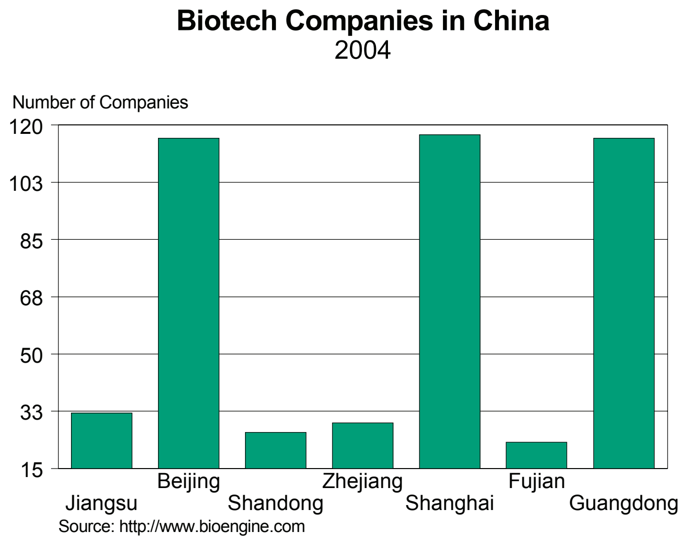
Statistics and data in China sometimes conflict. The research of Luyang Zhang finds a total of $3.6 billion in VC invested in China. Of this, 20 percent is in biotech, and half of that is in R&D.[36] "Until recently, foreign VC investors have been deterred by the fact that they could not get their profit out of China because of the money-exchange controls."

Biotech activities are highly concentrated: approximately one-third of the provinces account for 75 percent of the country's R&D expenditures.[37] Important drivers of biotech in Shanghai and Sichuan provinces are state-owned firms, such as Shanghai VC Corp., Shanghai Alliance Investment Ltd. and Chengdu VC Company Ltd.[38]

3. Clusters of Biotechnology

China's biotech industry is developing rapidly. In 1985, its revenue stood at $88.4 million, and by 2000 the sales had climbed up to $2.42 billion.[39]

In 2002, some 300 biotech companies were in operation, with most working in health care and agriculture. About half were small- and medium-sized enterprises, established between 1997 and 2002. Most had not yet grown or achieved significant profitability.[40]



More than 20 biotech parks were in existence by 2004, with the highest concentration of companies in Shanghai, Beijing and Guangzhou. Plans are also under way to develop Hangzhou, Zhejiang Province and Pudong, Shanghai, as hubs for the industry.[41] The budget for Zhongguanchun Life Science Park is estimated to double in the next five years, to $3 billion.[42]

4. Technology Transfer Mechanisms

China's universities and research institutes had spawned a third of the country's high-tech firms in 1992. Two years later, the total was more than 1,700 ventures, several of which compete internationally.[43] However, university-business links remain undeveloped. In addition to policy inadequacies, information is not shared among institutions, leading to overlapping R&D on similar products.[44] There also remains a lack of conviction that Chinese drugs are comparable to international ones.[45]

China uses large multinational enterprises (MNEs) to advance biotech commercialization. Notable MNEs manufacturing in China include: Pfizer, Merck, GlaxoSmithKline, Astra Zeneca and Roche. Some have established research institutes in China.

WuXi PharmaTech, China's leading chemistry-based pharmaceutical R&D service company, ranked ninth in Deloitte's 2004 Asia Pacific Tech Fast 500. Dr. Ge Li, Chairman and CEO of WuXi PharmaTech, described the company as "the bellwether in China's fast-growing R&D services industry." He predicted that the "privatization of hospitals is coming, which will open a major market for pharmaceuticals in China."

The government is encouraging its universities to invest heavily in stem cell research, thereby attracting not only public funds, but industrial support from companies like Beijing Stemcell Medengineering.

For years, Chinese universities have had the official authority to patent, license and collect royalties from work-related inventions by their faculty. However, it is only recently that they began to assert these rights. Leading universities are now establishing OTTs and requiring professors to report their scientific discoveries. Scientists receive a minimum of 20 percent of the royalty revenues resulting from the commercialization of their research. In addition, if after a year the OTT has been unsuccessful in licensing an innovation, the rights revert to the inventor.[46]

By 2001, China had established state tech transfer centers in six universities: Beijing's Tsinghua University, Shanghai Jiaotong University, Xi'an Jiaotong University, East China University of Science and Technology, Central China University of Science and Technology, and Sichuan University.[47] "Nearly two-thirds of China's large and medium-sized enterprises have no research and development institutes, and only 30 percent of the 30,000 technological achievements are being used commercially, with only 10 percent of those on large scale," according to a statement from Tsinghua University.[48]

5. Commercialization Success: Patents and Licensing

China is the only "developing country participating in the international human genome project."[49] It is also the first country to locate and clone the gene causing high-frequency nerve deafness and some genes causing hereditary diseases. Tsinghua University filed six biotech patent applications from 2000 to 2005.[50]

In 1997, the Chinese Ministry of Education reported that 1,300 applications were filed nationwide on university inventions, and 800 patents were issued. In 1998, 1,450 applications were filed, with 900 patents issued. By 1998, about 530, or approximately 28 percent, of the available pool of inventions had been licensed or assigned. "Most licenses are non-exclusive," a University of Tokyo study reports. "In the case of inventions made under sponsored-research agreements with companies, the sponsoring company has a guaranteed, royalty-free, non-exclusive license. The company can contract with the university for outright assignment even before filing a patent application; however, the university must receive some benefit under such an agreement. … If the sponsor or prospective licensee is foreign, special administrative approval is needed."[51]

International cooperative strategic alliances overcome some of China's regulatory hurdles. "In July 2004, for example, Beijing-based Starvax in-licensed the DNABarrier II technology from Mologen," a German DNA-based vaccine and therapeutics company.[52]

Sinovac Biotech Ltd.

Sinovac is one of the leading emerging biotechs in China, specializing in the development for vaccines against such infectious diseases as hepatitis A and B, SARS and influenza. In December 2004, Sinovac Biotech entered into an agreement with China's Center for Disease Control to co-develop an avian flu vaccine. Under the terms of the agreement, the commercial rights are to be owned by Sinovac. Weidong Yin, President, CEO and Co-founder of Sinovac, is credited with developing the IP rights that led to the development of Sinovac's Hepatitis A Vaccine.

Endnotes:

1. Motohashi, Kazuyuki and Yun Xiao. 2005.
2. Ministry of Science and Technology. 1990, 2000. State Science and Technology Commission.
3. Bai, C. J. *Nanoparticle*. 2001. Res. 3, pps. 251–256.
4. Hsiao, James C. and Kenneth Fong. 2004. "Making Big Money from Small Technology." See: http://www.nature.com/nature/journal/v428/n6979/full/428218a.html.
5. Li, Zhenzhen, J. Zhang, K. Wen, H. Thorsteinsdottir, U. Quach, P. Singer and A. Daar. 2004. "Health Biotechnology in China — Reawakening of a Giant," *Nature Biotechnology*, 22 Supplement.
6. Ibid.
7. Huang, Jikun and Qinfang Wang. 2002. "Agricultural Biotechnology Development and Policy in China." Chinese Academy of Sciences. *The Journal of Agrobiotechnology and Economics*, 5(4).
8. Ibid.
9. Ye, Xinsheng. 2000. "An Overview of Funding to the Biomedical Research in China via the Department of Life Sciences, NSFC." *U.S–China Forum on Biotechnology and Biomedicine.* Fogarty International National Institutes of Health Bethesda, Md. Dec. 4–5, 2000. Conference Proceedings.
10. Huang, Jikun and Qinfang Wang. 2002.
11. Ibid.
12. High Technology Research and Development Program in China. *Annual Report 2002*. See: http://www.863.org.cn/english/annual_report/annual_repor_2002/annual_repor_2002.pdf.
13. Huang, Jikun and Qinfang Wang. 2002.
14. Ibid.
15. Development Bureau of High-Tech Industry of the National Dev. Program Committee, Society of Bio-Engineering of China. 2003. *Report of the Development of Bio-Tech Industry in China*. 2002. Chemical Industry Press, Modern Bio-Technology and Medical Science and Technology Centre, Beijing.
16. http://www.index-china.com/index-english/agr-s.html.
17. Huang, Jikun and Qinfang Wang. 2002.
18. Li, Zhenzhen, J. Zhang, K. Wen, H. Thorsteinsdottir, U. Quach, P. Singer and A. Daar. 2004.
19. Huang, Jikun and Qinfang Wang. 2002.
20. http://www.china.org.cn/e-white/20050421/II.htm.
21. http://www.most.gov.cn/English/newletter/q362.htm.
22. Li, Zhenzhen, J. Zhang, K. Wen, H. Thorsteinsdottir, U. Quach, P. Singer and A. Daar. 2004. See also: "China's Biotech Experiments." *Nature Biotechnology.* 2005. 23(12), December. www.naturepublishinggroup.com.
23. National Science Foundation, Tokyo Regional Office. 2001.
24. Ibid.
25. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report*, "Health Sciences."
26. National Science Foundation, Tokyo Regional Office. 2001.
27. Ye, Xinsheng. 2000.
28. http://www.nsfc.gov.cn.
29. Wu, Jiaxi. "Biotechnology Innovation System in China: Development and Challenges," School of Economics and Management, Tsinghua University, Beijing. See: http://www.globelics-beijing.cn/paper/ Jiaxi%20Wu_biotechnology% 20innovation%20system%20in%20china.pdf.
30. Jia Hepeng. "China's Biotech Experiments." BioEntrepreneur. Published online Oct. 6, 2005. http://www.sibiono.com/uploadfile/20051012.pdf.
31. Louët, Sabine. 2004. "Can China Bring its own Pipeline to the Market?" news@nature.com. Nature Biotechnology. See: http://www.nature.com/news/2004/041206/pf/nbt1204-1497_pf.html#B3.
32. Liu, J.L. 2003. *BioEntrepreneur.*

33. Louët, Sabine. 2004.
34. UNCTAD World Investment Report. "Transnational Corporations and the Internationalization of R&D: Overview." See: http://www.unctad.org/en/docs/wir2005overview_en.pdf.
35. Zhang, Yanzhong. 2005. "Globalization of R&D: new trend of economy globalization." Paper presented at UNCTAD Expert Meeting on FDI and Development, Geneva, 24–26 January.
36. Louët, Sabine. 2004.
37. Nilsson, Anna, Henrik Fridén and Sylvia S. Serger. 2006. *Commercialization of Life-Science Research at Universities in the United States, Japan and China.* Swedish Institute for Growth Policy Studies.
38. Ernst & Young. 2005. *Beyond Borders*.
39. Wu, Jiaxi.
40. Ibid.
41. Ibid.
42. From Bio 2005 notes. Wallace.
43. National Science Foundation, Tokyo Regional Office. 2001.
44. Wu, Jiaxi.
45. Louët, Sabine. 2004.
SSTI Weekly Digest. 2004.
46. Kneller, Robert, Professor of the Research Center for Advanced S&T, University of Tokyo. "Ownership Rights to University Inventions in Japan and China." See: http://www.law.washington.edu/casrip/ Symposium/Number5/pub5atcl18.pdf.
47. http://news.tsinghua.edu.cn/eng__news.php?id=105.
48. Ibid.
49. Wu, Jiaxi.
50. Marks & Clerk. 2005. *Biotechnology Report.*
51. Kneller, Robert.
52. Ernst & Young. 2005. *Beyond Borders*.

Hong Kong Special Administrative Region (HKSAR)

1. National Innovation Policy

The transfer of Hong Kong Special Administrative Region (HKSAR) from British rule to Chinese governance in 1997 has influenced the direction of policy in Hong Kong, as have China's 2001 accession to the WTO and subsequent exponential growth in key regions and industries. Competitiveness is built upon its international reputation for the respect of intellectual property rights and its comprehensive legal framework.[1] But Hong Kong is relatively weak in R&D capability, particularly compared with its well-established economic system.

Biotechnology initiatives began in the late 1980s, in response to strong requests from faculty at the Chinese University of Hong Kong.[2] In 1992, the government set up a Biotechnology Committee to maintain close relationships with research institutes and business organizations.[3] By 2000, an Innovation and Technology Commission was created to promote and support applied R&D, technology transfer and application.[4] The commission also manages the Innovation and Technology Fund, and supports infrastructure projects, including Hong Kong Science Park[5] and the Hong Kong R&D Centre Programme. One of the program's newest centers focuses on nanotechnology.

In 2004, a Steering Committee on Innovation and Technology was established to "coordinate implementation of innovation policies and facilitate cooperation."[6] InvestHK led a campaign to attract foreign direct investment, particularly from high-tech companies.[7]

Hong Kong's technology and innovation policies reflect a positive, noninterventionist approach, a nondiscriminatory low-tax regime with minimal government investment in biotech innovation.[8]

2. Funding and Venture Capital

Biotechnology R&D is largely government-funded through the Innovation and Technology Commission to three universities: the University of Hong Kong (HKU), the Chinese University of Hong Kong (CUHK) and the Hong Kong University of Science and Technology (HKUST).[9] In 1993, the Industrial Support Fund (ISF) was initiated. Its biotech R&D funding totaled approximately $660 million in 1995, increasing to $2.9 billion in 1998 but decreasing to about $900 million in 2000. There was a corresponding decrease in the number of biotech projects funded. In 2000, the government replaced the ISF with the Innovation and Technology Fund (ITF) and allocated $642 million to support applied R&D. [10] As of February 2005, the ITF spent $164 million on 257 projects, more than $15 million (9 percent) to support 25 biotech projects.[11] Between 1999 and 2004, the ITF spent less than $200 million on biotechnology.[12] As of July 2005, the ITF provided only minor support for 17 university-industry collaboration programs: $29.1 million in biotech and one $1.5 million project in nanotechnology. [13]

In 2005/2006, the University Grants Committee awarded Competitive Earmarked Research Grants to 69 biotech projects, with a total funding of only $10 million.[14] The Research Grants Council provided initial funding, in the form of individual grant monies, for nanotechnology research at the Hong Kong University of Science and Technology, which opened its Institute for Nano Science and Technology in 2001.[15]

The government also sponsors the Applied Research Fund (ARF), which invests in technology ventures and commercially promising R&D projects. With capital of HK$750 million, the fund has been managed by two private-sector VCs since 1998. As of July 2004, the ARF supported 23 projects with $49.3 million[16] — but just 3 percent was allocated to biotechnology R&D.[17]

3. Clusters of Biotechnology

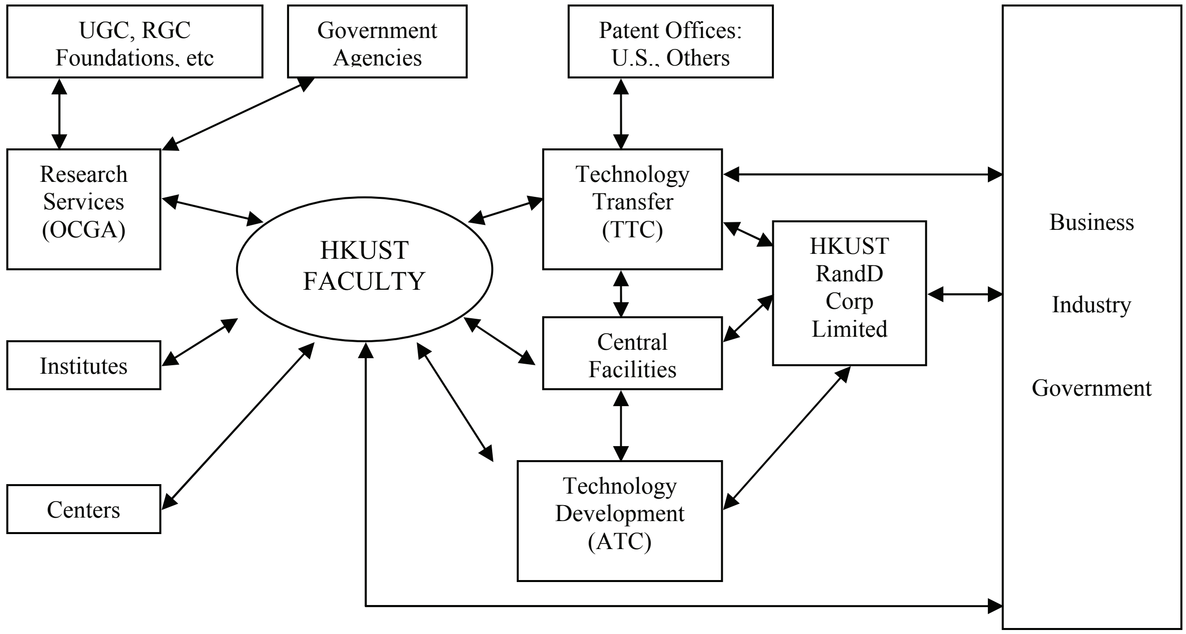
In May 2001, the government established the Hong Kong Science and Technology Parks Corporation (HKSTPC) to nurture clusters by providing infrastructure support to R&D for technology-based enterprises. The first phase of construction at Science Park, completed in late 2004, offers shared facilities for R&D in genomics, bioinformatics and therapeutics, as well as diagnostics, devices and traditional Chinese medicine. In addition, the science park corporation oversees developed land at three other sites for innovative manufacturing and services companies.[18]

The HKSTPC, although a significant initiative to nurture clusters, has mainly focused on studying the sector, instead of promoting R&D.[19] It has 15 biotech-related tenants, including the Hong Kong Jockey Club Institute of Chinese Medicine.[20] Phase II construction began in mid-2005.

4. University Technology Transfer Mechanisms

Although Hong Kong's universities tend to hold themselves aloof from the industrial sector,[21] the three leading universities — the University of Hong Kong (HKU), the Hong Kong University of Science and Technology (HKUST) and the Chinese University of Hong Kong (CUHK) — have tech transfer offices. In 1998, HKU set up a company, Versitech Limited, to act as its commercialization arm. The CUHK uses the Information Technology Entrepreneur Programme as a pre-incubator, government and industry funding, as well as the university's own resources.[22] At HKUST, RandD Corp. Ltd., a wholly owned company, began tech-transfer operations in 1993 to help with contract R&D, licensing, project management, and legal and business issues.[23]

HKUST has a faculty-driven OTT (see the following diagram). The R&D branch supports innovation through its tech transfer center, office of contract and grant administration, and applied technology center. Various biotech-related research institutes include: the Biotechnology Research Institute; the Institute of Integrated Micro Systems; the Institute of Nano Science and Technology; and the Institute of Nanomaterials and Nanotechnology (founded June 2003). The R&D Branch also operates the HKUST RandD Corp., created in 1993 to commercialize university research.[24]



Source: Hong Kong University of Science and Technology

5. Commercialization Success: Patents and Licensing

In 2003, 188 patents, agreements, assignments and companies were generated from the eight universities in the Hong Kong region.[25]

The Royal Hong Kong Jockey Club Trust funded construction of the Hong Kong Institute of Biotechnology and the Biotechnology Research Institute in 1988. The former is a subsidiary of the Chinese University of Hong Kong and provides incubator facilities for biotech startups. The latter focuses on biotech R&D, emphasizing traditional Chinese medicine (TCM). In 2005, the ITF and Hong Kong Jockey Club collaborated to donate approximately $65 million to support R&D in traditional medicines.[26] Among the three key universities, HKU and CUHK have programs (although limited to bachelor degrees) on TCM.[27] (Traditional Chinese medicine differs from conventional western medicine in its personalized techniques and use of drug combinations. As such, its clinical trials do not conform to international standards and tend not to be protected through patent filing.)

Using funding from the Industrial Support Fund, the Biotechnology Research Institute supports research in "molecular biology and micro-fabrication to develop gene-chip manufacturing capabilities at Hong Kong's University of Science and Technology."[28] The gene chip enhances the medical potential and commercialization of traditional Chinese medicine.[29]

Data from the Hong Kong University Grants Committee indicate that the University of Hong Kong led other institutions in 2002 and 2003 for biology and medical research outputs, and referred research outputs in both 2002 and 2003. However, the Chinese University of Hong Kong, which placed second in these categories, ranked first for the number of biology and medical prizes and awards received during those years. In 2004, HKU had 1,487 full-time-equivalent research postgraduate students enrolled (about $325 million in research grants were received); CUHK had 1,210 such students ($193 million research grants received), with Hong Kong University of Science and Technology recording 901 ($188 million in research grants received).

Endnotes:

1. Wu, C.T. 2000. "Diaspora Capital and Asia Pacific Urban Development." Bridge, G. and S. Watson, (eds.). *A Companion to the City*, Oxford: Blackwell Publishers.
2. Baark, Erik. 2005. "Innovation Policy Forensics: An Analysis of Biotechnology in Hong Kong." Paper presented at the DRUID Tenth Anniversary Conference on Dynamics of Industry and Innovation: Organizations, Networks and Systems in Copenhagen, Denmark, June 27–29.
3. Ibid.
4. http://www.itc.gov.hk/ and http://www.innotech.gov.hk/en/inno_forces/file_manager/doc/ InsertR&DOutput.pdf.
5. Baark, Erik. 2005.
6. "Hong Kong: The Facts." See: http://www.info.gov.hk/hkfacts/tech-e.pdf.
7. Baark, Erik. 2005.
8. Wong, Perry and Lorna Wallace. Jan 2005. "Achieving Long-term Competitive Advantage. The Role and Prospects for the HKSAR Economy." Santa Monica: Milken Institute, White Paper.
9. Cyranoski, David. 2001. "Hong Kong: Putting the Pieces Together." July. See: http://www.nature.com/ naturejobs/2001/010726/full/nj6845-04a0.html.
10. Baark, Erik. 2005.
11. http://www.itc.gov.hk/.
12. Baark, Erik. 2005.
13. http://www.itc.gov.hk/.
14. http://www.ugc.edu.hk/eng/.
15. http://instweb.phys.ust.hk/.
16. Hong Kong: The Facts.
17. Baark, Erik. 2005.
18. http://www.itc.gov.hk/en/area.bio.htm.
19. Global Bio-Clusters. 2003. BioSpectrum, Aug. 12. www.biospectrumindia.com.
20. Hong Kong Development and Trade Office in San Francisco. Nov. 5, 2004. http://www.hongkong.org/ehongkong32/sciencepark.htm.
21. Berger, S. and R. Lester. 1997. *Made by Hong Kong*. Hong Kong: Oxford University Press. See also: Enright, Michael J., Edith Elizabeth Scott and David Dodwell. 1997. *The Hong Kong Advantage*. Hong Kong. New York: Oxford University Press.
22. http://www.cuhk.edu.hk/ipro/000526e.htm.
23. http://www.ust.uk/˜webvprdo/corp.html.
24. www.ust.hk/.
25. www.ugc.edu.hk.
26. Baark, Erik. 2005.
27. HKUST Library. http://library.ust.hk/guides/tcm/tcm-centers.html.
28. Development of Molecular Biology and Biotechnology in Asia and the Pacific Rim. 2000. Asia-Pacific IMBN 2000.
29. "Genechip Technology Enables Fast Track Chinese Medicine Identification." June 5, 2001. http://www.ust.hk/~webopa/news/2001_News/news0605.html.

India

1. National Innovation Policy

India announced a major push into biotechnology in 1982 with the creation of the National Biotechnology Board, using input and financial support from all of the country's science and technology organizations.[1] Four years later, the board had grown into the national Department of Biotechnology (DBT), under the Ministry of Science and Technology. The DBT oversees India's biotech policy, research and development, international cooperation efforts and manufacturing.[2]

Increased globalization triggered liberalization and privatization in India in the early 1990s, and India's Parliament enacted the Competition Act in 2002, which bars anti-competitive market practices and exercises oversight of monopolies and partnerships in order to discourage abuse.[3] The country's policies invite foreign direct investment as long as the firms are registered in India.

In response to its vision as a global competitor in biotech, there is growing compliance in India with international standards, including the WTO's Trade-Related Aspects of Intellectual Property Rights agreement. "However," notes a recent OECD study, "despite two revisions of the 1970 Indian Patents Act and accession to the Budapest Treaty (on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure) in 2001, there is a lack of clarity on the patentability of biotechnology inventions," chiefly because neither the treaty nor India, nor the WTO's intellectual property agreement known as TRIPS (Trade Related Aspects of Intellectual Property Rights), has come up with a definition for "microorganism." [4]

In 2005, the Department of Biotechnology published a review of national policies. Acknowledging the need for India to improve, among other things, its university and postgraduate programs in the life sciences and devote more resources to training, IP and regulatory issues, the report also called for: the institution of a "Bio-edu-Grid" and databases linking universities (within India and abroad) and the private sector; flexibility for academic researchers to work in the private sector to commercialize their research efforts; the creation of "several technology transfer cells (TTCs)" that would each "service a cluster of institutions in a region or a large city"; increased tax exemptions for research and development; and a mechanism to facilitate biotech business loans. In addition, the review calls for the greater promotion of trade partnerships and increased support for incubators and 10 biotech parks.[5]

Several positive changes are already in effect:

- A scientific advisory council to the prime minister has been established.[6] Phase I and II global clinical trials are permitted on a case-by-case basis. Previously, only molecules developed in India were permitted to undertake clinical trials locally, thus leading to a phase lag for drug companies based abroad.[7]
- Under the Foreign Trade Policy 2004–2009, benefits enjoyed by Export Oriented Units are passed on to biotech parks, and firms located in biotech parks are allowed to retain 100 percent of export earnings.[8]
- One hundred percent of foreign equity investment is possible in almost all biotech sectors.[9] Foreign firms are also exempt from income taxes.

The Indian government currently provides incentives for biotechnology R&D investment. These include fast-track clearance for foreign direct investment, 100 percent rebate on privately funded R&D expenditures and 25 percent rebate if research is contracted in publicly funded R&D institutions.[10] Researchers and entrepreneurs may currently transfer technology to a third party for commercialization on an exclusive or non-exclusive basis. However, "the third party, exclusively licensed to market the innovation in India, must manufacture the product in India."[11]

India boasts strengths in its appreciation of American and European business norms, and in its reduced costs of discovery and development. Enforcement for the government's regulatory and inspection systems, which govern all businesses of more than 10 employees, generally comes under the discretion of the Indian states, which is the cause of some concern. "In India, as in many other developing countries," notes a 2005 World Bank policy paper, "individual government officers seem to have considerable discretion in deciding which rules to enforce. … In many cases, inspection visits are arbitrary or excessive, and are viewed by business owners as punitive or a veiled demand for bribes."[12]

"The Indian pharmaceutical market is the world's 13th largest in terms of value and the fourth largest in terms of volume," according to India's *Economic Times*.

Bioinformatics is a major focus of India's strategic biotech policy, and the DBT envisions positioning India as a "key international player in the field of bioinformatics; enabling a greater access to wealth of information created during the post-genomic era." Consequently, "India was the first country in the world to establish, in 1987, a Biotechnology Information System (BTIS) network to create an infrastructure that enables it to harness biotechnology." Biotechnology centers in the system grid now number 61.[13] Considerable resources exist within the network — databases, software, educational packages and personnel — and India has either set up, or is in the process of setting establishing, connectivity with similar bioinformatics centers in China, Indonesia, the Philippines, Thailand, Vietnam, Malaysia, the Maldives, Israel, Poland and Turkey. The 2005 national policy review acknowledged challenges in the areas of training and advanced university coursework, skilled human capital and the need for improved basic infrastructure, as well as supercomputer facilities.

Another government agency, the Indian Council of Medical Research (ICMR), works with 21 regional research facilities and six medical centers, and supports and coordinates biomedical research focusing on national health priorities. Likewise, the Council for Scientific and Industrial Research (CSIR), though not limited to oversight of biotechnology, coordinates support among 40 research institutes and "oversees several health biotechnology projects, including the application of molecular techniques to drug target and predictive marker discovery."[14]

India has 28 states and seven union territories governed by the central government. Each has its own science and technology council, as well as a department of science and technology.[15]

2. Funding and Venture Capital

Despite increases in India's biotech funding, figures remain low, compared to other nations. The 2003 budget allocations of the government's Department of Biotechnology totaled approximately $51 million. The DBT increased its funding from 1988 to 2003 at an annual rate of 12.5 percent, with reported growth from 2002 to 2003 of 26 percent.[16] However, government grants "tend to be small" and are earmarked for public institutions rather than private projects.

"About 85 percent of the funds for S&T come directly or indirectly from the government," notes the Embassy of India. "The S&T infrastructure in the country accounts for more than one percent of the GNP."[17]

State governments are setting up their own biotech development budgets and funds.[18]

> While China has outperformed India in terms of foreign investments, India outperforms China when it comes to returns on investments. The average Indian company posted a 16.7 percent return on capital in 2004, according to *Business Week*, compared to 12.8 percent for the average company in China.

The 2004 *Global Competitiveness Report* ranks India 28th for venture capital availability. There are almost 70 VC funds operating in India, which have $5.6 billion in assets under management. The biotech commitments come from leading public-sector banks and private VC firms, as well as agencies like the Technology Development Board. The Andhra Pradesh Industrial Development Corporation (Venture Capital Ltd.) and the Small Industries Development Bank of India are among the leading biotech funds, with market shares of 14 percent and 9 percent, respectively. Among the other leading venture capital funds are IL&FS Venture Corporation Ltd. and Walden International, which have identified biotechnology as a key area for investment. There are several other financial agencies with limited funds marked for biotech, including Kerala VC, Karnataka State Industrial Infrastructure Development Corp., Canbank VC, Chrys Capital Fund II, LIC, ICF Ventures, IFCI VCs and IndAsia Fund Advisors Pvt.[19] Two prominent VC firms, Morgan Stanley and the Industrial Credit and Investment Corporation of India, are fairly active.

SMEs have traditionally relied much more on debt financing than their counterparts elsewhere. However, the shrinkage of India's bank and non-bank financial institutions, in response to policy and regulatory changes since 1997, has limited the availability and increased the cost of debt financing to Indian entrepreneurs.[20]

3. Clusters of Biotechnology

Biotechnology activities are concentrated in the states of Andhra Pradesh, Karnataka, Maharashtra, Punjab, Uttar Pradesh, Rajasthan, Gujarat, Tamil Nadu and Kerala.[21] In Andra Pradesh, India produced the world's first locally developed hepatitis B vaccine, through a public-private partnership originating in Hyderabad.[22] The state's Genome Valley became "the first state-of-the-art biotech cluster in India for life-science research, training and manufacturing," and houses more than a hundred biotech companies and numerous centers of excellence, nine universities and more than 200 engineering colleges in a 600-square-kilometer area.[23]

In fiscal year 2005/2006, approximately 320 firms were listed as operating in India, according to a recent news story. "Of them, 175 companies were set up in Karnataka, including 158 in Bangalore."[24] In addition, Bangalore is headquarters for India's largest biotechnology company, Biocon, and "more than 32,000 students are pursuing biotech related courses in over 400 colleges affiliated to Bangalore University,"[25] which is India's largest university.

Located northwest of Karnataka is Maharashtra, the richest Indian state, accounting for 13 percent of the country's GDP and 20 percent of its industrial output. The state has long identified biotech as an area for special support, especially in the pharmaceutical industry. "Nearly 40 percent of drugs and pharmaceuticals produced in the country are manufactured in Maharashtra," notes one pharma source.[26] In addition to Mumbai (Bombay), the cities of Aurangabad and Pune host major biotech clusters.

Numerous organizations, such as the Association of Biotechnology Led Enterprises, the Association of Diagnostic Manufacturers of India and the Indian Society for Clinical Research, exist in support of biotech research, but most of these are narrowly focused and do not have multiple chapters for networking purposes, according to a 2005 *BioSpectrum* article.[27]

Human capital is one of India's greatest assets, and according to the federal Department of Biotechnology, "There are over a hundred National Research Laboratories employing thousands of scientists. There are more than 300 college-level educational and training institutes across the country offering degrees and diplomas in biotechnology, bio-informatics and the biological sciences, producing nearly 500,000 students on an annual basis. More than 100 medical colleges add approximately 17,000 medical practitioners per year. About 300,000 postgraduates and 1,500 PhDs qualify in biosciences and engineering each year."[28]

4. University Technology Transfer Mechanisms

The government's new Science and Technology Policy 2003 acknowledged that the commercialization of technology has so far proved to be an "inadequate" contribution to the nation's economy and made sweeping pledges to initiate reforms to facilitate new policy initiatives.[29]

The Ministry of Science and Technology and its Technology Transfer Division have successfully completed commercialization processes for the following universities and research facilities, to name a few: the National Institute of Immunology, the Center for Biomedical Technology, the Centre for Biotechnology, the All India Institute of Medical Sciences and University of Delhi (South Campus) all in New Delhi; the Seth S.G. Medical College & Hospital, the Cancer Research Institute and the Institute for Research in Reproduction in Mumbai; the University of Baroda; the Institute of Medical Sciences and Banaras Hindu University in Varanasi; the National Institute of Virology in Pune; the Central Drug Research Institute in Lucknow; and the University of Rajasthan.[30]

Research institutions are encouraged to seek IP protection. For example, while the patent may be taken in the name(s) of inventor(s), universities ensure that the patent is assigned to it as proprietor. The university is responsible for the commercialization of its research and permitted to retain the benefits and earnings arising out of the IP. Although the division of revenues differs among universities, each inventor is limited to a one-third share of the actual earnings.[31]

The 2004 *Global Competitiveness Report* ranks India in 51st place, in terms of university/industry research collaboration.

5. Commercialization Success: Patents and Licensing

The biotechnology sector in India is made up predominantly of small firms. The country's growing biotech entrepreneurship is shown in industrial enzymes, with approximately 70 percent controlled by Novozymes and Genencor.

Alla Venkata Rama Rao, Ph.D., D.Sc., whose research specialties include organic and medicinal chemistry, chiral synthesis and drug technology, is one of India's most distinguished scientists, with more than 30 patents. He has developed at least 50 drug technologies that have been commercialized by the pharmaceutical industry, and was also the first researcher, in 1996, to set up a contract research organization, Avra Labs, in India. Avra Labs has worked with Pfizer, Searle, Davos (U.S.), the National Cancer Institute, Cipla and Cadilla, among others. The company focuses on anti-cancer and AIDS therapies. Rao has served on numerous international bodies and agencies, including the U.N. Development Program, the World Health Organization, UNEP (Ozone cell) and the World Bank.

Shantha Biotechnics, based in Hyderabad, is the first Indian biopharmaceutical company in the country. The domestically developed hepatitis-B drug, Shanvac-B, is one of its successes. Pre-qualified by the WHO for supplies to U.N. agencies, Shanvac is used globally and priced much lower than imported vaccines.[32]

Additional successful university biotech transfers include:

- A technology for the production of recombinant anthrax vaccine, developed by the New Delhi-based Jawaharlal Nehru University and transferred to Panacea Biotech, a leading health management company in New Delhi.[33]
- Discovery of a new medicine to treat tuberculosis, a project launched in 2000 by 12 public-sector laboratories led by the Council for Scientific and Industrial Research and a private-sector firm, Lupin Laboratories of Mumbai.[34]
- Development of a process for mass production of targeted delivery of antigens through nanoparticles, using sendai virus system at the University of Delhi, and transferred successfully to Panacea Biotec Ltd. in New Delhi.[35]
- The technology for development of nutraceuticals, transferred from Anna University at Chennai to Parry Nutraceuticals Ltd., part of the $144 billion Murugappa Group.
- Polyherbal formulation (BHU-x) for artherosclerosis, transferred from the Institute of Medical Sciences at Banaras Hindu University to Surya Pharmaceuticals, a manufacturer and exporter of bulk semi-synthetic penicillin antibiotics.

The Indian Institute of Chemical Technology is the nodal agency for nanoscience R&D. The Institute developed synthetic nanotubes to deliver DNA material for gene therapy.[36]

Endnotes:

1. S.R. Rao. November 1, "Indian Biotechnology Developments in Public and Private Sectors: Status and Opportunities." *Asian Biotechnology and Development Review*.
2. http://dbtindia.nic.in/.
3. Atul Chitale. "India Overview." *Global Competition Review*. 2006. http://www.globalcompetitionreview.com/sr/sr_fullpage.cfm?page_id=112.
4. Chaturvedi, Sachin. 2005. "Dynamics of Biotechnology Research and Industry in India: Statistics, Perspectives and Key Policy Issues." *OECD Science, Technology and Industry Working Papers*. 2005/6. OECD Publishing. doi:10.1787/873577115356.
5. "National Biotechnology Development Strategy (Draft)." Department of Biotechnology, Ministry of Science and Technology. See: http://dbtindia.nic.in/biotechstrategy/Biotech%20strategy.doc.
6. http://www.ksg.harvard.edu/press/press%20releases/2005/juma_un_report_010305.htm.
7. Bio 2005. Country Profiles. See: http://www.bio.org/events/2005/international/ CountryProfiles.pdf#search='bio%202005%20country%20profiles'.
8. Ibid.
9. Devlin, Andrew. 2003. "An Overview of Biotechnology Statistics in Selected Countries." Economic Analysis and Statistics Division, OECD. See: http://hermia.sourceoecd.org/vl=1654057/cl=36/nw=1/ rpsv/cgi-bin/wppdf?file=5lgsjhvj7lg2.pdf.
10. Devlin, Andrew. 2003.
11. http://www.dbtindia.nic.in/proforma/wordfiles/AnnexureV.doc.
12. Lall, Somik V. and Taye Mengistae. "Business Environment, Clustering and Industry Location: Evidence from Indian Cities," *WPS* 3675.
13. http://dbtindia.nic.in/techtransfer/techmain.html.
14. "Indian biotechnology: rapidly evolving and industry led." *Nature Biotechnology*. December 2003.
15. http://dst.gov.in/scientific-programme/s-t_scst.htm#1.
16. Devlin, Andrew. 2003.
17. http://www.indianembassy.org/dydemo/science.htm.
18. http://www.altassets.com/casefor/countries/2002/nz2910.php.
19. Chaturvedi, Sachin. 2005.
20. Lall, Somik V. and Taye Mengistae.
21. As cited in "Indian biotechnology: rapidly evolving and industry led." *Nature Biotechnology.*
22. "Indian biotechnology: rapidly evolving and industry led." *Nature Biotechnology.*
23. http://www.genomevalley.org/default.htm.
24. "Western region leads Indian biotech growth." News Nerve of India. June 7, 2006. See: http://www.nerve.in/ news:2535004084.
25. "Biotech Clusters of India." See: http://www.biospectrumindia.com/content/BSTOP20/BSTop2004/ 10408124.asp.
26. "Mumbai pharma goes the extra mile," July 22, 2004. Mumbai bureau. Pharmabiz.com. See: http://www.pharmabiz.com/article/detnews.asp?articleid=23172&sectionid=50.
27. Narayan Kulkarni, "Fostering Growth Through Bioclusters." November 11, 2005. *BioSpectrum*. See: http://biospectrumindia.com/content/bioFocus/10511111.asp.
28. "National Biotechnology Development Strategy (Draft)."
29. "Science and Technology Policy 2003." Council for Scientific and Industrial Research. See: http://www.csir.res.in/External/Utilities/Frames/aboutcsir/main_page.asp?a=topframe.htm&b=leftcon.htm&c=../../../Heads/aboutcsir/about_us.htm.
30. http://dbtindia.nic.in/techtransfer/tech_trans2003-04.html.
31. http://www.dbtindia.nic.in/proforma/wordfiles/AnnexureV.doc.
32. http://www.shanthabiotech.com.
33. http://www.biospectrumindia.com/content/BioBusiness/10510112.asp.
34. Chaturvedi, Sachin. 2005.
35. http://dbtindia.nic.in/techtransfer/tech_trans2003-04.html.
36. Chaturvedi, Sachin. 2005.

Japan

1. National Innovation Policy

Japan's science and technology policy prioritizes the life sciences; however, as the world's second-largest economy and a technology leader, the country's biotech industry is not meeting its potential.

In 1995, the government initiated efforts to develop R&D with enactment of the Science and Technology (S&T) Basic Law, as well as funding support of close to $130 billion for the first S&T Basic Plan (1996–2001).[1] Under the plan, Japan initiated efforts to increase the flow of intellectual capital from the universities to industries. In 2000, the government abolished regulations that barred faculty members at national universities from working as executives in private companies[2] and introduced measures to encourage foreigners to participate in Japanese R&D.[3] These initiatives addressed concerns about the overemphasis on applied R&D to give more flexibility to researchers and encourage basic research.[4] They also allowed Japan to take advantage of existing industry conditions in which private companies drive the national innovation system.[5]

Also in 2000, the government enacted the Law to Strengthen Industrial Technical Ability, similar to the Bayh-Dole Act. Administrative reform in 2001 established the Ministry of Education, Culture, Sports, Science and Technology (MEXT); the Council for Science and Technology; the second S&T Basic Plan (2001–2006), with $207 billion funding; and the Center of Excellence program.[6] MEXT developed Venture Business Laboratories in 39 universities and provided material support for IP and personnel at OTT. The second national S&T policy targets four key areas — environmental technology, life sciences, IT and nanotechnology.[7]

International collaboration in biotech R&D is emphasized in Japan's National Biotechnology Strategy, a 2002 government initiative supported by the prime minister.[8] Biotechnology Strategy Guidelines and National University Reform Bills, which were initiated in 2003, converted "universities into independent administrative organizations."[9] With this transformation, affected faculty members were no longer treated as civil servants, and universities experienced more autonomy and competition.

Osaka University houses the Research Institute for Microbial Diseases, which has received worldwide recognition for its achievements in immunology and microbiology. The institute's achievements include the discoveries of vibrio parahaemolyticus, a bacterium that causes cholera, by Tsunesaburo Fujino; cell fusion by Yoshio Okada; and viral oncogenes by Kumao Toyoshima; and the development of various vaccines by Yoshitomi Okuno, Tsunehisa Amano and Noriaki Takahashi.

The late Yuichi Yamamura, who served as professor, then dean of the Osaka University Medical School and later president of the university, built up the research faculty that gained international acclaim, especially in the field of immunology. One of his students, Chuzo Kishimoto, also achieved worldwide recognition, in immune research and went on to become president of the university.

In 1993, Japan began implementing fast-track procedures to speed the approval of drugs where the target diseases are life threatening and the drugs are clearly superior in efficacy or safety.[10] Despite some setbacks, "(p)riority approvals have since become common and the trend seems certain to continue, if not accelerate," according to *Nature Medicine*.[11]

With respect to IP rights, there is no sharing of royalties among stakeholders; the owner has rights to all royalties received.[12] However, it is possible that the owner of the invention may not be the inventor. Scientists are therefore subjected to Japanese bureaucracy that may impede their motivation toward R&D. The second Basic Plan initiated changes to grant IP rights to institutions rather than individuals. As of June 2004, just over 38 percent of Japanese universities grant IP rights to institutions, with approximately 9 percent to individuals.[13]

Japan is relatively weak in terms of entrepreneurship, compared to the United States and the United Kingdom.[14] However, pubic policy introducing incentives to encourage individual entrepreneurship could strengthen biotech development in Japan. For example, direct rewards to university scientists for their R&D efforts could make Japan more attractive to foreign scientists.

2. Funding and Venture Capital

Despite the country's financial crisis in the 1990s, Japan's expenditures on science and technology have been increasing.[15] Of note, there was a 29 percent increase, to $3.1 billion, in the budget requested from FY 2004 to FY 2005.[16]

In 1995, national universities received almost all their research funds from Japan's Ministry of Education, Science and Culture, and those levels compared unfavorably with levels in the United States and Europe.[17] In 2002, the government set aside $720 million for the attraction of biotech foreign direct investments,[18] as well as METI funding support for startup firms, totaling more than $120 million in 2003, to spur the commercialization of university research.[19]

Expenditures of selected R&D were about $7 billion for life sciences and $276 million for nanotechnology in 2004. Some $6 billion and approximately $180 million were allocated to universities for life sciences and nanotechnology, respectively.[20]

R&D Expenditures on Life Sciences and Nanotechnology
2004

	Number of Organizations	Amount (US$ Mil.)	Number of Organizations	Amount (US$ Mil.)
Organizations	**Life Sciences**		**Nanotechnology**	
Universities	647	6,205	188	179
Short-Term Universities	62	66	-	-
University-Affiliated Institutions	45	324	19	42
Others	144	262	62	55
Total	898	6,857	269	276

Source: Statistics Bureau of Japan

More capital is now flowing into Japan's universities. In 2004, Osaka University formed a $32 million fund. Tokyo University's Edge Fund offers right of first refusal on research to investors and is the largest university fund to date. Tokyo University created a $93 million fund in 2004.[21]

Venture capital investment in the biotech industry has not been as great in Japan as elsewhere around the world. In fact, between 1990 and 1994, there was no biotech VC investment in Japan. With the introduction of the S&T Basic Plan, by 1999, the country saw $1.2 million VC investment in biotechnology, still just 2 percent of the total VC investment. In 2000, the country's VC biotech investment grew to approximately $13 million, about 5 percent of total VC funding.[22] Increasingly, VC firms are establishing more funds directed at Japan's life sciences. The Market for High Growth and Emerging Companies (known as Mothers Market), the Hercules Market and Jasdaq help biotech companies gain access to capital.[23]

3. Clusters of Biotechnology

There are several biotechnology clusters in Japan. In the north is the Hokkaido Super-Cluster Plan, with 50 startups. In the central region, 234 startups are located in the Tsukuba Science Park, Tokyo Genome-Bay Project, Chiba Kazusa Academia Park, Lifescience City Yokohama and the Shizuoka Pharma Valley Plan. Almost 90 startups are located in southern Japan: in Kobe Medical Industry City, Osaka Bio-Information Highway Plan, Saito Biomedical Cluster Plan and Nagahama Science Park.[24] Other clusters include the Toyama Bio-Valley Plan, Hiroshima Center Bio Cluster Plan and the Fukuoka Bio-Valley Plan.

Major cities in Japan house the country's industrial innovation. Tokyo is considered a "gateway to domestic and international markets." [25] In 2003, 154 bio-medical ventures were present in the Kanto area. Pharmaceuticals and diagnostics (94 companies) dominated the sector, followed by DNA and protein analysis (78 companies); bioinformatics (41 companies); and reagents and research tools (38 companies).[26] In the same year, more than 330 bio-ventures produced almost $910 million in total sales. [27]

The Hokkaido Bio 21 Council developed a program toward the active implementation of a biotechnology cluster. Universities involved in this cluster include Hokkaido, Sapporo Medical and Otaru. MEXT designated the Hiroshima Biocluster as a "Knowledge Based Cluster Creation Project." A key university in this biocluster is Hiroshima University — Kasumi and Higashi Hiroshima campuses.[28]

4. University Technology Transfer Mechanisms

In 1998, Japan passed the first laws to establish technology licensing offices.[29] In December 1998, the first four offices of tech transfer, based on the U.S. model, were approved at the University of Tokyo; Nihon University; Kansai OTT (jointly formed by universities such as Kyoto University and Ritsumeikan University); and Tohoku Techno Arch Co. Ltd (which constituted Tohoku University and other universities in the Tohoku region).[30] By April 2001, 20 OTTs had been formed,[31] increasing to 33 as of July 2003[32] and growing to 37 by July 2004, of which only one was not directly related to a university and seven remain inside universities.[33]

OTTs are supervised and financially supported by MEXT for five years at approximately $30 million per year, subject to annual reviews, after which they operate independently.[34]

Prior to the incorporation of Japan's universities, industry-funded research generally became the property of the company. Now the universities own nearly all inventions made by their researchers, including inventions by most graduate students and industry employees working in university labs. The reality remains, however, that regardless of legislative reform, discoveries resulting from joint public/company research in Japan tend to be controlled by firms. Since joint research (as opposed to commissioned research) is the most rapidly growing form of sponsored research in Japan, university OTTs must be keen negotiators and knowledgeable about legal agreements if they are to expect any control over, and revenue receipts from, their portion of the innovation.[35]

5. Commercialization Success: Patents and Licensing

The Japan Science and Technology Corporation provides a patenting service, and the Ministry of Education, Culture, Sports, Science and Technology sponsors seminars for faculty members on intellectual property rights.[36]

As of December 2002, Japan's technology transfer offices filed more than 2,900 patent applications.[37] But its patent system emphasizes "the diffusion of technology" rather than the protection of IP,[38] a necessary ingredient for the successful commercialization of university discoveries.

GeneticLab is a bio-venture spin-off (September 2000) formed by two professors from Hokkaido University. The company, which focuses on gene analysis for cancers and infectious diseases, has a staff of 64 and also specializes in immunochemistry and drug discovery.

The Japanese Patent Office is the third largest in the world. In December 2002, a new IP law was enacted, advancing Japan's first Patent Law, which dates from 1885.[39] "In contrast to the United States, Japan, like Europe, allows the same patent to be extended multiple times, provided that each extension is applicable to a different product," according to a report by the U.S. law firm Wiggins & Dana. "Japan also allows multiple patents covering a single product to be extended so long as the multiple extensions are regarded by the patent office as necessary."[40] This is aimed at compensating for the time lost during the regulatory review, subject to various eligibility requirements.[41]

"The number of bio-related new ventures in Japan increased from 60 firms in 1998 to 334 by the end of 2002."[42] According to the Japan BioIndustry Association (JBA), as reported by Ernst & Young, the number of biotech startups increased by more than 80 percent from 2000 to 2004. "JBA officials said that 34 percent of these startups are identified as emerging companies based on innovations from universities. This is in marked contrast to earlier research by Darby and Zucker, who found that some 88 percent of the new biotechnology firms in Japan began as spin-offs of existing firms rather than startups from universities.[43]

Independent business surveys have also shown that biotech startups from universities have been among the most successful ventures in recent years. The report notes that in 2004, "Edge Capital invested (close to $1 million) in Mebiopharm, a startup formed by Tokyo University researchers that develops medicines for cancer of the large intestine."[44]

A groundbreaking discovery by Ryuichi Morishita, a professor at Osaka University, led to the spin-off MedGene Co. Ltd. in 1999. The firm, renamed AnGes MG in 2002, specializes in R&D, as well as the practical application of genetic medicine.

AnGes MG is developing the HVJ Envelop Vector through its subsidiary, GenomIdea, in Osaka. This is a new delivery technology for medicines directed at patients suffering from incurable diseases. AnGes MG partnered on the development of hepatocyte growth factor (HGF) gene-based drugs in the United States, Europe and Japan.

Currently the partners are developing two new drugs: the (HGF) genetic medicine, which improves blood circulation by regenerating blood vessels, and the NFkB decoy, which controls various inflammations. Major partners include Ishihara Sangyo Kaisha, Daiichi Pharmaceutical Co., Seikagaku Corporation and Goodman Co.

The AnGes MG research laboratory is based in Osaka, with a branch office in Tokyo. Additional subsidiaries include AnGes, Inc. in Maryland (U.S.) and AnGes Euro Ltd. (Sussex, UK). AnGes was listed on the Tokyo Stock Exchange in 2002. Its initial market cap of approximately $270 million had more than doubled, to more than $600 million, by October 2005.

Endnotes:

1. Angelino, Henri and Nigel Collier. 2004. "Research and Innovation Policies in France and Japan: Similarities and Differences." National Institute of Informatics. See: http:www.nii.ac.jp/hrd/HTML/ OpenHouse/h16/archive/PDF/704.pdf.
2. Robinson, Teri and Bob Violino. 2005. "Global Positioning." Bio-IT World. http://www.health-itworld.com/archive/101404/global.html.
3. University of Waterloo Gazette. "Japan Will Continue to Increase Its Government Funding for Research." Oct 2, 1996. See: http://www.communications.uwaterloo.ca/Gazette/1996/October02/Japan%20approves% 20research%20plan.
4. Commandeur, Peter. 1995. "The Japanese Government's Role in Biotechnology R&D." *Biotechnology and Development Monitor*. 22. http://www.biotech-monitor.nl/2202.htm.
5. Wu, Weiping. 2005. "Dynamic Cities and Creative Clusters." World Bank Policy Research. WP 3509.
6. Angelino, H. and N. Collier. 2004.
7. Fujita, Kuniko. 2003. "Neo-industrial Tokyo: Urban Development and Globalization in Japan's State-centered Developmental Capitalism." *Urban Studies*, 40(20).
8. Japan External Trade Organization. 2003. "Biotechnology Strategy for Bioindustry Begins to Take Shape." See: http://www.jetro.go.jp/israel/files/03Feb/biostrategy_fj_english.doc.
9. Angelino, H. and N. Collier. 2004.
10. http://www.jetro.go.jp/en/market/attract/biotechnology/policy.html.
11. Sipp, Douglas. 2004. "Fast-track drug approvals hit speed bumps in Japan." News@Nature.com. See: http://www.nature.com/news/2004/040823/pf/nm0904-883a_pf.html.
12. Erskinomics Consulting Pty Limited. 2003. "Critical Factors in Successful R&D: An International Comparison." Discussion paper for Australian Innovation Association and the Australian Institute for Commercialisation.
13. http://www.jauiptm.jp/jauiptm/jauiptm.html.
14. Angelino, H. and N. Collier. 2004.
15. Wu, Weiping. 2005.
16. Bio 2005. See: http://www.bio.org/events/2005/international/ CountryProfiles.pdf#search= 'bio%202005%20country%20profiles.

17. Commandeur, Peter. 1995.
18. Peterson, Ronald. 2003. *When Venture Capitalists Say 'No': Creative Financing Strategies & Resources*. Bethesda, Md.: Comanche Press.
19. Angelino, H. and N. Collier. 2004.
20. Statistics Bureau of Japan.
21. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report*.
22. Devlin, Andrew. 2003. "An Overview of Biotechnology Statistics in Selected Countries," Economic Analysis and Statistics Division, OECD. See also: METI et al. 2002. "Trends in Japan's Industrial R&D Activities: Principal Indicators and Survey Data."
23. Ernst & Young. 2005.
24. Bio 2005. Country Profiles. 2005.
25. Fujita, Kunido and Richard Child Hill. 2004. "Innovative Tokyo." Paper presented at the World Bank "Workshop on Creative Industries in East Asia," February, 22–23, Bangkok, Thailand.
26. "Japan to have 1000 Biotech Companies" by 2010. See: www.biospectrumindia.com/content/ BioClusters/.
27. Ibid.
28. The "Hiroshima Biocluster: Laying the Foundation for Bio Hills." 2002. See: http://ricchi.hiwave.or.jp/ ricchi/english/aratana/bio.htm.
29. Japan Inc. People. Takafumi Yamamoto, CEO and President, CASTI. See: http://www.japaninc.net/mag/ comp/2000/11/nov00_people_yamamoto.html.
30. Yamada, H. 2001. "Founding Technology Licensing Organizations. Japanese Institute of Global Communications," *Japan Technology Review,* 12. Aug 9. For a review of two interesting case studies on tech transfer offices at the University of Tokyo and Tohoku University. See Nilsson, Anna, Henrik Fridén and Sylvia S. Serger. 2006. "Commercialization of Life-Science Research at Universities in the United States, Japan and China." Swedish Institute for Growth Policy Studies.
31. Yamada, H. 2001. "Founding Technology Licensing Organizations." Japanese Institute of Global Communications. Japan Technology Review No. 12. Aug. 9, 2001.
32. Lynn, Leonard and R. Kishida. 2004. "Changing Paradigms for Japanese Technology Policy: SMEs, Universities, and Biotechnology," *Asian Business & Management,* May.
33. "TLOs and University IP Centers." 2004. National Science Foundation. Tokyo Regional Office. See also: White Paper of S&T, 2003. See: http://wwwwp.mext.go.jp
34. Ibid.
35. Kneller, Robert. 2005. "Surface Convergence Masking Contrasting Styles of Technology Transfer: The Case of Joint Ownership of Japanese University Inventions." September.
36. White Paper of S&T, 2003 http://wwwwp.mext.go.jp
37. According to Japan TLO Association. See: White Paper of S&T. 2003. See: http://wwwwp.mext.go.jp
38. Lynn, Leonard and R. Kishida. 2004. "Changing Paradigms for Japanese Technology Policy: SMEs, Universities, and Biotechnology," *Asian Business & Management,* May, p. 466. This article also cites the research work of: Wineberg, 1988; and Maskus and McDaniel, 1999 on this subject.
39. Intellectual Property Law in the 21st Century. Chapter 10. http://www.wipo.int/freepublications/en/intproperty/834/wipo_pub_834_ch10.pdf.
40. Wiggin and Dana. 2003. BioInsights. Patent Term Extentions Extend Revenues. See: http://www.wiggin.com/db30/cgi-bin/pubs/BioInsights%20Issue%206%20June%202003%20revised%207-11-2003.PDF.
41. Ibid.
42. Lynn, Leonard and R. Kishida. 2004. (p. 472).
43. Darby, Michael and L. Zucker. 1999. "Local Academic Science Driving Organizational Change: The Adoption of Biotechnology by Japanese Firms," Cambridge, MA, NBER WP #7248.
44. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report*.

The Republic of Korea

1. National Innovation Policy

The Ministry of Science and Technology (MOST) has oversight of the Republic of Korea's (ROK) biotech industry.[1] Throughout the 1980s, MOST initiated the country's R&D programs, based on the Technology Development Promotion Law, to facilitate domestic innovation. Public R&D expanded to induce private investments.

Imitation, copying and reverse engineering have been important means of learning in much of East Asia. In 1992, for example, the Republic of Korea's government launched the Highly Advanced National (HAN) Project as an inter-ministerial program to develop the country's self-reliance on science and technology through imitation. However, implementation of the 1997 Creative Research Initiative represented a major shift from imitation to innovation. The ROK is now an innovator rather than a mere imitator.[2]

With the increasing emphasis on biotechnology, the 21st Century Frontier R&D Program succeeded the HAN Project with new management systems that focused on innovation.[3] In conjunction with the new emphasis on innovation, the National Science and Technology Council created a Biotechnology and Industry Committee to coordinate national biotech policy among several ministries.[4] A government-funded project to develop an integrated database and e-commerce system in the biotech industry is also under way.

In 2004, the ROK passed legislation permitting the cloning of human cells.[5] Many of the country's biotechnology policy initiatives have been shaped by its efforts in stem cell research.

Although there are large differences in countries' innovation capabilities and their ability to benefit from R&D internationalization, the United Nations categorized the Republic of Korea among those with high capabilities.

The ROK remains "relatively weak in drug screening, safety evaluation, clinical trials and product commercialization," according to a report from Industry Canada, making its pharmaceutical biotech firms keen on partnerships.[6] Government funds reach pharmaceutical biotech companies via the Korea Drug Research Association, which assists alliances through its Pharma Tech Business Center.[7] On the academic front, 33 percent of all articles published by Korean genomics and biotech researchers were co-authored internationally.[8]

Since 1995, the government has revised its IP laws to comply with WTO Trade Related Aspects of Intellectual Property Rights, or TRIPS. However, Korea's IP protection system remains weak.[9] More effective IP regimes could promote domestic innovation and strengthen the country's ability to attract foreign partners.

The ROK's efforts position the country as an emerging player in the global biotech scene. In 2000, the country successfully bid to be the permanent host for the International Vaccine Institute. Partly funded by the government and operated out of Seoul National University, the institute attracts scores of researchers from around the world.[10]

2. Funding and Venture Capital

"Between 1981 and 2001, government investment in R&D increased 40 times, from $320 million (0.56 percent of GDP) to $12.2 billion (2.96 percent of GDP)," the RAND Corp. reported.[11] As of 2002, MOST had invested $270 million in genomics, proteomics and bioinformatics.[12]

The government spent $14.4 billion on biotechnology in 2002.[13] The focus is on four projects: (1) development of genetically modified animal organs for human transplants; (2) a protein chip that facilitates the detection of diseases; (3) a technology that can control the immune system; and (4) an intelligent medicine-delivery system.[14] MOST also seeks to commercialize genetically modified animal organs among other bioengineered products within the next five years.

By 2007, the country's R&D expenditures are projected to reach 7 percent of GDP. "These growth figures are the highest in the world," notes the report in *Innovation Strategy Today*. "The average annual growth rate in R&D funding per GDP from 1981 to 1991 was 24.2 percent, compared to 22.3 percent in Singapore, 15.8 percent in Taiwan province of China and 7.4 percent in Japan."[15]

Over the past decade, R&D expenditures worldwide rose sharply, reaching approximately $677 billion in 2002. Ten countries account for more than 80 percent of the total. Only two developing countries, China and Korea, feature among the top 10.

A United Nations survey suggests that the pace of R&D internationalization may be accelerating. Japanese and Korean multinational enterprises exhibited the lowest share of foreign R&D: 15 percent and 2 percent, respectively.

Approximately 70 percent of R&D expenditures by affiliates of U.S. multinational enterprises in 2002 were concentrated in the following five developing economies: China, Singapore, Brazil, Mexico and Korea.

— UNCTAD, 2005, World Investment Report

The Korean economy is dominated by four *chaebols*, or family-owned business conglomerates — Hyundai, Samsung, LG and SK Group — each of which receives tremendous government support. Since the financial crisis of 1997, policies have changed to favor business ventures. Although there are other big players, these four continue to play a significant role in all aspects of the economy.

The private sector is increasingly investing in biotech. The following are some examples:

- Samsung Advanced Institute of Technology: $300 million for 2001 to 2003
- LG Chemical: $50 million in 2000 and plans for bio-venture funds of $100 million
- Hanwha Chemical Research & Development Center: $50 million in 2000
- SK Global: $35 million from 2000 to bio ventures

- Hansol: $150 million from 2000 to 2006
- Isu Chemical: $150 million for the period of 2000–2005[16]

As elsewhere in Asia, access to capital remains a challenge for biotech development. However, the funding situation in the ROK appears positive. Support from private industry, especially three of the four *chaebols*, adds optimism.

3. Clusters of Biotechnology

The Republic of Korea's most important cluster is located in the Daeduk Science Town in Taejon. It was built around the Korea Research Institute of Bioscience and Biotechnology's Bio Venture Center to promote and incubate new biotech firms. Bioneer, a company specializing in DNA synthesis, was started by Han-Oh Park, who did his dissertation research at the institute. Bioneer was incubated at the Bio Venture Center.[17]

Seoul National University (SNU) and the Korea Advanced Institute of Science and Technology (KAIST) are Korea's top research universities. The latter is located near Daetuk Science Town. Between 1991 and 2002, SNU and KAIST accounted for 23 percent and 13 percent, respectively, of health biotech publications in international peer-reviewed journals.[18]

Invest Korea Plaza, scheduled to open in September 2006, is situated in the Seocho area of Seoul. This foreign business incubation center is a planned international cluster.

Despite biotech's infancy, encouragement by the government facilitated the establishment of 86 research institutes, eight facilities-based Bio Venture support centers and 300 small biotech R&D firms as of 2003. Among these, 79 are pharmaceutical. The government also promotes the development of bioclusters oriented around cooperative relationships among industry, academia and research.[19]

4. University Technology Transfer Mechanisms

Korean universities and research institutes were not major sources of technology for the country's industry during the 1980s and most of the 1990s. Thus, most Korean companies wishing to obtain new technology looked outside the country.[20] Beginning in the late 1990s, the government instituted changes to recognize the importance of IP creation at universities and public R&D institutes.

> In 2000/01, according to UNCTAD's *World Investment Report*, developing countries accounted for 62 percent of global tertiary enrollments and 52 percent in technical subjects (pure science, engineering, math and computing). Korea ranked fourth in the world in technical enrollments, impressive for a country of 47 million people.

The Patent and Technology Transfer Promotion Acts were revised to promote IP creation and management in universities. Public universities were allowed to retain ownership of new IP and encouraged to establish tech transfer offices. Guidelines for sharing licensing income, with specific allotments for the inventors, were also set.[21] With these initiatives, IP ownership changed from the state to the university OTTs. Although revenue-sharing rules vary by institution, upon successful licensing, generally 50 percent of royalties go to inventors.[22]

The Korea Technology Trade Center facilitates tech transfers. The Korea Intellectual Property Office designated 55 universities as Patent Cooperation Universities, based on such requirements as the availability of computer training facilities, quality of IPRs curricula and retention of IP professors. The aim of this is to promote the creation and use of IPRs, develop a knowledge base and provide adequate training.[23] New programs were instituted to encourage academic/industry cooperation and spin-offs, the creation of technology markets and patent fee discount plans.[24]

The Korea Association of Technology Licensing Organization is comprised of the Metropolitan TLO in the northern region, Daedeok Valley TLO in the west-central region, Jung-Bu TLO in the northeast, Yung-Nam TLO in the southeast and Honam-Jeju TLO in the country's southwest.[25]

5. Commercialization Success: Patents and Licensing

In 2001, the number of Korean patents registered in the U.S. market was only 1.2 percent that of the U.S. and 12.5 percent that of Japan. However, in the same year, Korean domestic patent applications were more than twice that of the United States and Japan.[26] The total number of patents granted in 2000/2001 in the ROK was 832.[27]

In 2003, developed countries accounted for 83 percent of all foreign patent applications to the U.S. Patent and Trademark Office. The increasing share from developing countries jumped from 7 percent in the period 1991–1993 to 17 percent from 2001 to 2003. The annual average number of applications from developing countries increased from around 5,000 to close to 26,000 between the two periods. Taiwan and Korea accounted for four-fifths of the total.

While the government accounted for about 27 percent of R&D investment in the late 1990s, it constituted less than 5 percent of patent applications, or around 6 percent of total patent applications by Korean nationals, in both 1998 and 1999. In particular, patenting activities by universities were minimal, representing just 0.47 percent, 0.12 percent and 0.62 percent of total patent applications in 1998, 1999 and 2000.

According to a 1997 survey by the Korea Intellectual Property Office, only 31 percent of the total patents awarded were licensed. The rate of licensing for state-owned patents was just 19 percent.[28] This trend is also shown in biotech. Although the number of patents filed and articles published by public research organizations increased from 1990 to 1996, biotech transfers were very low in general and particularly low in the life sciences — just three tech transfer cases of basic research in the life sciences.

The results are even more sobering, given that as of 1995, close to 35 percent of total R&D personnel and more than 77 percent of Ph.D.s were working at universities. In biotech, specifically, more than 38 percent of all R&D personnel and more than 78 percent of Ph.D.s were employed in universities.[29]

The following data break down the Republic of Korea's pattern of spending and tech transfers.

Center of Excellence Program in the Republic of Korea
1990 to 1996

Discipline	Research Centers	R&D (US$ Mil.)	Number of Projects	Published Articles	Technology Transferred	Commercialized Products	Domestic Patents
Math & Physical Science	11	39.3	1,037	3,130	27	9	11
Life Sciences							
SRC	6	28.7	872	1,050	3	2	55
ERC	4	17.8	918	454	45	29	14
Engineering	17	75	4,449	3,781	324	168	154
Total	38	160.8	7,296	8,415	399	208	234

Note: Scientific Research Center (SRC), Engineering Research Center (ERC)
Source: http://www.stepi.re.kr/researchpub/

In 2002, there were 20 OTTs established in the country's private universities. The government financed each university from $36,500 to $48,700. Commercialization efforts resulted in around 2,500 transferable technologies with 98 SMEs from mid-2001 to mid-2002. Of these, 10 were biotech-related. The Pohang University of Science and Technology was the most active licensor, representing more than 28 percent of the total technology transferred.[30]

A 2000 survey by Technobusiness (a consulting firm in Daeduk Science Park) reveals that almost 70 percent of the scientists expressed interest in venture businesses. This enthusiasm is supported by the increase in the number of startups — less than 5 in 1993 to almost 150 in 1999. By mid-1999, more than 24 percent of the 4,000 venture firms surveyed by the Office of Small and Medium Enterprises were spin-offs from the country's universities or institutes. In 1999, there were approximately 50 such startups per 10,000 researchers — more than 50 percent used university venture-incubation centers.[31]

The Republic of Korea has produced several internationally competitive products, including: Amino acids, with a 20 percent global market share ($75 million); Ryfamycin, 10 percent ($7.5 million); and hepatitis B vaccine, developed in 1987 by Korea Green Cross Corp., with a 40 percent market share in 1999. Recombinant human growth hormone was developed by LG Chemical. In addition, SK Chemical developed an anti-cancer medicine technology; more than 300 new drugs are presently in the development process. Even though technologies like recombinant DNA, bioprocess and fermentation are well developed in the Republic of Korea, safety evaluation technology is still at an early stage.[32]

Pohang University of Science and Technology (POSTECH) is a private, nonprofit research university established in 1986. It offers sciences and engineering facilities and has academic agreements with 49 universities in 13 countries. The university's Biotech Center was opened in 2003; the school also has a bio-nanotechnology center.

The POSTECH Venture Business Co., the Business Incubation Center and the Cyber Technomart encourage the commercialization of innovation. In January 1999, the Pohang Technopark Foundation was established under joint participation with the Pohang city government, POSCO and POSTECH. The Technopark provides the infrastructure for the transfer of technology between academia and industry.

The POSTECH Licensing Center, its dedicated OTT, was established in 1999 and is financed by the central administration. It has four full-time employees.

POSTECH licensed 14 patents in 2001, approximately 60 percent of which were biotech-related, and created eight spin-offs and seven startups. It held 160 patents in that year, 127 domestic and 33 foreign. Exclusive licensing revenues in 2001 of close to $300,000 were divided as follows: 50 percent central administration, 10 percent department and 40 percent to the inventor. It licensed five biotech-related patents between mid-2001 and mid-2002. At the earlier stage of these agreements, the transfer process came to the OTT at a very mature stage, where the terms of the agreement were largely established. In 2004, a total of 213 faculty undertook 670 research projects with research funds of nearly $90 million. It held 233 patents in 2004, 121 domestic and 112 abroad.

In 1997, the university had 1,074 papers published by 206 full-time professors. Of these papers, 442 were cited in the Science Citation Index. These figures rose in 2004, to 1,466 papers.

Endnotes:

1. http://www.un.org/esa/earthsummit/rkore-cp.htm.
2. Kim, Linsu. 2003. "Technology transfer and intellectual property rights." *Issue Paper*, 2. Geneva: ICTSD and UNCTAD. See: http://www.ictsd.org/pubs/ictsd_series/iprs/CS_kim.pdf.
3. http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN008045.pdf.
4. Ibid.
5. http://www.bioethics.iu.edu/Woo.html.
6. http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr117482e.html.
7. Ibid.
8. Science-Metrix. 2004. "Benchmarking of Genomics and Health Biotechnology in Seven Developing Countries, 1991–2004." University of Toronto, Joint Centre for Bioethics 9Science–Metrix, Quebec.
9. Lall, Sanjaya. 2003. "Indicators of the relative importance of IPRs in developing countries," *Research Policy*, 32(9).
10. Wong, Joseph, U. Quach, H. Thorsteinsdóttir, P. Singer and A. Daar. 2004. "South Korean Biotechnology: A Rising Industrial and Scientific Powerhouse," *Nature Biotechnology*. Supplement 22.
11. Mahoney, Richard, K. Lee and M. Yun. 2005. "Intellectual Property, Drug Regulation, and Building Product Innovation Capability in Biotechnology: The Case of Hepatitis B Vaccine in Korea," *Innovation Strategy Today*, 1(2). See: http://www.biodevelopments.org/innovation/ist2.pdf.
12. Reported by RAND Corp. in "Phase Transition in Korea–U.S. Science and Technology Relations. http://www.rand.org/pubs/monograph_reports/MR1644/. See also: Wagner, Caroline, A. Wong, S. Ho Le and I. Brahmakulam. 2003. "Phase Transition in Korea–U.S." *Science and Technology Relations*.
13. Armbrecht, F.M. Ross, Jr. 2005. R&D and Innovation in Industry. *Industrial Research Institute*.
14. Insead Innovasia. 2005. "South Korea sets sights on specific biotech targets for 2005." *Asian Innovation News*.
15. Mahoney, Richard, K. Lee and Mikyung Yun. 2005. "Intellectual Property, Drug Regulation, and Building Product Innovation

Capability in Biotechnology: The Case of Hepatitis B Vaccine in Korea," *Innovation Strategy Today*, 1(2). See also: Ministry of Science and Technology. Korean Science and Technology Development. See: www.most.go.kr.

16. http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr116480e.html.
17. Wong, Joseph, U. Quach, H. Thorsteinsdóttir, P. Singer and A. Daar. 2004.
18. Ibid.
19. http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr117482e.html.
20. Mahoney, Richard, K. Lee and M. Yun. 2005.
21. Ibid.
22. Choi, Jong-Hyub. 2003. "Creation, Management and Use of IP: An Integrated and Proactive IP Policy and Strategy." WIPO Asia Pacific Regional Seminar on Intellectual Property Strategy for Economic Development.
23. Ibid.
24. Yun, Mkiyung. Korea Institute for International Economic Policy "Regulatory Regime Governing Management of Intellectual Property of Korean Public Research Organisations: Focus on the Biotechnology Sector." Chapter 13.
25. http://www.nus.edu.sg/enterprise/newsletter/mar05/happenings/korea.htm.
26. Korea Institute of Industrial Technology Evaluation and Planning.
27. OECD. 2003. "Turning Science into Business: Patenting and Licensing at Public Research Organisations."
28. Yun, Mkiyung. "Regulatory Regime Governing Management of Intellectual Property of Korean Public Research Organisations: Focus on the Biotechnology Sector."
29. Ibid. See also: Ahn, D. and K. Chung. 1998. "Suggestions to Promote Technological Transfer by Universities." *Trends in Biotechnology,* 6(1). Korea Institute of Bioscience and Biotechnology, Seoul. See also: Joo, N.C. 2001. "Management of Patents at Public Universities: Issues and Directions for Reform." Seoul National University Seminar.
30. Yun, Mkiyung. "Regulatory Regime Governing Management of Intellectual Property of Korean Public Research Organisations: Focus on the Biotechnology Sector."
31. Ibid. See also: Yoon, S.M. and Y. Kwon. 2001. "The University-Industry Linkage System and Spin-offs." *Policy Research 2001-0.* Seoul: STEPI.
32. http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr116480e.html

New Zealand

1. National Innovation Policy

New Zealand's biotech industry has grown rapidly, with half of its "core biotech companies" founded just since 2002.[1] However, while New Zealand boasts a well-educated population and well-funded science R&D — with eight universities and nine state-owned but partly commercialized crown research institutes — the country is experiencing a brain drain attributable to low compensation and a focus on short-term projects.[2] In addition, the science base is small, compared to G7 and OECD countries. Between 1973 and 1996, New Zealand's national innovation capacity lagged behind 17 sampled OECD countries.[3]

In 2002, the government set up the Biotechnology Task Force to develop human capital and investment funding through a Growth and Innovation Framework for Action.[4] In addition, the Science and Innovation Advisory Council, an independent advisory body, was established to increase the public status and recognition of scientific research, and to enable coordination of government policies and community activities at the highest levels.[5]

National innovation policy in New Zealand is somewhat fragmented, with research concentrated among small organizational links rather than networked in a wider system of innovation.[6] The country's biotech industry tends to focus on forestry and agriculture.[7]

2. Funding and Venture Capital

Government initiatives to boost university/business collaboration include: the Technology New Zealand Fund; the Grants for Private Sector R&D plan; the Foundation for Research, Science and Technology (FRST); the New Economy Research Fund; the Marsden Fund (which funds research through the Royal Society of New Zealand); and the Health Research Council, which is responsible for investment in health research.

In 2001, the government funded approximately $186 million for biotech R&D.[8] In 2004, biotech expenditures totaled $430 million, with income valued at $675 million.[9] In 1996 gross expenditures on R&D were less than 1 percent of GDP.[10] Private spending on R&D, although increasing, is low by international standards.[11] Only a handful of biotech firms are listed on the New Zealand Stock Exchange.[12]

Until the past few years, little venture capital was available for biotech in New Zealand.[13] And even with the marked increase in recent years — VC investment in Australia and New Zealand combined increased sharply from 1997 to 2000, especially in health/bioscience, from some $5 million in 1998 to more than $55 million in 1999[14] — private-sector funding remains a challenge for the country. As of 2000, more than $350 million in venture capital was available for high-tech firms, with an additional $411 million committed by 30 VCs.[15]

New Zealand ranked lowest among OECD countries for R&D tax subsidies; the country offers 100 percent deductibility on R&D costs.[16] In March 2005, BioPacificVentures, the country's first life-science VC fund, was launched. Partners include the venture capital firms Direct Capital and inventages, and AgResearch, a governmental research agency. Investors include Nestlé and Wrightson, an agribusiness.[17]

3. Clusters of Biotechnology

Biotech activities are concentrated in four clusters located within close proximity to one another.[18] While much of the context for cluster development involves new technology and high-growth regions, "cluster promotion in New Zealand tends to focus on small firms outside Auckland, the country's largest regional economy."[19]

In the late 1990s, regional economic development agencies, with support from local governments, began to lend support for clusters; the central government soon followed, with the creation of a Cluster Development Programme (CDP). In 2002, the Allan Wilson Centre for Molecular Ecology and Evolution (Massey University at Albany, Auckland) and the Centre of Molecular Biodiscovery (Auckland University) were chosen as centers of research excellence.[20] In early 2004, almost half of approximately 95 cluster initiatives received CDP support.[21]

4. University Technology Transfer Mechanisms

Technology transfer in New Zealand is characterized by a large number of small firms and has a significant presence in the crown research institutes (CRIs) and universities. Since 2001, some CRIs have provided profit-sharing incentives for researchers to commercialize their innovations. Universities have also established OTTs. Some, such as Massey at Albany, Auckland, have established tech commercial incubator facilities.

The table below shows that by 2001, 70 percent of partners in alliances were either crown research institutes or universities.

New Zealand Based Strategic Partners 2001

Organizations with Whom Biotechnology Enterprises Have Alliances	No. of Alliances Reported by Respondents	Percentage (%)
Crown Research Institute	69	37
Universities	66	33
Polytechnics	3	2
Related Business Research/ Professional Associations	39	21
Unrelated Business Research/ Professional Assoc.	12	6
Total	189	100

Source: Statistics New Zealand

Although a challenge given New Zealand's remote location, international collaboration among universities and research organizations is increasing, and not just with Australia.

Distribution of Foreign-Based Strategic Partners

Types of Overseas Organizations	Country					
	Australia	USA	Europe	Asia	Others	Total
Universities	24	24	21	12	3	87
Research	0	0	0	0	24	24
Other Organizations	18	24	18	9	3	69

Source: Statistics New Zealand

5. Commercialization Success: Patents and Licensing

New Zealand scientists are productive, in terms of published papers, but with the exception of some narrow fields like pharmacology, their research is not widely cited.[22] The number of successful biotech patents doubled between the periods 1995 to 1999 and 1999 to 2004.[23] These patents constituted 2 percent of the total number of patents issued in the year to June 1999, and 1 percent of total patents issued between 1995 to 1999. The July 2003 *New Zealand Biotechnology Industry Capability Survey* notes that "at least 244 patents have been granted to core biotechnology companies during the last five years."[24] "The total number of patents issued in New Zealand is boosted by foreign companies in pharmaceuticals and electronics," according to a 2001 report on the country's biotech activity.[25]

Successful Biotech Patents in New Zealand

Period in Which Successful Applications Were Made	Number of Successful Biotech-Related Applications	Total Patents Granted in New Zealand
In the year ending in June 1999	56	3,806
1995-1999	156	16,400
In the year ending in June 2004	117	NA
1999-2004	348	NA

Source:Statistics New Zealand, 2001/2004

Survey results show that enterprises in scientific research and tertiary education obtained 49 of the 56 patents granted in the year that ended in June 1999, and 120 of the 156 patents related to biotech between 1995 and 1999.[26]

Massey University has "achieved a 50 percent increase in research and consultancy income over recent years," according to a press release from the vice chancellor's office. "A remarkable achievement when you consider we do not have a medical research faculty. We achieved more research degree completions in 2004 than any other provider, and we are the only New Zealand university involved in all the Centres of Research Excellence."

Two examples of non-agricultural university biotech transfer initiatives include:

- *Neuren Pharmaceuticals* (http://www.neurenpharma.com/), a spin-off of the University of Auckland with a number of products in its pipeline, including the neuroprotective drug glypromate, which is about to begin Phase 3 clinical trials. The U.S. Army is a partner on this and at least one other project.
- *Pacific Edge Biotechnologies* (http://www.peblnz.com/), a spin-off of the University of Otago working on cancer diagnostics and therapeutics.

Endnotes:

1. Bio 2005. See: http://www.bio.org/events/2005/international/CountryProfiles.pdf#search='bio%202005%20country%20profiles.
2. Marsh, Dan. 2002. "Does New Zealand have an Innovation system for Biotechnology?" University of Waikato. WP. See: ftp://mngt.waikato.ac.nz/RePEc/wai/econwp/0203.pdf.
3. Stern, S., M. Porter and J. Furman. 2000. "The Determinants of National Innovative Capacity." NBER, WP 7876.
4. The Biotechnology Taskforce. 2003. "Growing the Biotech Sector in New Zealand." See: http://www.biospherenz.com/download/biotech_taskforce_report_nopix.pdf.
5. Ministry of Research, Science, and Technology. 2001. "The Role of Technology in Transforming the New Zealand Economy: Technology Transfer." See: http://www.morst.govt.nz/uploadedfiles/Documents/Publications/policy%20discussions/role%20of%20technology/technology%20transfer%20paper.pdf.
6. Marsh, Dan. 2002.
7. http://www.investmentnz.govt.nz/section/14246.aspx.
8. Ministry of Research, Science and Technology. 2002. "New Zealand Biotechnology Strategy."
9. http://www2.stats.govt.nz/domino/external/pasfull/pasfull.nsf/7cf46ae26dcb6800cc256a62000a2248/ 4c2567ef00247c6acc256fe10014c569?OpenDocument.
10. Engelbrecht, H.J. and J. Darroch. 1999. "A Comparative Macro-Level Assessment of New Zealand's National Innovation System," *Prometheus,* 17(3).
11. Ministry of Research, Science and Technology. 2002. "New Zealand Biotechnology Strategy." See: http://www.conversations.canterbury.ac.nz/resources/genetics/nz-govt-biotech-strategy.pdf.
12. Ernst & Young. 2005. *Beyond Borders: Global Biotechnology Report.*
13. Marsh, Dan. 2002.
14. "Almost $1 Billion Invested in 1999," *Australian Venture Capital Journal*. 2000. 9(85).
15. Caragata, P., 2000. "Could you Sell your Great Ideas to a Venture Capitalist?" *The Independent Business Weekly,* 12.
16. OECD. 1999. "Science, Technology and Industry Scoreboard 1999: Benchmarking Knowledge-Based Economies." Paris: OECD. See also: http://www.investmentnz.govt.nz/section/14246.aspx.
17. http://www.investmentnz.govt.nz/section/14258.aspx.
18. Ibid.
19. Perry, Martin. 2004. "Business Cluster Promotion in New Zealand and the Limits of Exemplar Clusters." *Policy and Society*, 23(4).
20. Ministry of Research, Science and Technology. 2002. New Zealand Biotechnology Strategy. See: http://www.conversations.canterbury.ac.nz/resources/genetics/nz-govt-biotech-strategy.pdf.
21. Perry, Martin. 2004.
22. Marsh, Dan. 2002.
23. Statistics New Zealand. 2001/2004. "Modern Biotechnology Activity in New Zealand." See: http://www2.stats.govt.nz/domino/external/pasfull/pasfull.nsf/7cf46ae26dcb6800cc256a62000a2248/4c2567ef00247c6acc256fe10014c582?OpenDocument.
24. BIOTENZ. 2003. *The New Zealand Biotechnology Industry Capability Survey.* Report to New Zealand Trade and Enterprise, July.
25. Statistics New Zealand. 2001.
26. Ibid.

Singapore

1. National Innovation Policy

Singapore's biotech industry is relatively new and poised for rapid development. "Strong government support and a pro-business environment have attracted industry leaders such as Albany Molecular, Aventis, Baxter, Becton-Dickinson, Eli Lilly, GlaxoSmithKline, Johns Hopkins, Merck & Co, Novartis, Pfizer, Schering-Plough, Siemens and Wyeth."[1] As such, Singapore is strengthening its position as a strategic manufacturing base for global pharmaceuticals.

In 2000, the government introduced a Biomedical Sciences (BMS) Initiative, with the goal of doubling the biotech industry's manufacturing output to S$12 billion by 2005.[2] The initiative (supported by the Economic Development Board and its subsidiary, Bio*One Capital, as well as the Biomedical Research Council) worked to develop the biomedical sciences industry, made up of pharmaceuticals, medical technology and biotech companies, and health-care services.[3] The initiative has proved tremendously effective: by 2005, manufacturing output for the industry reached S$18 billion, according to the Economic Development Board, which noted, "Pharmaceuticals accounted for 88 percent of the total, while medical technology enjoyed a strong 10.6 percent growth to reach S$2.1 billion in output. Employment also expanded by a healthy 8.6 percent, to cross the 10,000 mark. Of the 10,200 jobs in the BMS manufacturing sector, 62 percent are in medical technology."[4]

> Two researchers at A*STAR's Institute of Bioengineering and Biotechnology in Singapore, Dr. Yi Yan Yang and Li Shan Wang, used nanostructured materials to create a transparent wound dressing that has a polymer membrane allowing air and moisture to circulate and protect a wound from bacterial infection. The membrane sticks to human skin at body temperature but does not damage newly formed skin upon removal.

Singapore's rapid economic growth is attributable in part to the "transparency, efficiency and integrity of the courts and authorities," according to a report from Ernst & Young and the German law firm Luther Rechtsanwaltsgesellschaft, which also takes note of the country's highly protected IP rights and overall low crime rate.[5]

Beyond infrastructure and VC support initiatives, Singapore's R&D innovation policy is largely focused on recruiting and incorporating foreign experts to its universities, which are becoming world-class institutions, with a promising knowledge base for biotech R&D. In 2005 the National University of Singapore ranked 15th worldwide among biomedicine universities by the *Times Higher Education Supplement*, up from 25th in 2004. Nanyang Technological University ranked 26th worldwide in technology (NUS placed ninth in technology).[6]

"Singapore banned reproductive cloning in September 2004 but does permit "cloning for harvesting embryonic stem cells for research," according to *Modern Drug Discovery*.[7]

2. Funding and Venture Capital

Since 2000 and compared with India, Korea, Japan and Taiwan, "Singapore is by far the most aggressive in providing a ready pool of capital for immediate deployment in biotech companies," according to a 2002 story in *Business Times*.[8] Citing a report in *Asia Private Equity Review*, the *Times* article states that "Singapore's government has so far channeled more than $700 million into biotech funds. This includes … $568 million in the Biomedical Sciences Investment Fund and $120 million in other initiatives, including the Bio Innovation Fund, the Pharm Bio Growth Fund and Life Sciences Investments." In 2003, the Singapore government committed more than $600 million to its BioMedical Sciences Investment Fund, in sharp contrast to Hong Kong, with about $65 million in funds for biotech.[9]

In 2000, $17 million was jointly injected by Life Sciences Investment and ES Cell Australia Ltd. to conduct and commercialize embryonic stem cell research by the National University of Singapore, Monash Institute of Reproduction & Development, and the Israeli Hadassit Medical Research Services & Development.[10]

Some examples of government funding in Singapore follow:

- The Biomedical Research Council has funded more than $30 million for projects at Singapore's universities, hospitals and disease centers.
- The U.S. National Institutes of Health awarded a $1 million grant to the Genome Institute of Singapore.[11]
- In 2005, a joint project by A*Star's Institute for Infocomm Research and Johns Hopkins University also received an NIH research grant.[12]

Firms that set up operations in Singapore enjoy tax breaks, funding and other incentives. "Bio*One Capital manages $700 million in funds to invest in overseas or local projects with economic spin-offs to Singapore," according to the Biotechnology Industry Organization. "The BMS Innovate 'N' Create Scheme provides seed capital for startups." In addition, a BMS Proof of Concept plan, launched in 2003, provides pre-seed funding for domestic innovation.[13]

3. Clusters of Biotechnology

Singapore's first science park was built in 1980 and today houses about 300 companies, both foreign and domestic.[14] Five research institutes are situated at Biopolis, a 2 million-square-foot science complex near the National University of Singapore, which is also the location of pharmaceutical and biotech R&D labs employing more than 2,000 scientists in the public and private sectors.[15]

The Tuas Biomedical Park in western Singapore attracts global pharmaceutical and medical technology companies, and has additional areas under development.[16] It currently houses manufacturing operations from Merck, Novartis, Pfizer, Wyeth and CIBA Vision, among others.

The National University of Singapore, National University Hospital and Nanyang Technological University (NTU) have also attracted cluster development. NTU provides scholarships and stipends specifically to encourage students to pursue research careers in biology.[17]

4. University Technology Transfer Mechanisms

Both the National University of Singapore and Nanyang Technological University have tech transfer offices, known as INTRO and ITTO, respectively. Similarly, the Agency for Science, Technology and Research (A*STAR) facilitates industry access to institutional research through its IP-management and commercialization arm, Exploit Technologies.[18]

In 2004, the National University of Singapore Student Enterprise Program was launched to assist aspiring entrepreneurs from the university through funding support. It is open to full-time undergraduates, postgraduates and alumni within 12 months of graduation. The business venture, however, must have been initiated or conceived while the individual(s) were at the university.[19]

Singapore has several dozen commercial and government incubators. Many focus on the biotech and medical or health-care industries. The life-sciences incubator BioVenture Centre Singapore works in partnership with BD Technologies and Johns Hopkins University, having been established in 2002 as an extension of Bioventure Center RTP in North Carolina's Research Triangle Park. The Economic Development Board itself has an incubation unit to nurture new businesses with growth potential.

Singapore is also home to an island-wide network of "HOTSpots," or locations and facilities for "technopreneurs," a program launched by the Economic Development Board in 2002. These "HOT" (for Hub of Technopreneurs) sites bring together entrepreneurs and technology-related companies.

Although Singapore's policy framework is centralized, there appears to be little data-sharing among agencies and departments.

5. Commercialization Success: Patents and Licensing

Lynk Biotechnologies is Singapore's first privately funded biotech startup. The company was established in February 2000 by Professor Lee Chee Wee from the National University of Singapore with $1.16 million and has since pioneered techniques that reduce drug development time. "In September 2001, the company announced its discovery of a new class of compounds that are able to cure cancer in mice," according to a 2002 online article (www.sciencecareers.org). "When mice were injected once with these new compounds, their tumors disappeared 2 weeks later, with no signs of relapse. The company is currently testing the compounds on mice implanted with human tumors."

Singapore promotes international collaboration in biotech R&D. One example is the global pharmaceutical GlaxoSmithKline (GSK). The relationship between GSK and Singapore began over 30 years ago, when the company invested in an antibiotics manufacturing facility at Quality Road. Today GSK is one of the largest pharmaceutical investors in Singapore, with close to $600 million in fixed assets and 600 employees.[20]

Despite Singapore's strengths, global competition is tough, and high R&D costs deter investors, including VCs.

Endnotes:

1. Bio 2005. See: http://www.bio.org/events/2005/international/CountryProfiles.pdf#search ='bio%202005%20country%20profiles'.pdf.
2. "Singapore's Biomedical Sciences Industry Recorded Exceptional 33% Growth in Manufacturing Output for 2004." BMS Initiative Media Briefing. Jan. 31, 2005. See: http://www.biomedsingapore.com.
3. "Singapore Biomedical Sciences." http://www.biomedsingapore.com.
4. "Biomedical Sciences Industry Maintained Growth Momentum in 2005." BMS Media Briefing. Jan. 27, 2006. See: http://www.biomed-singapore.com.
5. Luther Rechtsanwaltgesellschaft mbH, in association with Ernst & Young. 2004. "Legal and Court System in Singapore." See: http://www.entersingapore.info/Business_Pilot/Bus03.htm.
6. Times Higher Education Supplement University Ranking Database. See: http://www.ntu.edu.sg/ home2003/kokc0001/THES.pdf.
7. Kling, Jim. 2004. "Drug Discovery in Singapore." *Modern Drug Discovery*. See: http://pubs.acs.org/ subscribe/journals/mdd/v07/i12/pdf/1204business2.pdf.
8. "Singapore is Asia's top investor in biotech sector." July 2002. *Business Times*. See: http://www.gene.ch/ genet/2002/Jul/msg00012.html.
9. "Global Bio-clusters." 2003 survey. See: http://www.biospectrumindia.com/content/BioSpecia_l/103081201.asp.
10. "Major Venture Capital Injection $17 Million Into Regenerative Medicine." Aug. 11, 2000, press release. Economic Development Board. See: http://www.biomed-singapore.com.
11. Ernst & Young. *Beyond Borders: Global Biotechnology Report.* 2005. See: http://www.ey.com/global/ content.nsf/International/Biotechnology_Report_2005_Beyond_Borders.
12. http://computerworld.com.sg/ShowPage.aspx?pagetype=2&articleid=1358&pubid=3&issueid=50.
13. Bio 2005.
14. UNCTAD. 2005. *World Investment Report*. See also: Zhang, Yuchua. 2004. "Effecting science park management for development: tracing the 20-year history of Singapore Science Park for experience and lesson." New Zealand: University of Waikato. See: http://blake.montclair.edu/~cibconf/conference/DATA/ Theme6/Australia.pdf.
15. Bio 2005.
16. "Tuas Biomedical Park." 2006. See: http://www.biomed-singapore.com/etc/medialib/bms_downloads/ newsroom/media_kit.Par.0008.File.tmp/Factsheet%20-%20TBP.pdf.
17. Niem, Andrea. 2004. Singapore Strives to Become Biotech Hub. See: http://www.voanews.com/english/ 2004-11-25-voa24.cfm.
18. Agency for Science, Technology and Research. See: http://www.a-star.edu.sg/astar/about/action/ about_astar_organisation.do.
19. National University of Singapore. 2005. See: http://www.nus.edu.sg/enterprise/newsletter/mar05/ success/sep.htm.
20. GlaxoSmithKline. http://www.gsk.com.

Taiwan, Republic of China

1. National Innovation Policy

Taiwan's efforts to develop its biotechnology industry date back to the early 1980s, when the government prioritized it among eight technology sectors key to economic development. In 1998, in an effort to better coordinate and facilitate research efforts, the government established the Frontier Program on Medical Gene Research, which spanned three years and funded 66 R&D projects.[1]

Academia Sinica has general oversight of implementation, coordination and standards of the country's research. Founded in 1928, the academy now comprises 25 research institutes, including the Molecular Biological Research Institute, the Biomedical Research Institute and the Genome Research Center.[2] In 2002, the government initiated the National Science and Technology Program in Genomic Medicine.[3]

Several Taiwanese biotech startups are conducting research in traditional Chinese medicine (TCM),[4] which involves personalized techniques and drug combinations, as opposed to uniform techniques and pure chemicals. The government is working to include TCM in the national health system so as to legitimize it as an orthodox therapy. Under the instituted regulations, TCM practitioners have to pass an examination before they are allowed to practice it; however, given the nature of TCM, it is still a challenge to completely institutionalize TCM.[5]

In contrast to Hong Kong, Taiwan does not have strict laws to govern technology transfers. As such, it is working to bring its tech transfer laws within international standards,[6] making it easier as well to absorb foreign technologies.

Taiwan's efforts to develop biotech can be best exemplified by the Promotion Plan for the Biotechnology Industry, initiated in 1995 and revised biannually.[7] Also in 1995, the nonprofit National Health Research Institute was established.[8]

In 1999, the government implemented the National Program for Pharmaceuticals and Biotechnology; the program was renamed in 2003 to the National Science and Technology Program in Pharmaceutical and Biotechnology[9] and "focuses on the development of new drugs, herbal medicine, and biochip technologies and analysis methodologies."[10]

Taiwan's ruling cabinet, the Executive Yuan, makes recommendations based on regular observations on the biotech industry. These led to the country's five-year Development Investment Plan,[11] the Foundation Law for technology development, establishment of Taiwan's Biomedical Engineering Center[12] and the Executive Yuan's "One-Stop Service Office for the Biotechnology Industry."[13] In 2002, "Challenge 2008," a six-year development plan with biotech as a key industry, was approved.[14]

However, despite Taiwan's efforts, the country still needs a more efficient legal system to support biotech growth. Under the S&T Basic Law, universities own and manage their R&D patents, but the high fees for filing and maintenance may result in conservatism.[15] Insufficient government funding to help researchers secure patents in 2000 resulted in universities having difficulty accumulating capital for the continuation of R&D.[16]

Taiwan lacks human capital.[17] The government thus adopted three strategies to resolve the human resource issue: Recruit trained scientists from abroad, strengthen current education programs and relax immigration policies for postdoctoral students.[18] In addition, the government is trying to lure back Taiwanese scientists working abroad.[19]

2. Funding and Venture Capital

"In 2002, the government allocated $495 million to bioscience research and development — 29 percent of the total national science budget — and an increase of 46 percent over the previous year's $339 million."[20] The government has also instituted R&D corporate tax incentives.

In 2002, the Executive Yuan documented government funding allocated to different biotech programs. More than $1 million targeted drug development for cancer treatment in a collaboration involving Tri-Service General Hospital, National Taiwan University, National Cheng Kung University and Taipei Medical University.[21] Also, a four-year program on genome R&D was initiated with close to $9.1 million.[22] In the same year, more than $1.5 million was allocated to develop startups working with traditional Chinese medicines over five years.[23]

In 2003, Taiwan's R&D budget for biotechnology reached over $50 million. Between 2000 and 2002, the R&D budget allocations were as follows: National Science Council (30.4 percent); Department of Health (20.4 percent); Ministry of Economic Affairs (16.1 percent); Council of Agriculture (21.6 percent); and Academia Sinica (11.5 percent).[24]

Government funding for nanotechnology totals almost $675 million[25] for the period 2003 to 2008.[26] Further expansion of clinical trial research is supported with up to 40 percent financing by Taiwan's Ministry of Economic Affairs.[27]

Taiwan is home to more than 220 private venture capital firms. VC biotech investment in 2001 totaled almost $64 million.[28] Taiwan's Science and Technology Advisory Group is developing a biotech VC fund "with initial capitalization of $1 billion." The integration of IT and biotech is a key focus for this mega-fund.[29] In 2005, the Executive Yuan directors approved some $280 million for "biotech venture seed funds."[30]

3. Clusters of Biotechnology

Taiwan's premier biotech hub is Hsinchu Science Park. Established in 1980, it attracts both domestic and international companies (15 percent in 2004).[31] To the north and south are two biomedical zones: the Hsinchu Biomedical Science Park (scheduled for completion in 2016) and anchored by the 600-bed National Taiwan University Medical Center; and Chunan Base, which houses the National Health Research Institute and Animal Technology Institute of Taiwan. The Hsinchu science park is located close to the National Hsing Hua University and National Chao Tong University.[32]

The Southern Taiwan Science Park, located between the cities of Tainan and Kaohsiung, began operations in 1996. As of late 2003, the park contained 116 companies, 24 of which (including ScinoPharm Tawian) were in the life sciences.[33]

ScinoPharm is an R&D and manufacturing services firm for the global pharmaceutical industry. According to its web site, the company's facilities are among "the largest stand-alone non-brand, multi-product API (active pharmaceutical ingredient) operations in the world." Its primary business focus includes custom synthesis for early-phase pharmaceutical activities, generic API manufacturing and brand company outsourcing.

Other clusters include the Neihu District and the Nankang Software Park, both located in the Taipei area. Biotechnology Plaza, which opened in 2003, is Taiwan's first biotech center focused on R&D. The Plaza draws upon the expertise and resources of nearby Academia Sinica, the Development Center for Biotechnology and major medical centers.[34]

4. University Technology Transfer Mechanisms

The Development Center for Biotechnology, set up in 1984, "is a nonprofit research institute and service-provider undertaking research at the pre-clinical stage."[35] The center's operations include: the transfer of academic research to industry, transfers of foreign biotechnologies to domestic industries, and consulting services on market and industrial information research for local and overseas enterprises.[36] The government has also established task forces for various R&D projects like artificial liver, cell cultivation and high frequency treatments, among others. These efforts are aimed at transferring results of research projects to startups.[37]

Most Taiwanese universities have offices that facilitate tech transfers. As documented by the National Science Council, these offices are fairly transparent through publicly listing their contact personnel and information. Both public and private universities are involved in tech transfers.

5. Commercialization Success: Patents and Licensing

Biotech research in Taiwan, as within the Asia-Pacific region generally, is mostly conducted by government laboratories and universities. It is advancing international alliances, albeit more slowly than its Asian competitors, particularly Singapore and Japan.[38] However, the government's efforts in initiating collaborations with universities "are likely to provide the much-needed impetus for the biotech industry," according to marketresearch.com.[39]

International R&D collaboration is emphasized in Taiwan's TaiGen, a leading biotech firm operating in Taipei, Beijing and Shanghai.

TaiGen Biotechnology was founded by Ming-Chu Hsu in May 2001. "Before her return to Taiwan in 1998, Dr. Hsu was Research Director for Oncology and Virology for over 10 years with Hoffmann La Roche," according to the company's web site. Her résumé includes an assistant professorship at Rockefeller University in New York and a research fellowship at Caltech and Stanford. She earned a Ph.D. in biochemistry from the University of Illinois.

The company focuses on the discovery and development of oncology drugs, as well as treatments for immune disorders and infectious diseases.

Endnotes:

1. Hung, Yu Shi. 1999. "Frontier Program of Medical Gene Research in Taiwan." http://www2. unescobkk.org/eubios/EJ91/ej91g.htm.
2. http://www.biopharm.org.tw/en/policy.html.
3. Biotechnology and Pharmaceutical Industries Program Office, MOEA, Taiwan. 2005. Taiwan's Biotechnology Policy and Promotion Status. http://www.biopharm.org.tw/en/policy.html. Accessed Sept 1, 2005.
4. http://www.biotecheast.com/modules.php?op=modload&name=News&file=article&sid=783&mode =thread&order=0&thold =0&topic=4.
5. Wiseman, Nigel. 2000. "Education and Practice of Chinese Medicine in Taiwan." http://www.paradigm-pubs.com/refs/TAIWAN.htm.
6. Nystedt, Dan. 2005." Taiwan May Increase Penalties for Illegal Tech Transfer." *InfoWorld*. April 28.
7. http://www.biotecheast.com/modules.php?op=modload&name=News&file=article&sid=783&mode=thread&order=0&thold=0&topic=4.
8. http://www.biopharm.org.tw/en/policy.html.
9. Ibid.
10. http://www.biotecheast.com/index.php?module=htmlpages&func=display&pid=21.
11. http://www.biopharm.org.tw/en/policy.html.
12. Ibid.
13. Executive Yuan. Biotechnology and Pharmaceutical Industries Programs Office. 2005. "Biotechnology in Taiwan White Paper 2002."
14. http://www.biopharm.org.tw/en/policy.html.
15. Hsiao, Kuan Hsiu. 2000. "The University Office of Technology Transfer: Taiwan." University of Washington School of Law. *CASRIP Symposium Publication Series*. 5.
16. http://biotech.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Fwww.taipeitimes.com% 2Fnews%2F2000%2F12%2F04%2Fstory%2F0000064145.
17. Feldman, Maryanne and Johanna Francis. 2004. "Homegrown Solutions: Fostering Cluster Formation." *Economic Development Quarterly*. Sage Productions.
18. http://www.marketresearch.com/product/print/default.asp?g=1&productid=1119092.
19. http://www.biotecheast.com/index.php?module=htmlpages&func=display&pid=21.
20. Ibid.
21. Executive Yuan. Biotechnology and Pharmaceutical Industries Programs Office. 2005.
22. Biotechnology Pharmaceutical Industries Program Office, MOEA, Taiwan.
23. Ibid.
24. http://www.biotecheast.com/index.php?module=htmlpages&func=display&pid=21.
25. Interest rate for 2003 used for calculation.
26. Dellah, Majid. 2004. "Science and Technology Overview. 2003: Taiwan." International Trade Canada, Trade Commission Service. http://www.infoexport.gc.ca/science/Taiwan_2003-en.htm.
27. www.taigenbiotech.com.
28. Executive Yuan. Biotechnology and Pharmaceutical Industries Programs Office.
29. Ernst & Young. 2005. *Beyond Border: Global Biotechnology Report*.
30. Ibid.
31. UNCTAD. 2005. *World Investment Report.*
32. Murray, L.W. and A.M. Efendioglu. 2003. "Clustering and the Development of Biotechnology in Taiwan." Paper presented at Conference on Clusters, Industrial Districts and Firms, Modena, Italy, Sept.
33. Biotech East. 2005. http://www.biotecheast.com/index.php?module=htmlpages&func=display&pid=5.
34. Ibid.

35. Ibid.
36. http://www.biotecheast.com/modules.php?op=modload&name=InfoResources&file=index&req= showcompany&cid=1846.
37. Executive Yuan. Biotechnology and Pharmaceutical Industries Programs Office. 2005.
38. Ernst & Young. 2005.
39. http://www.marketresearch.com/product/print/default.asp?g=1&productid=1119092.

The Americas:

Latin America Overview

Because biotech throughout Central and South America is concentrated in agriculture rather than life sciences, this regional analysis is brief and highlights some of the region's health-related biotech initiatives.

Nations in Latin America have signed on to numerous agreements and belong to consortiums aimed at promoting biotechnology. Most, however, lack systems for integrating the various elements of the R&D value chain. In general, nations that lead in biotech commit more than 1 percent of their GDP to research and development, but Latin America and Caribbean nations on average commit just 0.05 percent. Exceptions are Brazil, Chile and Mexico.[1] Furthermore, the high quality of intellectual and human capital necessary in biotech is often undermined by Latin America's lack of resources, regulations, incentives or organizations that could expedite commercialization.[2]

International organizations working to develop health-care biotech in Central and South America include the WHO Special Program for Research and Training in Tropical Diseases, the UNDP/UNESCO/UNIDO Regional Biotechnology Program for Latin America and the Caribbean, the Organization of American States and various Pan American Health Organization programs.

There have been several major successes for Latin American biotech transfer that stem from multinational cooperation. One such collaboration paired the regional biotech academic network Program of Science and Technology for Development (CYTED) with Chembio Diagnostic Systems in Medford, N.Y., for the production of kits for the detection of Chagas disease, a debilitating parasitic infection found predominantly in Central and South America.[3]

Argentina

The Ministry of Science and Public Education is the main governmental branch responsible for creating and implementing innovation policy. It governs the Secretariat of Science and Technology, which manages both the National Council for Scientific and Technical Research and the National Agency for the Promotion of Science and Technology — the organization responsible for financing R&D activities. Funding is allocated from national budgetary contributions, as well as credits from the Interamerican Development Bank. The Scientific and Technological Research Fund (FONCYT) and the Argentine Technological Fund (FONTAR) are responsible for dispensing these resources. In 2002, FONCYT supported more than 100 projects with funding of $6.3 million; FONTAR provided funding of approximately $9.6 million in support of about 20 enterprises.[4]

"Four percent of the total annual (pharmaceutical) sales (US$2 billion) correspond to biotech products protected by Argentine patent law," according to the country's profile at Bio 2005, and Argentina has also become the second-largest producer of genetically modified organisms (GMOs), following the United States.[5] Agrobiotech, particularly GMOs, is generally considered a priority over medical biotech because of the market demand.

Established in 1986, the nonprofit Foro Argentino de Biotecnología (Argentine Biotech Forum) works to encourage public awareness and collaboration between business and science. FAB also works in conjunction with the Argentine government to promote innovation policies supporting biotech.[6]

Brazil

With the promise of economic growth and improved legal support, Brazil has the infrastructure necessary to play a large role in biotechnology. The House of Representatives of the Brazilian Congress passed the Innovation Law in 2004 to improve the nation's ability to develop and commercialize technology.[7] Under the law and proposed changes, professors would be able to work for limited periods of time in the private sector without jeopardizing their academic positions.[8] The law also "requires universities to create Offices of Technological Innovation" that will focus on intellectual property and licensing.[9] Brazil's Patent Office is also undergoing reform to improve the patent granting process.[10]

The Ministry of Science and Technology and the Ministry of Health are the two major branches responsible for development of Brazil's biotech sector. In September 2005, the government announced nearly $5 million in funding for stem cell research.[11] Although the majority of biotech funding is from the federal government,[12] regional states, such as Minas Gerais and its capital, Belo Horizonte, are launching programs to develop biotech under the States Research Support Foundations.

Leading Brazilian biotech research universities include the Universidade Estadual de Maringá, the Universidade Federal de Santa Catarina and the Universidade Federal do Rio Grande do Sul, Porto Alegre. The university system is conducive to domestic collaboration as various academic centers establish collaborative "virtual institutes."[13] Furthermore, Brazil ranks relatively high in university/industry research collaboration, placing 28th among 104 countries.[14] It is estimated that there are approximately four researchers per 10,000 inhabitants, with 26 percent working in biological and health areas.[15]

> Latin America's first attempt at promoting innovative clusters was Brazil's creation of 13 "technological innovation nuclei in selected universities and research centers throughout the country in 1982."
>
> *— Carlos Quandt, 1999*

In terms of patents, Brazil did not emerge as a contributor until 1996, yet the number of scientific publications has been on a steady rise since 1991.[16]

The number of biotech firms in Brazil grew dramatically, from 76 in 1993 to 354 in 2001. Of these, about 70 percent are local private firms, 25 percent are multinational, and 5 percent are owned by the government. The health-care market constitutes just over one-quarter of their combined products; agricultural, industrial and environmental markets account for the remainder.[17] The Latin American Biotechnology Federation and ABRABI, the Brazilian Association of Biotech Companies, work to bring Brazil to the global biotech market.[18]

Chile

With a 2004 GDP growth rate of 5.8 percent,[19] Chile has been labeled the most competitive country in South America.[20] Its biotech industry is the third largest in the region, following Brazil and Argentina.[21]

Chilean-born Pablo Valenzuela earned a degree in biochemistry from the University of Chile, a Ph.D. in chemistry from Northwestern University and conducted postdoctoral research at UC San Francisco. In 1981, with two colleagues from UCSF, he co-founded the California-based biotech firm Chiron and served as its director of research until 1994, "overseeing the development of the recombinant hepatitis B vaccine, the sequencing of the AIDS virus and the discovery of the hepatitis C virus." Valenzuela later returned to Chile and founded the biotech company Bios Chile in 1986. He also holds professorships at the Universidad Católica de Chile and the Universidad Andrés Bello, where he directs the Ph.D. program in biotechnology. He helped establish the Life Sciences Foundation of Chile, which fosters ongoing collaboration between various UCSF schools and programs, and Chilean students and researchers.

The Chilean government has announced plans to reach 1 percent of GDP in science and technology spending by 2006.[22] It has created an infrastructure that could aid industry growth. The Chilean Economic Development Agency is the main source of support for the development of scientific and technological initiatives. Numerous funds have been established to finance the overall commercialization process. These include: the Fund for Advanced Research in Priority Areas; the National Fund for Scientific and Technological Development; the Fund for the Promotion of Scientific and Technological Development, which focuses on promoting the collaboration between academia and industry; and the National Fund for Technological and Productive Development, which encourages technology transfers. [23]

The Chilean Commission for the Development of Biotechnology and the National Commission for Scientific and Technological Research are the two main sources of political support.[24] In 2003, the government initiated the National Policy for Biotechnology Development to address "industrial development, R&D growth, biotech awareness, human resource training and development of a legal framework."[25]

Human resources in biotechnology remain small, compared to leading nations, but growth is promising. From 1990 to 2002, the number of scientists rose almost 57 percent, to 8,507; of those, about three-quarters work in universities.[26] As of 2002, approximately 600 people worked in the biotech industry.[27] The Universidad de Chile in Santiago and the Universidad de Concepción, particularly its Centro de Biotecnologia, are among the major universities conducting biotech research. Also important are the Centro de Biotecnologia at the Universidad Federico Santa Maria and Centro de Biotecnologia at the Universidad de la Frontera.

Alfredo E. de Ioannes, President of the Chilean Association of Biotechnology Businesses, said his country plans to attract foreign direct investment to advance the transfer of biotechnology expertise and fund further research. "Much of our efforts presently are on the development of a critical mass of researchers and diversity of disciplines at universities, and increased industrial R&D," he said.[28] The U.S. National Institutes of Health funds biotech in developing nations, especially related to disease that, according to de Ioannes, "may encourage students to study in the U.S. and return, spreading the knowledge."

About 95 companies work in biotech-related fields in Chile; the majority are academic startups.[29]

Mexico

Mexican biotech is a government priority under the National Program of Science and Technology. But R&D investment stood at less than 0.06 percent of GDP in 2001, and 95 percent of the nation's granted patents were owned by foreigners. The Biotechnology Committee of the National Council of Science and Technology, and of the National Academy of Sciences, uses academic and industry input to study the industry's weaknesses and propose areas for development and legislation.[30] The nation has yet to establish a clear innovation policy.

Most firms working in Mexico's biotech industry focus on the fermentation process and other agricultural applications, but at least 13 companies are working in health-related areas.[31]

"In 1990," according to a 2005 U.N. report, "Mexico started to create business incubators, with support of the National Council for Science and Technology, and from the Association of Incubators and Technological Parks."[32] In July 2004, the government announced the allocation of $196 million to create the National Institute of Genomic Medicine in Mexico City. The new center will conduct research on health issues found within Mexican populations.[33]

There are more than 110 institutions and some 750 researchers in Mexico conducting study into biotech-related areas. In addition, approximately a hundred Ph.D. students study biotech or related areas each year.[34]

Government funding generates government-owned technology; university tech transfer offices are virtually nonexistent.

Endnotes

1. Organization of American States. Inter-American Council for Integral Development. 2004. "Biotechnology for the Americas." First Meeting of Ministers and High Authorities of Science and Technology. Oct. 25. See: http://www.science.oas.org/Ministerial/ingles/documentos/Document_001.pdf.
2. Ibid.
3. Rangel-Aldao, Rafael. 2004. "Realities for Latin American and Caribbean Biotech." Correspondence. *Nature Biotechnology*, 22(1). See: http://www.nature.com/nbt/journal/v22/n1/full/nbt0104-20.html. See also: http://www.cdc.gov/NCIDOD/DPD/PARASITES/chagasdisease/factsht_chagas_disease.htm#what.
4. Bio 2005. See: www.bio.org/events/2005/international/CountryProfiles.pdf.
5. Ibid.
6. Foro Argentino de Biotecnología. See: http://www.foarbi.org.ar/ppal/english.php.
7. Páscoa, Maria Beatriz Amorim. "In Search of an Innovative Environment: The new Brazilian Innovation Law." See: http://www.wipo.int/sme/en/documents/brazil_innovation.htm.
8. Thorsteindóttir, Halla et al. 2005. "Different Rhythms of Health Biotechnology Development in Brazil and Cuba." *Journal of Business Chemistry.* 2(1). September. See: http://www.wirtschaftschemie.de/journal/ 20053-99-106.pdf.
9. "European Trend Chart on Innovation: Annual Innovation Policy Trends Report for United States, Canada, Mexico and Brazil. European Commission." 2005. See:http://trendchart.cordis.lu/reports/documents/Country Report_NAFTA-BRAZIL%20Countries_2005.pdf.
10. Bio 2005.
11. Almeida, Carla. "Brazil Announces US$5 Million for Stem Cell Research." Science and Development Network. 2005. See: http://

www.scidev.net/News/index.cfm?fuseaction=readNews&itemid =2333&language=1.
12. Bio 2005.
13. Ferrer, Marcela, H. Thorsteinsdóttir, U. Quach, P.A. Singer and A.S. Daar. 2004. "The Scientific Muscle of Brazil's Health Biotechnology," *Nature Biotechnology*. 22. (Supplement DC8).
14. Porter, Michael E., K. Schwab, X. Sala-i-Martin and A. Lopez-Claros. 2004. *The Global Competitiveness Report: 2004-2004*. Geneva: World Economic Forum.
15. Marques, Marília Bernardes. 2003. "Health-Related Biotechnology in Brazil: Some Regulatory and Ethical Considerations." *International Journal of Biotechnology*. 5(1).
16. Ferrer, Marcela et al. "The Scientific Muscle of Brazil's Health Biotechnology."
17. Ibid.
18. Brazilian Association of Biotech Companies. http://www.abrabi.org.br.
19. *CIA World Factbook*. See: http://www.cia.gov/cia/publications/factbook/geos/ci.html.
20. Porter et al. *The Global Competitiveness Report*.
21. As cited by C. Hernandez-Cuevas, P.D.T. Valenzuela. 2004. "Strategies to Capture Biotechnology Opportunities in Chile." See: http://www.ejbiotechnology.info/content/vol7/issue2/full/6/6.pdf.
22. Bradley, Ruth. 2005. "Biotechnology: A Silent Revolution," *Business Chile*. December. See: http:// www.businesschile.cl/portada.php?w=old&id=148&lan=en.
23. Hernandez-Cuevas, C. and P.D.T. Valenzuela. 2004.
24. Ibid.
25. Bio 2005.
26. Ibid.
27. Hernandez-Cuevas, C. and P.D.T. Valenzuela. 2004.
28. Bio 2005. Wallace, Lorna H. notes.
29. Bio 2005.
30. Ibid.
31. Ibid.
32. UNCTAD. *World Investment Report: Transnational Corporations and the Internationalization of R&D*. Chapter 7. "The Role of National Policies." 2005. See: http://www.unctad.org/en/docs/wir2005ch7_en.pdf .
33. http://genomebiology.com/researchnews/default.asp?arx_id=gb-spotlight-20040805-02.
34. Bio 2005.

Canada

1. National Innovation Policy

Canada's innovation policy is directed from the top, by the national science advisor to the prime minister. Governance of scientific technology, however, is not top-down decision-making, but linkages, networks and partnerships.

Industry Canada, the federal agency responsible for innovation strategy, was created in 1993, when the government united the responsibilities of several departments under one umbrella agency.[1] This joining of forces began three decades earlier, when a report by the Royal Commission on Government Organization (the Glassco Commission) found the government's science agencies lacked adequate oversight and coordination.[2] The ensuing 30 years saw a number of unsuccessful attempts to establish a national science and technology strategy.[3] The country's current regulatory policy was written in 2000 and is currently under review.

Industry Canada partners with the National Research Council, the Canadian Biotechnology Secretariat and the Canadian Institutes of Health Research. Private industry support is typically organized along sector lines,[4] limiting interdisciplinary and intra-system synergies.

In February 2002, the government released a national innovation strategy that emphasized, among other things, the commercialization of research.[5] Networks of Centres of Excellence (NECs) — research collaborations among universities, industry, government, investors and nonprofit organizations — constitute an integral part of this strategy. The NEC web site offers details: In 2003–2004, more than 880 companies, 243 provincial and federal government departments and agencies, 49 hospitals, 184 universities and more than 300 organizations were involved in the NCE program. During 2002–2003, NECs attracted over $41 million in investment capital, $16 million of which came from the private sector.[6]

2. Funding and Venture Capital

Canada lacks entrepreneurs; "angels" are largely absent. Canadian culture is risk-averse.

In 2001, the federal government spent more than $1 billion on university research.[7] Three departments and agencies accounted for the majority of biotech funding: the Canadian Institutes of Health Research; National Science and Engineering Research Canada, which funds OTTs throughout the country; and the Canada Foundation for Innovation (CFI), which funds infrastructure to support cutting-edge research. From its founding in 1997 to 2004, CFI committed almost $2.9 billion for 3,891 research infrastructure projects at 128 institutions in 62 municipalities.

> "Some of the biggest challenges facing Canada in commercializing new technologies are the lack of a culture of entrepreneurship, a shortage of skilled managers to lead and grow high-tech startups and gaps in the risk capital system for financing early-stage ventures."
>
> *— Arthur Carty, National Science Advisor to the Prime Minister*

The Biotechnology Industry Organization reports that in 2003, Canadian biotech firms invested more than $1 billion in R&D, 80 percent more than industry's funding support in 1999. In 2004, this investment increased by 224 percent over the total spending from 1998 to 2003.

Montréal is a major biotech center, with the Province of Québec receiving the largest share of biotech investment in Canada. This is despite the loss in 2004 of Québec-based VC activity in biopharmaceuticals and other life sciences. In 2004, 50 Québec companies received $122 million, down more than 30 percent from the total invested in 61 firms during 2003.[8]

Although U.S. VCs and other foreign investments were active in Québec during 2004, only a few American VC companies invested in the province's life-sciences industry.[9] G. Steven Burrill, CEO of Burrill & Co, a San Francisco-based life-sciences merchant bank, said that although his organization had VC money invested in roughly 50 U.S. and European-based start-up firms, the bank had not yet invested in a Canadian company.

3. Clusters of Biotechnology

Canada consists of 10 provinces and three territories, and has the second-largest land mass in the world. As a consequence, successful technology development in the country is dependent upon domestic and international coordination and collaboration.

> "Collaborate with a Canadian, and biotechnically speaking, you might just have the time of your life."
>
> — *James Peterson, Canadian Minister of International Trade*

Clusters of biotech exist throughout the country, most notably in Vancouver, Toronto, Montréal and Ottawa.[10] Toronto is home to 40 percent of Canada's biotech companies and is one of the largest biotech research centers in North America. But Montréal, with its focus on drug development, is the leading Canadian biotech cluster. Every major international pharmaceutical company has facilities in Montréal, drawn by dozens of research centers and thousands of health-science graduates from Québec universities. More than 300 biotech firms (and the highest concentration of biotech startups in Canada) employ about 24,000 workers in the area. The city is home to about 125 public and para-public research organizations, including four universities: Université de Montréal, McGill University, Université du Québec à Montréal and Concordia University.[11]

Biotech businesses in Ontario serve diagnostic, therapeutic, agri-bio, chemical, environmental and supplier markets.[12] MaRS, the Medical and Related Sciences discovery district, is the focal point for commercialization of university research and the hub of future tech transfer activities in the province.

In Edmonton, the University of Alberta works with the National Institute for Nanotechnology, which opened in 2001. Edmonton's biotech community is part of the larger nanotechnology cluster that has been growing for the past 20 years, thanks to the university's strength in nanotech, engineering, medicine and computer science.[13] Westlink, located in Calgary, is a best-practice innovation cluster that promotes the commercialization of members' scientific inventions.[14]

Vancouver's cluster comprises more than 90 privately owned firms in the health-care sector, as well as six clinical-trial organizations, several government facilities and a major research center at the University of British Columbia. More than 2,500 employees work directly in the biotech industry, with another 1,100 at pharmaceutical firms. Long-awaited revenues are beginning to flow into Vancouver's biotech cluster. QLT Inc. has been selling its Visudyne drug for several years, and Angiotech, one of the area's most successful firms, is profiting from Boston Scientific, which uses the company's paclitaxel drug for its coronary stent system. Xenon Pharmaceuticals recently signed a $157 million deal with Novartis to develop drugs for obesity and metabolic disorders.[15]

4. University Technology Transfer Mechanisms

More than a hundred teaching hospitals and research institutes are affiliated with 16 universities, according to the Biotechnology Industry Organization.[16]

Until 1991, ownership of IP rested with the federal government. Since then, IP ownership has been decentralized, varying from university to university. Revenues are divided among scientists and institutions based upon fixed percentages or highly negotiated terms. Simon Fraser University in British Columbia, for example, grants 100 percent of net revenues from commercialization to the innovator (including students and co-creators).[17]

PARTEQ, a nonprofit organization that has been affiliated with Queen's University at Kingston, Ontario, since 1987, assists in the commercialization of IP from university-generated research. Since its founding, PARTEQ has returned more than $20 million to the university and its inventors.

"Stove pipes" of isolation exist among science and business faculties within some Canadian universities; faculty interaction is rare. Stronger linkages within and among universities, more networking with industry and scientists with business management skills would facilitate the transfer of technology from university labs to Bay Street.

5. Commercialization Success: Patents and Licensing

The Biotechnology Industry Organization reports that Canada had the fastest rate of growth in external patent applications and industrial R&D investment among the G7 nations and cites a KPMG study also in which Canada ranks first in terms of cost competitiveness for biomedical R&D, compared to other industrialized nations. Canada has the second highest number of biotech companies in the world; more than 500 products are in Canada's biopharma product pipeline.[18]

Recent research by Statistics Canada finds that, as in many other countries around the world, university inventions are rare, only a fraction reach the market and an even smaller number produce significant income.[19] In 2003, Canadian universities and research institutions spent more than $2.6 billion on research and reported 1,177 inventions, with only 350 resulting in prospects for commercialization. On average, research expenditure per invention costs about $2.2 million in Canada, as opposed to $2.5 million in the United States.[20]

University of British Columbia

UBC, incorporated in 1908, is Canada's third-largest university and the second-largest employer in the province. Faculty members receive approximately $250 million a year in research funding from government, industry and nonprofit foundations. UBC researchers are members of 21 of the 22 networks funded under the Networks of Centres of Excellence program. They conduct more than 4,000 projects a year. In June 2005, *The Scientist* ranked UBC one of North America's top 10 universities for both the quantity and quality of life-sciences patents. As of March 2004, its OTT facilitated some 115 spin-offs.

The late Michael Smith, Ph.D., a former UBC faculty member and 1993 Nobel Prize winner, made a small fortune in 1988, when he sold his share of Zymogenetics Inc., a Seattle-based biotech spin-off he had co-founded in 1981. His genetic engineering techniques were commercialized to produce human insulin.

More than 30 Canadian universities responded to the most recent annual Association of University Technology Managers survey. These universities reported issuing 150 patents, forming 45 startup companies and receiving adjusted gross licensing income of over $54 million in 2004. As in previous years, the data are somewhat skewed. For example, seven of the reporting universities were not issued any patents; fewer than 50 percent were successful at any startup formation; and eight received no licensing income in 2004. The University of British Columbia topped the list for licensing income received, reporting almost $14 million.

McGill University

McGill is Canada's leading research-intensive university. Nobel Prize-winning alumni include Andrew Schally (Medicine, 1977); Val Fitch (Physics, 1980); David Hubel (Medicine, 1981); and Rudolph Marcus (Chemistry, 1993).

In 2002–2003, McGill signed 148 new contracts worth nearly $12.7 million. Investigators at the university's Health Centre Research Institute disclosed 74 inventions since 1997 and created more than 25 biotech startups, which employ more than 1,500 people.

AUTM reports that McGill received more than $1.5 million in gross licensing income in 2004 and formed five startup companies. During that same year, it was issued 30 U.S. patents, the most of any university in Canada; only UBC (18 patents), the University of Alberta (13 patents) and Université Laval (11 patents) reported double-digit success in this category.

As of July 2004, McGill had received close to $160 million from the Canada Foundation for Innovation. Because CFI grants are matched by Recherche Québec and other funding partners, almost $400 million was invested in research facilities and technology at the university.

Endnotes:

1. Including: Industry, Science and Technology Canada and programs from the Department of Communications; the market and business framework responsibilities from Consumer and Corporate Affairs Canada; and investment research, policy and review functions from Investment Canada. See: http://www.ic.gc.ca/ cmb/welcomeic.nsf/ICPages/Milestones#actionplan.
2. As cited in the documents "Science and Technology: The New Federal Policy," prepared for distribution by staff of the Parliamentary Research Branch of the Library of Parliament. See: http://www.parl.gc.ca/ information/library/PRBpubs/pb414-ehtm.
3. Auditor General's 1994 Report to Parliament, Section 9.95.
4. A 2004 study: http://strategis.ic.gc.ca/epic/internet/inict-tic.nsf/vwapj/107730e.pdf/$FILE/107730e.pdf.
5. www.innovationstrategy.gc.ca.
6. http://www.nce.gc.ca/about_e.htm.
7. OECD. 2003. *Turning Science Into Business: Patenting and Licensing at Public Research Organisaitons.*
8. http://www.lifesciencesworld.com/pages/articles_eg/reseau-capital/reseau-capital.htm.
9. www.reseaucapital.com.
10. Bogomolny, Laura, C. Gagne, B. Guthrie and D. Calleja. 2004. "Biotech Nation," *Canadian Business*. 77.
11. http://strategis.ic.gc.ca/epic/internet/inict-tic.nsf/vwapj/Montreal_e.pdf/$FILE/Montreal_e.pdf.
12. Bagchi-Sen, Sharmistha, L. Hall and L. Petryshyn. 2001. "A study of university-industry linkages in the biotechnology industry: perspectives from Canada," *International Journal of Biotechnology*, 3(¾).
13. Bogomolny, Laura, C. Gagne, B. Guthrie and D. Calleja. 2004.
14. www.westlink.ca/. Westlink is a concept first discussed in 1994. Initial efforts to form a network were carried on under the name Western Canadian Universities Tech. Network, incorporated in 1999, known as the Canadian Technology Transfer [Western] Network Ltd. UBC is a member organization.
15. Bogomolny, Laura, C. Gagne, B. Guthrie and D. Calleja. 2004.
16. Bio 2005.
17. For a breakdown of Canadian university IP policies, see Clayman, Bruce. 2004. Vancouver, B.C.
18. Bio 2005.
19. http://communications.uwo.ca/western_news/opinion.html?listing_id=18039.
20. Ibid.

United States

1. National Innovation Policy

The global biotechnology industry is dominated by the United States, where it originated — with Genentech in 1976.[1] This is due in large part to the direct and indirect role of the government in setting the environment for innovation.[2] The passage in 1974 of the Employee Retirement Income Security Act, or ERISA — allowing pension fund managers to invest in startups — laid the groundwork for expansion of the industry. "The amazing growth that America has enjoyed in venture capital has come from this legal policy," wrote Alfred Berkeley III, former president and vice chairman of the Nasdaq Stock Exchange, in 2004. "Venture funds are creatures of the pension industry."[3]

In 1980, Congress passed two bills that inaugurated an era for the transfer of publicly funded intellectual property to private firms: the Stevenson-Wydler Technology Innovation Act, which facilitates the transfer of technologies originating and owned by federal labs to the private sector (amended by the Federal Technology Transfer Act of 1986); and the Bayh-Dole University and Small Business Patent Act, permitting small businesses, universities and nonprofit institutions to retain title to inventions resulting from federally funded grants and contracts.

These acts revolutionized the management of intellectual property in universities; they allowed individuals to leapfrog previously formidable barriers, license technology and create spin-off and startup companies. The provisions of the Bayh-Dole Act — which *The Economist* called "possibly the most inspired piece of legislation to be enacted in America over the past half century" — established university property rights over federally funded inventions and encouraged universities to promote the transfer of those inventions to commercial use.[4]

Small Business Innovation Research Program grants, established in 1982, also assist commercialization.[5] Research shows that SBIR-funded startups affiliated with academic scientists perform significantly better than non-linked SBIR firms, in terms of follow-on VC funding.[6] Small biotech firms with more than 51 percent VC ownership do not qualify for SBIR grants.[7]

More recently, the government increased IP enforcement capabilities, implemented the National Cooperative Research Act to reduce antitrust restrictions and emphasized global protection of IP rights in trade negotiations.[8] The government has also used more structured models of biotechnology regulation, such as congressional bills (beyond appropriations legislation) and presidential executive orders. The Technology Administration, within the U.S. Department of Commerce, addresses trade issues, industry standards and research investments.

The tragedy of September 11, 2001, and the anthrax attacks that soon followed, increased America's focus on innovations in defense technology. Congress created the following programs (which had a combined 2005 budget of $64 million):

- the *2003 Defense Acquisition Challenge Program*, which expands opportunities for emerging defense suppliers and widens the U.S. defense industrial base;
- the *Technology Transition Initiative*, which accelerates the introduction of new technologies into operational capabilities for the armed forces;
- the *Quick Reaction Fund*, which fields and tests prototypes designed for immediate and emerging war-fighter needs.[9]

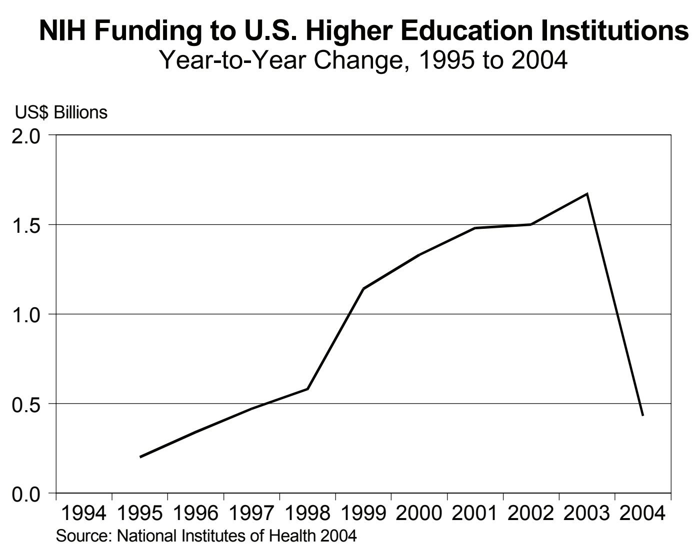
Historically, R&D funding was largely driven by national security concerns, with military services dominating the federal R&D budget and, in many years, counting for more than half of federal R&D obligations.[10] After the end of the Cold War, federal research funding became less military- and more civilian-driven, but the post-9/11 threat of terrorism has swung the pendulum back again.

America's National Nanotechnology Initiative (NNI), established in 2001, and the 21st Century Nanotechnology Research and Development Act (2003) provide funding for research. Annual NNI-related funding is up 112 percent from $464 million in 2001 to a requested $982 million in 2005.[11] The United States leads the world in nanotechnology R&D, in the number of nanotech startups and in research output, measured by patents and publications. This position, however, is under increasing competitive pressure. In 2005, federal allocations for nanotechnology R&D totaled about $1 billion, but that is just 25 percent of current global investment. Around the world, nations have increased their investment in nanotech since 2000, but in the United States, federal allocations are leveling off, and President Bush's 2006 request for the NNI decreased by 2 percent.[12]

2. Funding and Venture Capital

The federal government leads the world in support of academic research. The National Science Foundation and National Institutes of Health reinforce university commitment to research. The NIH, part of the federal Department of Health and Human Services, is the primary agency for conducting and supporting medical research, and directs the type and extent of most major biotech research activities. In 2003, the government funded more than $24 billion for academic research, the highest level since 1985 and representing close to 62 percent of total academic funding that year, up from just over 60 percent in 2002. But belt-tightening for 2006 has cut back NIH spending for the first time since 1970 and leaves the NSF with a negligible increase.[13]

The following graph depicts NIH funding to higher-educational institutions from 1995 to 2004. Data show that NIH funding increased from 1994 to 2004, but grew at a decreasing rate after 1999.



Increasingly, state and local governments are creating technology development initiatives to attract domestic and foreign direct investment. In 1999, the State of Michigan announced a spending initiative, totaling $50 million per year for 20 years, to build a life-sciences corridor. Innovation Philadelphia, a public-private collaboration, promotes area resources and entrepreneurial development. Illinois is a best-practice example of stakeholder collaboration in nanotech initiatives. The Illinois governor's office works with the Chicago mayor's office, as well as universities, corporations, startups, nonprofits and investors. In all, more than 40 states have announced initiatives to improve local and regional economic development in the life sciences. Twenty-two states and territories receive assistance from the National Science Foundation Experimental Program to Stimulate Competitive Research.[14] In the Boston and Cambridge area, clusters of universities, businesses and trade associations facilitate biotech R&D.

In 2004, state and local governments poured more than $400 million into nanotechnology research, facilities and business incubation programs, aiming to attract more of the $1 billion being disbursed at the federal level. State-supported academic R&D rose 5.9 percent between 2002 and 2003, but represents just 6.6 percent of the total research investment. That percentage share has shrunk from 15.1 percent in 1950, even as total state support has grown.[15]

Industrial funding focuses on applied R&D. Many global biopharmaceutical companies are investing in U.S. industrial R&D and drug development research.[16] However, total industry support for academic R&D in 2004 ($2.1 billion) was down for the third straight year. Industry's share of total academic R&D fell from 6 percent in 2002 to 5.4 percent in 2003 and to 4.9 percent in 2004.[17] According to a report from the National Science Foundation, which conducted a "Survey of Research and Development Expenditures at Universities and Colleges," "The industrial sector is the first source of academic R&D funding to show a multiyear decline since the survey began, in fiscal year 1953."[18]

In October 2004, the federally funded National Cancer Institute committed $144 million to nanotech research. Approximately 40 percent of nanotech VC since 1998 has gone to life-sciences startups.[19]

Although America leads the world in the availability of venture capital, there is still a shortage of funds for biotechnology. Over the past few years, however, VC funding in the industry has shown steady growth. G. Steven Burrill, CEO of Burrill & Co., a life-sciences merchant bank, said that in 2004 the U.S. biotech industry raised over $20 billion in debt and equity capital, breaking previous records for cash generated through partnering ($10.9 billion), debt transactions ($8.4 billion) and VC investment ($3.7 billion). Furthermore, the industry exited the year with a market cap of $400 billion, up 14.5 percent over 2003 (down from the nearly $500 billion during the market hyperactivity surrounding genomics in 2000).[20] Some traditional pharmaceutical firms, for example, Eli Lilly and Company with its Lilly Ventures, have created their own VC funds, which also invest in biotech companies.

> Memory Pharmaceuticals, a company started by Columbia University's Eric Kandel (and which recently moved to New Jersey), got its start in 1998 by licensing Nobelist Kandel's discoveries. The firm received early-stage financing from Venrock Associates, the New York City-based VC arm of the Rockefeller family fortune that also provides seed financing to a number of life-sciences companies in New York.

The United States ranks first worldwide in biotech venture capital. Total VC in the nation is estimated at over $20 billion in 2004. The biotech's industry share totaled $5.849 billion (29 percent), up from the 2001–2003 average annual U.S. biotech VC funding of $2.7 billion.[21]

California's No. 1 ranking for biotech funding ($2.36 billion) is mainly the result of its strong centers in San Francisco, San Diego, San Jose, Oakland, Los Angeles and Orange County.[22] Second- and third-ranked states for VC biotech funding in 2004 are Massachusetts ($976.9 million) and Pennsylvania ($351.2 million).[23] The Boston metropolitan area is home to many firms aided by nano- and biotech VC in their initial growth phase.[24]

- The New York-based financial consulting firm Frost & Sullivan reported 2004 investment from biotech firms totaling almost $17 billion out of approximately $47 in total revenues.
- The Biotechnology Industry Organization's (BIO) estimate for 2003 is $17.9 billion.
- PhRMA published a figure of $10.5 billion for non-PhRMA member biotech R&D in 2003.
- Hamilton Moses (et al.) report that industry sponsored 57 percent of biomedical research funding in 2003.

Journal of the American Medical Association, Sept. 2005

In an earlier study of 12 metropolitan areas, the Milken Institute found that San Jose, Calif., America's leading VC center, garnered more than 15 percent of total U.S. biotech VC between 2000 and 2003.[25] New Jersey's VC funding was powered by its biopharmaceutical industry. In Colorado, several biopharmaceutical companies play a pivotal role in locating new VC investment. Colorado is home to a large number of dedicated pharmaceutical and biotech companies, including Array BioPharma, a drug discovery company in Boulder that creates a new small-molecule drug, and Roche Colorado Corporation of Boulder. Among the state's larger companies are Amgen, Sandoz and Geneva Pharmaceuticals, a leading generic pharmaceutical manufacturer and marketer.[26]

Support from private foundations, voluntary health organizations and institutes increased 36 percent (when adjusted for inflation) from 1994 to 2003, from $1.8 billion to $2.5 billion.[27]

3. Clusters of Biotechnology

California has several of the nation's leading biotech clusters, including San Francisco, San Diego, San Jose, Oakland, Los Angeles and Orange County. The East Coast has Boston, Philadelphia and Washington, D.C., with Raleigh-Durham, N.C., a leading newcomer in the biotech cluster race. Seattle and Austin, Texas, also appear to be biotech cluster contenders.[28]

San Diego, with particular strength in R&D assets, is a good example of cross-institutional, inter-disciplinary biotech clustering. The Scripps Research Institute, the Salk Institute for Biomedical Studies, the Burnham Institute and the University of California, San Diego, provide a rich knowledge base for the region, which also has a disproportionate share of locally produced Ph.D.s attracted to the industry, as opposed to academic research, a key advantage for commercialization success.[29]

NanoBioNexus is a San Diego nonprofit that facilitates communication and relationships among scientists, entrepreneurs, technology experts and VCs. In its first year of operation, the organization was invited to join UC San Diego, UC Riverside, UC Santa Barbara and other institutions in a $20.5 million grant application for the creation of a Cancer Center of Nanotechnology Excellence in San Diego, one of seven such centers the National Cancer Institute committed funds to create in 2005.[30] UCSD serves as the lead institutional member, and NanoBioNexus as the center's education administrator for participating research institutions and their tech transfers.

"On the Upper East Side of Manhattan — within a 10-block span between 63rd Street and 73rd Street — is assembled one of the most prestigious biomedical communities in the world," noted *The Scientist* in November 2004. "Located here are Weill Medical College and Graduate School of Medical Sciences of Cornell University — with its major clinical partner New York-Presbyterian Hospital; The Rockefeller University; Sloan-Kettering Institute; and Hospital for Special Surgery — powerhouses of scientific pursuit and discovery."

The competition for clinical trials is fierce, so in 1998, the Montefiore Medical Center, NYU School of Medicine, Mount Sinai School of Medicine, North Shore-Long Island Jewish Health System and Saint Vincent Catholic Medical Centers founded the Biomedical Research Alliance of New York (BRANY). Each contributed $1.5 million to create the group, whose goal is to attract pharmaceutical trials to the area. So far, BRANY has facilitated some 700 clinical trials for such clients as AstraZeneca, Pfizer, Merck, Sanofi, Eli Lilly and Amgen, as well as numerous contract research organizations, and is currently involved in 400 ongoing trials.

New York is also home to the Nanobiotechnology Center, which promotes collaborative research among scientists and engineers from Cornell University, the Wadsworth Center (New York State Health Department in Albany), Princeton University, Oregon Health and Science University, Clark Atlanta University and Howard University. It involves the active collaboration of K–12 educators, the Sciencenter Museum in Ithaca, industry and government.

4. University Technology Transfer Mechanisms

According to federal law, universities must share royalty income with their scientists. While the percentages differ, net tech transfer revenues are generally divided as follows: one-third to the scientist(s), one-third to university department(s) and one-third to universities' overall budget funds.[31]

In recent years, universities have begun to realize that many kinds of intellectual property are created in the course of academic research and that certain types of IP may require different treatment, either with regard to ownership of the IP or the institution's policies for sharing revenue from its licensing.[32] At the University of Virginia, for example, scientists can reap substantial gains. The university uses a fairly common tiered approach to distribute royalty income, with the inventor's share starting at 50 percent of gross revenues, depending upon the amount of cumulative royalties paid. University–scientist sharing is determined by a "patent family" approach. If $100,000 is received under a license for two patents covering the product, and the two patents are not in the same "patent family," half the money is attributed to the first patent and half to the second. This slows the approach to the lower tiers of the distribution schedule, ensuring that faculty receive a greater percentage of revenues.

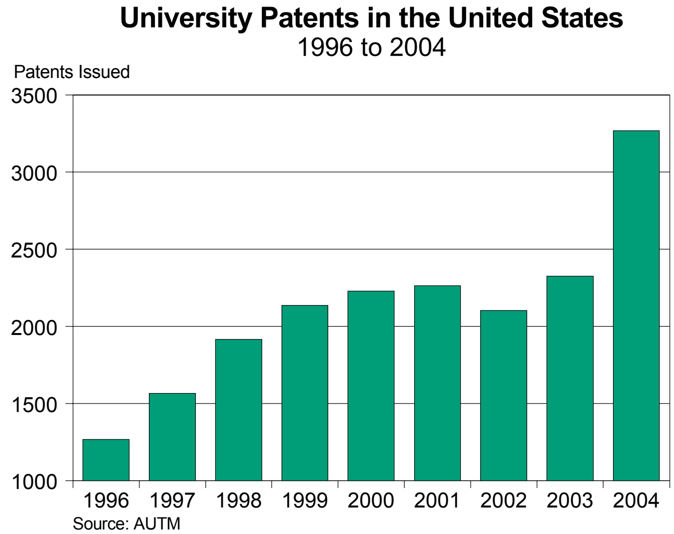
Generally, in the United States, university polices require that research results generated at the university be publishable, and that any resulting IP from research projects developed by university employees with university resources belongs to the university. In this context, industry sponsors receive an exclusive (or non-exclusive) option to license patents and commercialize inventions arising from research they sponsor, and the government is granted a non-exclusive license to patents from federally funded research. If joint private-public funding is involved, the company's rights are subject to the university's obligations to government.

Research shows that royalty-bearing licenses motivate university scientists more so than patent title assignments.[33]

5. Commercialization Success: Patents and Licensing

In the past five years, biotech-related patent filings have increased some 46 percent, and pharmaceutical and chemical-related filings climbed approximately 42 percent. With some of these applications filed on CD-ROMS containing up to a million paper pages or more of information, the system is severely strained. According to Joanne Hayes-Rines, publisher of *Inventors' Digest,* increased delays at the USPTO are obstacles to success.[34]

Prior to 1981, fewer than 250 patents were issued to universities in America each year.[35] In 1996, this number rose above 1,200 patents, and it climbed to more than 2,300 in 2004 (although there was slight a drop in 2002). In addition, more universities are following up research with patents. The Association of University Technology Managers survey results reveal that 3,268 patents were issued at U.S. universities in 2004; at least one patent was issued to 149 universities.



In many cases, neither prestigious universities nor large public campuses generated patents in the early 1980s. They were relative latecomers to tech transfers, creating formal OTTs later in the decade. Nevertheless, these institutions showed dramatic increases in relative patent rankings and, in three cases (Columbia, Emory and Rutgers), sizable increases in academic reputation.[36]

In a survey of technology transfer offices, Jensen and Thursby found that only about 12 percent of the licensed technology in the United States is ready for commercialization.[37] Most licensed technology requires significant developmental work and ongoing cooperation by faculty to realize commercial success,[38] and it is common for universities to file provisional applications on the lion's share of their disclosures.

Small startups dominate the commercialization of America's industrial research, with universities, government and corporate establishments functioning as important incubators for innovation. This pattern is especially evident in biotechnology.[39] For example, approximately 25 percent of scientists who receive funding from the National Cancer Institute start new firms.[40] The results of the Association of University Technology Managers survey reveal that total U.S. university gross licensing income exceeded $922 million in 2004, and that more than 400 startup companies were formed.

In June 2005, the National Governors Association adopted the first major revisions of its National Research, Development and Technology Policy Position statement since 2003. It calls for greater partnerships between states and the federal government to accelerate technology commercialization.[41] Such recommendations address the need for diligence and continual review of the commercialization process. This is especially necessary since less than a third of disclosed inventions result in licenses and startups garner only one in eight licenses.[42]

Endnotes:

1. DeVol, Ross, Perry Wong, Armen Bedroussian, Lorna Wallace, J. Ki. Daniela Murphy and Rob Koepp. 2004. *Biopharmaceutical Industry Contributions to State and U.S. Economies*. Santa Monica: Milken Institute. See also: H.L. Smith. 2002. "The Biotechnology Industry in Oxfordshire: Dynamics of Change," at "The Economics and Business of Bio-Sciences & Biotechnologies: What can be learned from the Nordic Countries and the UK?" conference in Götenborg, Sweden.
2. DeVol and Wallace have written on the effects of federal legislation on stem cell research funding and student immigration procedures in the United States, particularly the impact of policy on the ability to attract and retain top research scientists and maintain a competitive advantage. *Milken Institute Review.* 2005.
3. Berkeley III, Alfred R. 2004. "The Economic Impact of University Technologies: Guest Commentary." *Journal of the Association of University Technology Managers.* Summer.
4. Feldman, M. P., I. Feller, J. E. L. Bercovitz and R. M. Burton. 2002. "Equity and the Technology Transfer Strategies of American Research Universities." *Management Science*, 48. Note: Two additional major U.S. policy initiatives include: amendments to the Stevenson-Wydler Technology Innovation Act, specifically the Federal Technology Transfer Act and National Competitiveness Technology Transfer Act; and the Small Business Innovation Development Act (see Feldman and Francis, 2004). See also: http://radio.weblogs.com/0114726/2002/10/21.html.
5. This is mandated by the Small Business Innovation Development Act (1982), the Small Business Research and Development Enhancement Act (1992) and the SBIR Program Reauthorization Act (2000).
6. Toole, Andrew A. and Dirk Czarnitzki. 2005. "Biomedical Academic Entrepreneurship Through the SBIR Program." *NBER Working Paper*. No. 11450, June.
7. http://www.nvca.org/pdf/SBIR-Update-7-05.pdf. See also: http://www.nvca.org/med_policy-agenda.html.
8. Mowery, David and Nathan Rosenberg. 1998. *Paths of Innovation: Technological Change in 20th Century America*. New York: Cambridge University Press.
9. http://www.gao.gov/docsearch/abstract.php?rptno=GAO-05-480.
10. Mowery, David and Nathan Rosenberg. 1998.
11. http://www.nano.gov/html/about/funding.html.
12. The National Nanotechnology Initiative at Five Year: Assessment and Recommendations of the National Nanotechnology Advisory Panel. See: http://www.ostp.gov/PCAST/pcast.html.
13. *SSTI Weekly Digest*. Sept. 12, 2005. See also: http://www.washingtonpost.com/wp-dyn/content/article/2006/02/05/AR2006020501058.html.
14. For details see: www.her.nsf.gov/epscor.
15. *SSTI Weekly Digest*, Sept. 12, 2005.
16. DeVol, et. al., 2004. *Biopharmaceutical Industry Contributions to State and U.S. Economies*. Milken Institute. October. See also: Mansfield, Elaine. 2003. *Emerging U.S. Biopharmaceutical Companies: New Drug R&D and Investment/Partnership Opportunities*. Multimedia Research Group, Inc.
17. *SSTI Weekly Digest*. Sept. 12, 2005 and May 4, 2006. See also: http://www.cra.org/wp/ index.php?cat=10.
18. "Industrial Funding of Academic R&D Continues to Decline in FY 2004." National Science Foundation. April 2006. National Science Foundation, http://www.nsf.gov/statistics/infbrief/nsf06315/.
19. *SSTI Weekly Digest*. Sept. 12, 2005.
20. http://www.pharmalive.com/magazines/medad/view.cfm?articleID=2302.
21. Biotech is defined here by codes 3254 and 5417102 under the NAICS. Our source for VC funding is PricewaterhouseCoopers/Venture economics. Note: national total is based on a 4th quarter 2004 estimate.
22. DeVol, et al. 2004. *America's Biotech and Life Science Clusters — San Diego's Position and Economic Contributions*, Santa Monica: Milken Institute.
23. See: DeVol, Ross, Rob Koepp, Lorna Wallace, Armen Bedroussian and Daniela Murphy (with Perry Wong, Kevin Klowden, Anna Babayan and J. Ki). 2005. *The Greater Philadelphia Life Sciences Cluster: An Economic and Comparative Assessment*. Santa Monica: Milken Institute, for an analysis of life science activities in the state.

24. DeVol, et al. 2004.
25. Ibid
26. Ibid.
27. *JAMA*. 2005. September. See: www.the-scientist.com/2005/12/5/18/1.
28. DeVol, et al., 2004.
29. Ibid.
30. http://www.nanobionexus.org/files/news/Anniversary1.doc and http://www.nanobionexus.org/files/ news/NBN_Support_CCNE_Apr2006.pdf
31. Bastani, Behfar, Evelyn Mintarno and Dennis Fernandez. 2004. *University Tech Transfer: Licensing Intellectual Property from Universities.* Larta Institute.
32. Glass, David. 2004. *Revenue Distribution Report*. D. Glass Associates Inc.
33. De Juan, Veronica. 2002. "Comparative Study of Technology Transfer Practices in Europe and the United States," *Journal of the Association of University Technology Managers*, XIV.
34. Michael, Tom. 2005. "Slow Going at the Patent Office." *TechComm, The National Journal of Technology Commercialization*, February/March
35. http://www.cogr.edu/docs/BayhDoleQA.htm.
36. Owen-Smith, Jason. 2003. "From Separate Systems to a Hybrid Order: Accumulative Advantage Across Public and Private Science at Research One Universities." *Research Policy*.
37. Jensen, Richard A., M. Thursby and J. Thursby. 2003. "The Disclosure and Licensing of University Inventions." NBER WP 9734.
38. Feldman, M. P., I. Feller, J. E. L. Bercovitz and R. M. Burton. 2002. "Equity and the Technology Transfer Strategies of American Research Universities." *Management Science*, 48.
39. Wu, Weiping. 2005. "Dynamic Cities and Creative Clusters," World Bank Policy Research, WP #3509.
40. Audretsch, David, Taylor Aldridge and Alexander Oettl. 2006. "The Knowledge Filter and Economic Growth: The Role of Scientist Entrepreneurship." Draft WP, March.
41. http://www.westgov.org/wga/policy/05/competitiveness.pdf.
42. http://www.ssti.org. Aug. 1, 2005.

About The Authors

About the Authors

Ross DeVol is Director of Regional Economics at the Milken Institute. He oversees the Institute's research on the dynamics of comparative regional growth performance, and technology and its impact on regional and national economies. He is an expert on the intangible economy and how regions can prepare themselves to compete in it. He authored the groundbreaking study *America's High-Tech Economy: Growth, Development, and Risks for Metropolitan Areas*, an examination of how clusters of high-technology industries across the country affect economic growth in those regions. He also created the Best Performing Cities Index, an annual ranking of U.S. metropolitan areas that shows where jobs are being created and economies are growing. His most recent work involves the study of biotechnology and other life-sciences clusters, and the impact these industries have on regional economies. Prior to joining the Institute, DeVol was senior vice president of Global Insight, Inc. (formerly Wharton Econometric Forecasting), where he supervised their Regional Economic Services group. He was the firm's chief spokesman on international trade. He also served as the head of Global Insight's U.S. Long-Term Macro Service and authored numerous special reports on behalf of the U.S. Macro Group. He is ranked among the "Super Stars" of Think Tank Scholars by *International Economy* magazine.

Armen Bedroussian is a Research Economist with the Milken Institute. Bedroussian has graduate training in econometrics, statistical methods and other modeling techniques. Before joining the Institute, he was an economics teaching assistant at UC Riverside, where he taught intermediate micro- and macroeconomics. At the Institute, he has co-authored numerous studies, including *The Impact of 9/11 on U.S. Metropolitan Economies*; *Manufacturing Matters: California's Performance and Prospects; America's Biotech and Life Science Clusters*, *Biopharmaceutical Industry Contributions to U.S. and State Economies*; *The Greater Philadelphia Life Sciences Cluster; and Economic Benefits of Proposed University of Central Florida College of Medicine*. In addition to co-authoring annual reports on *Best Performing Cities,* Bedroussian is responsible for compiling *the Milken Institute's Cost of Doing Business Index.* He earned a B.S. in applied mathematics and a master's in economics from UC Riverside.

Anna Babayan joined the Milken Institute as a Research Analyst. Her interests are in the development of regional and industrial economics, and behavioral finance. Babayan previously worked in investment banking and taught mathematics. *The Greater Philadelphia Life Sciences Cluster* and the *Los Angeles Economy Project* are among studies to which she has contributed. Babayan is fluent in Armenian and Russian, and has a working knowledge of Italian. She earned a master's degree in economics at Bocconi Universita in Milan, Italy, and a B.A. in economics from the University of Southern California.

A recent graduate from the University of San Diego, **Meggy Frye** joined the Institute as a Research Assistant in Regional Economics. At the University of San Diego, Frye earned a B.A. in economics with honors (minoring in mathematics) and presented a forecast for the San Diego housing market at the USD Burnham-Moores Center for Real Estate's annual conference. Her thesis focused on coffee demand in the United States.

Before joining the institute as a Senior Research Analyst in Regional Economics, **Daniela Murphy** worked for Bank of America, where she researched market development and the economic conditions shaping California's real estate market. Her research interests center on regional economic development, information technology and the impact of technology on regional and national economies. Murphy's doctoral dissertation emphasized the tasks and organization of the former East German Secret Service and its influence on the German economy. She worked for the German government on the Enquete-

Commission, performing research on international security, political stability and economic growth, predominantly in Eastern Europe. Murphy earned an MBA and Ph.D. at the University of Lueneburg.

Tomas J. Philipson is a Senior Fellow at the Milken Institute, as well as a professor at the Irving B. Harris Graduate School of Public Policy Studies and a faculty member of the University of Chicago. An expert in the field of health economics, Philipson served as senior economic advisor to the commissioner of the U.S. Food and Drug Administration and senior economic advisor to the administrator of the Centers for Medicare and Medicaid Services. He was a visiting faculty member at Yale University and a visiting fellow at the World Bank. He is the recipient of several international and national awards, and is a co-editor of the journal *RAND Forums in Health Economics* of Berkeley Electronic Press. His research has been published widely in leading academic journals. Philipson earned his undergraduate degree in mathematics at Uppsala University in Sweden and a Ph.D. in economics at the University of Pennsylvania.

Lorna H. Wallace is a Research Fellow in Regional Economics at the Milken Institute. Her expertise is in international business, especially the impact of foreign direct investment on the competitiveness of subnational, national and regional economies. She designs, develops and performs research on international trade issues, particularly determining the relationship among the triad of global trade — imports, exports and foreign direct investment. Her research relates international business to workforce development, with an emphasis on the systemic role of government. Wallace has work experience around the world in both the public and private sectors; her research is widely published. Wallace was educated in Canada (B. Admin.) and obtained an MBA and Ph.D. in international business at Rutgers University.

A Senior Managing Economist in Regional Economics at the Milken Institute, **Perry Wong** is an expert on regional economics, development and econometric forecasting, and specializes in analyzing the structure, industry mix and development of regional economies. He designs, manages and performs research on labor and workforce issues; the relationships between technology and economic development; and trade and industry, with a focus on policy development and implementation in leading and disadvantaged regions. He is involved in regional economic development in southern China, Taiwan and other parts of Asia. Prior to joining the Institute, Wong was a senior economist and director of regional forecasting at Global Insight Inc. (formerly Wharton Econometric Forecasting), where he managed regional, state and metropolitan area forecasts and provided consultation. Wong was born in the Yunan province of China, raised in Guang Zhou and lived in Hong Kong. He earned a master's degree in economics at Temple University in 1990 and has completed course requirements for his Ph.D.

Benjamin Yeo is a Research Analyst in Regional Economics at the Milken Institute and a Ph.D. candidate at Pennsylvania State University. Yeo's doctoral dissertation is aimed at developing a theory of sustainability for the knowledge economy. His expertise comprises information technology (IT), planning and knowledge management for e-business and economic development; information systems/process management; and national information policy studies. Yeo obtained his undergraduate and graduate degrees at the School of Communication and Information at Nanyang Technological University in Singapore. Recent projects include the Keystone Workforce Cluster project in Pennsylvania, where he assisted in the execution of an in-depth analysis of the statewide IT work force; a study of Pittsburgh's technology strategy; and Florida life-sciences projects.