MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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BIOTURKU: "NEWLY" INNOVATIVE?

THE RISE OF BIO-PHARMACEUTICALS AND THE BIOTECH CONCENTRATION IN SOUTHWEST FINLAND

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MIT-IPC-LIS-03-001

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The rise of bio-pharmaceuticals and the biotech concentration in southwest Finland

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MIT IPC-LIS Working Paper 03-001

This paper is based on research carried out under the auspices of the Local Innovation Systems (LIS) Project, conducted in cooperation with the Industrial Performance Center at MIT, the University of Cambridge Center for Business Research, the University of Tokyo, University of Tampere/Sente, and the Helsinki University of Technology. Financial support was provided by Sloan foundation and the Finnish Technology Agency (Tekes.)

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Contents

1 Background to case Turku

1.1 Introduction

This case study profiles the rapid gain in visibility of the Finnish city of Turku, where pharmaceutical and other industries have adopted the use of post-1970s molecular biology breakthroughs in "biotechnology" and have risen to some prominence. Finland is now listed in numbers of biotech firms as the 10th largest in Europe and Turku's biotech hub as one of the most innovative in Europe.

Our research uses a case study method to look at the determinants of the concentration and rise of biotechnology, particularly biopharmaceuticals, in the city of Turku and asks whether local universities have been catalysts in this change.The case focuses in particular on the role of two specific universities in Turku and their involvement in the creation of "BioTurku".A total of 36 interviews were conducted, of which 3 were second interviews with the same people. Fieldwork was carried out in April and August 2002 in Turku and interview was held in Helsinki.[2] Structured, open-ended interviews were conducted with academics, policy makers at various levels, CEOs or R&D heads of companies, as well as business managers within the "biotech" industry of Turku, broadly defined. Specifically, the focus was on pharmaceutical (therapeutic) firms involved in drug discovery, development and manufacturing, many of whom used advances in cell and molecular biology in their research, thus "bio-pharmaceuticals".

Our research findings demonstrate that Turku should be seen as a case of industrial transformation and renewal rather than an emergence of a new biopharmaceutical cluster. The evidence strongly suggests that the rise of biotechnological, specifically biopharmaceutical capability in the 1990s in Turku arises from a much older story, with historical capabilities being gradually built up within pharmaceuticals (both therapeutics and diagnostics) over decades. What has fuelled the recent rise of biotechnology concentration has been a combination of dire circumstance and new opportunities which have been strategically funnelled into building a new conceptualisation around a modern high-tech label of biotechnology. These nevertheless draw on decades-old capability across a variety of earlier unrelated sectors in food, pharmaceuticals and materials sciences but which have now been pulled together with a common technological base.

Furthermore, regarding the role of local universities, we argue that resource constraints at the local level and new national science and technology institutions propelled the universities forward to building new organisations for cross-university, cross-departmental work that have been particularly innovative and open to interactions with industry. However, there has, until recently, been little strategic focus on technological innovation that itself has provided an impetus to university administrators and researchers alike. Universities here cannot be seen to be central agents driving change, but as institutions that have benefited and evolved from changes emerging in Turku. The

[2] The authors jointly carried out most interviews together and in English.

learning process within the universities to create new products and services has had teething problems, and this, we argue, is because the focus has not been technological, but driven by resource-scarcity. We argue that what interaction does exist between universities and companies has been primarily driven and institutionalised to varying degrees by large pharmaceutical and diagnostic companies in the past, and more recently by start-ups and spin-offs generated by the consolidation of R&D within these companies, who now no longer have large corporate R&D capabilities and must thus depend to a greater extent on external (university) research links developed earlier within the larger pharmaceutical and diagnostics companies.

From the policy standpoint, the development of the innovation "system" to support the growth of biotechnology in Turku has been different from many other cases we know of worldwide in that the public sector has not played a very active role in its birth. The mobilisation of local resources and the successful attempts to influence national S&T policy have mainly been a result of a network of individuals working in industry and in universities rather than a general strategy of the universities or the local government. The City Council, although arguably late off the bench, has recently been instrumental in galvanising public and private support for "BioTurku", as a means to pull Turku through the recession and to substitute for its lack of an IT-boom, when the rest of Finland was riding an ICT-wave.

Our central hypothesis is that the nature of technology influences the nature of the city's growth path and the institutional changes that accompany its growth. Thus, a central difference with the previous studies of Turku is that this study focuses on the link between technology and institutions and which organisations might have been central to the process of building capability and generating new products and services. Earlier studies have been interested in how policy processes were formed, without giving much, if any, consideration to the characteristics of the technologies themselves within Turku, and how they might drive the process of institution and organisation creation, and thus policy mix and future path.

1.2 Definition of the region and the industry

Turku is situated in the southwest corner of Finland and has a population of approximately 250,000 people, if we generously count not just the city itself, but the surrounding region comprising the towns of Salo, Kaarina, and Raisio. The city of Turku city itself has a population of 173,000. Turku is 160 km west from Helsinki and 320 km by sea from Stockholm. Throughout the history, the city has been one of the major ports in Finland and connections with Sweden have been particularly dense. The city's traditional industrieshave been metal work, shipbuilding, real estate services and construction, food and pharmaceutics and graphics/printing. At the present time, the main industries in the region are foodstuffs, metal, energy, oil, electronics, pharmaceutical and chemical industries.

Culturally, Turku stands distinct from other cities in Finland. It is the oldest city of Finland, dating back to the 13th century. It was the capital of Finland until the 18th century, and the religious and political centre of the embattled territory, providing Swedish monarchs and Russian competitors alike a breeding ground for religious and political foment and the base for future national planning. Turku as home to Finland's 6% Swedish minority dates from this time. Although nowadays the city hosts only a 5.2% Swedish-speaking minority, compared with 5.6% for the country, its historical ties to the Swedish community as well as the presence of the Swedish speaking multidisciplinary university Åbo Akademi, have also earned it status apart from other Finnish cities. For centuries, Turku has perceived itself as the nation's cultural centre and apex of religious and historical importance.

Turku slowly continued until the late 1980s in this fashion with its traditional economic bases working somewhat independently of the rest of Finland, and earning Turku a reputation of a lone player, and its residents of being smug with the pace of their lives and the unique culture of the area.[3] The local culture has been visible also in the way that local development activities have been initiated. Compared with other mid-sized cities like Oulu and Tampere, Turku became active in local economic development quite late. This has been partly a consequence of the local industrial structure – the impacts of economic restructuring were not as severe as in many other cities. Turku has also never been a big centre in the Information and Communication Industry (ICT), which has affected the path the local economy has taken. Instead in Turku, the attention has been turned to the emerging biotechnology cluster that is supported by strong university research activity in the fields of natural and medical sciences and the old pharmaceutical and diagnostic industry. Most of the new biotechnology related companies have been established during the last 15 years.

Biotechnology in Finland

As the table below indicates, , the biotech industry in Finland in 2000 was broadly categorised into the development of medicine (no. of companies 17), large medical companies such as Orion, Leiras and Santen (3), diagnostic companies (30), biomaterials companies (9), food companies (12), those specialising in industrial enzymes (3), agro companies(6), services (28), others (15), for a total of 123 biotech-related companies nationwide in 1999. The turnover was 1860 million €. However, excluding the top three large companies, the turnover was 663 million €. The employment numbers also demonstrate the dominance of the large pharmaceutical companies in Finland; the total employment in the biotech sector within these 123 firms was 10,813, but excluding big pharmaceuticals, these employment figures dropped to 4, 178. (Source: FinBio)

[3] QUOTE

Table 1. The Total Volume of the Biotechnology Sector, 2000. (Source: Finnish Bioindustries 2000, http://www.finbio.net/fib-english.htm)

Sector	Companies	Turnover EUR million	Personnel
Pharma:			
-small	17	19	335
-medium	3	1 197	6 615
Diagnostics	30	254	2 020
Biomaterials	9	14	136
Food	12	250	1 000
Industrial enzymes	3	73	287
Agro	6	11	50
Services	28	27	270
Other	15	15	100
Total	123	1 860	10 813
Total excluding big pharma	120	663	4 178

Turku is the second biggest concentration of biotechnology activities in Finland after Helsinki. Other regions with dedicated centres for developing biotechnology are Oulu, Tampere and Kuopio. Moreover, there are also many universities with biotechnology related research and education in Finland. In the Finnish perspective, the Turku region is especially strong in biopharmaceuticals, but also has activities in diagnostics, biomaterials and functional foods. The figure below shows the distribution of university-based biotech R&D across Finland.

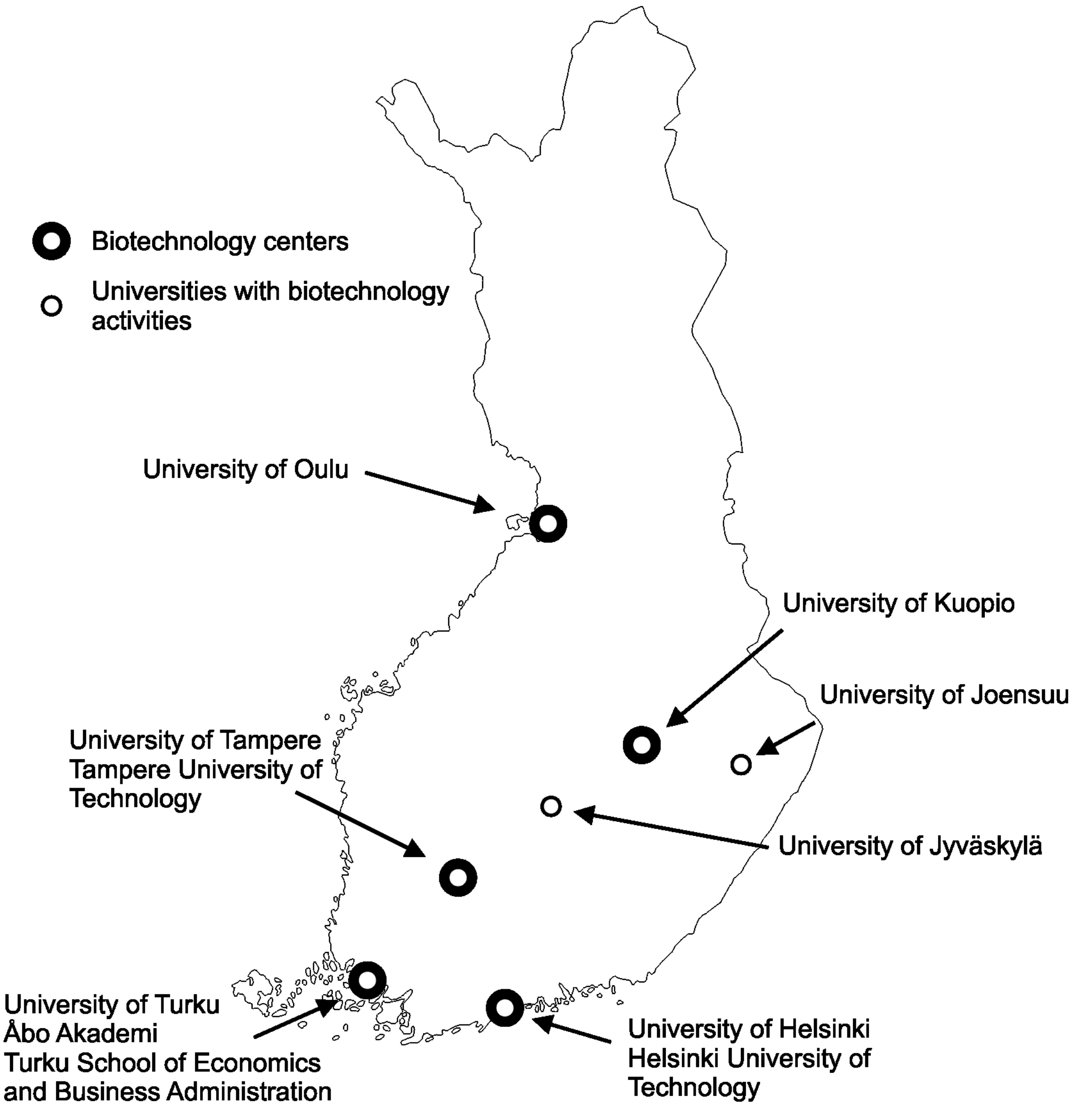


Figure 1. Finnish cities with biotechnology activities (Big circles are cities with a dedicated Biocentre).

The public sector[4] spending in biotechnological research in Finland in 2000 totalled €24.1 million, 4.8 per cent of the total public sector R&D. The higher education sector (excluding polytechnics and university hospitals) put in 2000 a total of €91.1 million to the biotechnological research, which was 11.5 per cent of the total higher education sector R&D expenditure. (Statistics Finland 2002).

[4] Here public sector consists of general government, public research institutes (e.g. VTT) and non-profit private spending.

Table 2. R&D in all Finnish firms practising Biotechnology. (Source: Statistics Finland).

Branch	**Total R&D**	R&D in firms practising biotechnology	
	€ million	€ million	%
Food products (SIC 15-16)	62.7	37.0	59.0
Chemicals. incl. pharmaceuticals (SIC 24-25)	231.0	117.4	50.8
Research and development (SIC 73)	135.8	24.8	18.2
Other branches	2706.5	43.7	1.6
Business enterprises total	3135.9	222.8	7.1

Biotechnology patents only account for a small number of all patent applications in Finland and the proportion has even fallen to 1.6 per cent in 2000. This might partially be explained by Finland joining the European Patent Office in 1996. Even when it comes to EPO patent applications, biotechnology only accounted for 1.3 per cent of all Finnish patent applications in 1997 (OECD). The dominant field in biotech patents has been micro-organisms and enzymes, which account for approximately two thirds of all biotechnology patent applications, and often originating in industrial biotechnology

Table 3. Biotechnology patent applications in 1995 and 2000 (Source: the National Board of Patents and Registration of Finland)

Year	Patent applications total	Biotechnology applications	
	N	N	%
1995	6762	194	2.9
2000	3137	50	1.6

In 2000, the Finnish turnover of "life-science" industries was1.4% of GNP and 2.1% of industrial employment (0.4% total employment) and 2/3 of this was in the pharmaceutical industry. (Tulkki et al 2001). From a sectoral standpoint, pharmaceutical production in Finland in 1998, for example, was €575 million compared to €15,980 million for the Finnish electrical and electronic industries in the same year, or about 5.75 % of the electrical and electronic industries' production figures. The dominance of academic leanings towards medical and biological research in Finland can be seen in the fact that the natural and medical sciences jointly published 85.3% of all Finnish academic publications in 1999 compared to 7% in engineering and technology areas.[5] However, if sites for clinical trials and the new chemical entities (NCEs) they introduce into the market are anything to go by, then Finland

[5] However, with the blurring of engineering and life science areas in biotechnology fields, these publication categories and figures may change.

has a strong advantage. It introduced 8.6% NCEs introduced in clinical trials, had 0.4% of the world pharmaceutical market and 0.1% of the world's population in 1998. (Brännback et al 2001, 26).[6]

The figures on the structure of the Finnish biotechnology related industry clearly demonstrate that the 'big pharma' related companies still account for almost two thirds of the turnover. However, the small companies mainly concentrate on R&D-activities. In Turku region, biopharmaceuticals are especially strong area compared to the whole country.

Table 4. Size of Finnish pharma industry (Source: Brännback et al. 2001 (Tekes), all data except for VC data taken from Pharma industry, Statistics Finland. VC data taken from Finnish Venture Capital Association)

Finnish pharmaceutical industry (million EUR)	
Total gross sales 2000 (wholesale prices)	1583
Total gross sales 2000 international operations (wholesale prices)	370
R&D expenditure 1997	132
1999	145
Finnish venture capital investments in 1999	31

In 2000, the sales of pharmaceuticals in Finland was €1.15 billion with the annual growth of 9.6% (Orava et al. 2001). The biggest manufacturing and marketing companies in Finland were Orion, Astra Zeneca, Suomen MSD, Glaxo Wellcome and Leiras.[7] Despite the heavy internationalization and R&D orientation of the Finnish pharma industry, the home market seems to be still quite important.

A Finnish pharma cluster-Vision 2010 was sponsored by Tekes to study the possible future trajectory of biotechnology in Turku and other cities in Finland, and suggest areas of strength and weakness on which policy could be constructed. (See Brännback et al 2001). The desire of the pharma cluster (comprising academics, industries, policy makers at various levels), is to host 140[8] companies throughout Finland in pharmaceutical and closely related industries in 2010, which would approximately double the total number of current companies in this biotech sub-sector. The goals were also to create 10-15 new companies that would go public in the pharmaceutical sector, draw in foreign capital market investments into the Finnish pharma sector, and to create at least ten new chemical entities (NCEs) and new formulations that are internationally competitive and innovative. The annual gross sales target is a fivefold increase to EUR 2500 million (in wholesale prices), of which more than half comes from international operations. The labour targets are doubled to 14000 professionals. The overall goals of the Pharma Cluster with the support of the government are in keeping with an overall

[6] This is partly explained by well organised healthcare system. Finland the trials conducted in Finland are considered reliable and precise, Finland has comprehensive health registers and there is a good co-operation between industry, universities and hospitals.

[7] Note that many of these are foreign multinational companies

[8] This objective relates to pharmaceuticals only. It does not include other biotechnology related fields like diagnostics, biomaterials and food industry.

industrial policy mandate in Finland to create new jobs in high technology areas like pharmaceuticals, and not in traditional manufacturing areas.

Biotechnology in Turku

Turku's own biotech concentration deserves further analysis. The primary specialisation of firms within the Turku biotech cluster in 1999-2000 was in diagnostics and input materials (35%), followed by pharmaceutical product development (29%), services (research, marketing and consulting) (22%), biomaterials and functional foods (7% each). The 1996-2000 period saw the sharpest rise (~65) in new biotech firms in Finland. Companies started in the 1998-2000 period were broadly categorised as biomedicine (37%), diagnostics (31%), biomaterials (13%) and others (19%) (Orava et al 2001 and FinBio*)*.

The estimated size of the workforce in biotechnology in the region is about 3000. In terms of employment, pharmaceuticals are the biggest field. Schering (formerly Leiras) has about 900 employees and Orion 600 in addition to many smaller drug discovery companies. During late 2002 and early 2003, however, the amount of people working in biotech actually declined because of the financial problems of many of the SMEs. This phase is seen as temporary by many and is related to the world market situation (Uudet bioyhtiöt…, 2003).

There are three universities and a polytechnic in the Turku region - all with connections to the biotechnology industry. The most important of them is the University of Turku with a long history of high level research in medical and natural sciences. Åbo Akademi also has strong areas related to the field. Turku Business School has also started biotechnology related activities, including an industry-specific management program. Biotechnology-related activities are the strongest science-based source of knowledge in Turku. It has been estimated that biosciences account for an impressive 70% of all external funding and the same percentage of publications in the University of Turku, which is the biggest university in the region. Also at the Swedish-speaking Åbo Akademi, biotechnology related activities are strong. In addition, the university research bases are supplemented by research at organisations such as the University hospital and research oriented companies that provide new knowledge and expertise to the region.

Turku's technological highlights come from recent developments at the early stages by its smaller drug discovery and development firms, for drugs launched for inflammatory diseases, Parkinson's disease and osteoporosis. Its clinical base for testing has also been very robust, and Benecol, one of the world's very first functional foods to actually hit the market, was developed near Turku, in Raisio. There is also a slow emergence of bioinformatics capability in the Turku region.

In this paper, we take a look at different fields related to biotechnology in Turku – pharmaceuticals, diagnostics, biomaterials and food industry. Our main emphasis, however, is on biopharmaceuticals, which is the strongest and most developed sub-area. The paper is divided in five parts. In the first part we describe the regional economy, the industry and the innovation system that supports biotechnology in Turku area. In the second chapter we pay more attention to the transition process that has made the industry what it is today. In the third part we take a look at the nature of the innovation process in the biotechnology industry and how this is reflected in Turku. Next we examine the interaction between the industry and the university, not forgetting the other supporting organisations. In the last section we draw conclusions and discuss the future challenges facing the industry in Turku.

1.3 The structure of regional economy

Turku region has been one of the notable growth areas in Finland alongside Helsinki, Oulu, Tampere and Jyväskylä regions. In contrast to many other cities, however, Turku grew quite slowly in the period of rapid urbanisation in the 50s and 60s. The city started to grow again during the last decade after the recession ended but the growth has been slower than in other big cities.

Turku had been an important trading center for centuries. It had strong cultural and educational roots, dating back to its position as a former capital of Finland. Despite also being a strong industrial center, the service and cultural functions of the city are visible in the statistics. The amount of service jobs was relatively high in the 70s when the transformation from industry to service jobs was just beginning in many other cities.

On the other hand, certain industry sectors, especially ship building, machinery and the food industry have been historically strong. These industries however have been quite slow or even stagnant in their growth compared with some other industries, most notably information and communication technologies (ICT), broadly defined. Turku does not have a tradition of engineering or information technology education, which partly explains why the city did not experience the same growth in this field as did urban centres such as Helsinki, Tampere and Oulu regions in the 90s.

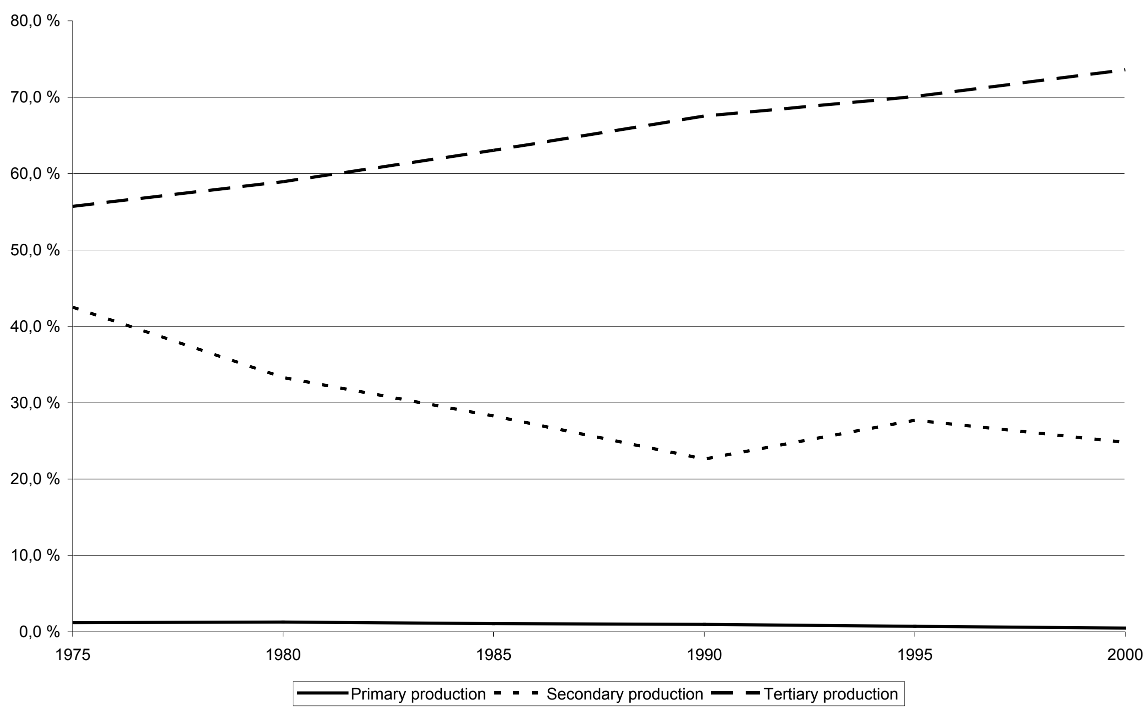


Figure 2. The development of employment in primary, secondary and tertiary fields in Turku 1975-2000 (Source: Statistics of Finland).

A widely shared challenge in the region has been that many highly educated people have left the region after graduation. The table below shows the development of education levels compared with the strong university influence in the region. Despite this phenomenon, the number of educated people is still relatively high, especially those with post graduate degrees. This could be seen as a result of a strong education system, but is more likely evidence of the strong position of medical and natural sciences for which higher levels of education are often required.

Table 5. The development of education levels from 1985 to 1995 (Source: Statistics Finland).

		Population over 15	Population with a degree	All higher level	The lowest higher level	Bachelor level	Master level	Post graduate
Finland	1985	100.0	45.7	8.2	3.2	1.8	2.9	0.3
	1990	100.0	50.4	9.7	3.9	1.9	3.6	0.4
	1995	100.0	55.0	12.3	5.1	2.3	4.4	0.5
Turku Sub-Region	1985	100.0	47.6	9.9	3.5	2.2	3.6	0.6
	1990	100.0	52.4	11.5	4.2	2.2	4.4	0.7
	1995	100.0	57.3	14.4	5.5	2.6	5.4	0.9

As the table below shows, in terms of employment, the fastest growing fields during the 90s were real estate and renting activities, education, health and social services and hotels and restaurants. The jobs in manufacturing comprise one fifth of all jobs in the region. However, the number of manufacturing jobs has decreased significantly over 13% in ten years while the comparable decrease nationwide was9%. At the same time, the number of jobs in real estate and renting services, education, hotels and restaurants has grown faster than in the country as a whole.

The slow growth in manufacturing in Turku region is also visible in the production statistics. The change in the gross value of industrial production between 1995 and 2000 increased 3% as it increased over 13% in Helsinki-region and 8% in Oulu region.

Table 6. The employment base in Turku sub-region in 1990 and 2000 (Statistics Finland).

	1990		2000	
Agriculture. hunting and forestry	3 636	2.9	2 261	1.8
Fishing	121	0.1	75	0.1
Mining and quarrying	44	0.0	93	0.1
Manufacturing	29 213	23.3	25 529	20.2
Electricity, gas and water supply	1 249	1.0	1 060	0.8
Construction	9 161	7.3	8 493	6.7
Trade	15 980	12.7	15 040	11.9
Hotels and restaurants	3 155	2.5	3 651	2.9
Transport, storage and communications	11 171	8.9	10 179	8.1
Financial intermediation and insurance	4 033	3.2	2 715	2.1
Real estate and renting activities	10 374	8.3	15 531	12.3
Public administration and defense	6 285	5.0	6 722	5.3
Education	7 164	5.7	9 446	7.5
Health and social work	15 584	12.4	18 418	14.6
Other community, social and personal service activities	5 807	4.6	5 554	4.4
Private households with employed persons	3	0.0	4	0.0
Extra-territorial organizations and bodies	72	0.1	-	-
Industry unknown	2 529	2.0	1 665	1.3
Total	125 581	100.0	126 436	100.0

But Turku still has an industrial employment base. The manufacturing of transport equipment is the biggest employer in the Turku region, employing 16.7% of all industry workers and covering 25% of all exports as shown in the table below. Transport equipment covers mainly ship building and related industries. In the whole of Southwest-Finland, ship building (SIC 351) employs about 5000 people alone. The food industry is also very important, being the biggest producer and the second biggest employer, providing 16% of all manufacturing jobs. The third biggest industry field is machinery and equipment, which is very export oriented and accounts for 29% of all exports. The fourth biggest industry is chemicals and chemical products, in which our story of pharmaceutical production belongs. The small production figures compared with the employment base confirms our interview findings that a large part of the industry is concentrated in R&D rather than production. The manufacturing of medical and precision equipment accounts for only 2.4% of production but is very export oriented. This area covers most of the diagnostic industry.

Table 7. The industrial structure of Turku sub-region in 2000 (Source: Statistics Finland)

SIC	Industry	Employment	%	Production 1000€	%	Export 1000€	%
15-16	Food products and beverages; Tobacco products	3940	16.0	803458	17.9	123799	6.7
17	Textiles and textile articles	204	0.8	22681	0.5	9022	0.5
18	Clothing and footwear	383	1.6	26848	0.6	4284	0.2
19	Leather and leather products	4	0.0	256	0.0	x	x
20	Wood and wood products	199	0.8	21407	0.5	3438	0.2
21	Pulp and paper products	104	0.4	15948	0.4	1479	0.1
22	Printing and publishing	2042	8.3	231814	5.2	21278	1.2
23	Petroleum products and fuels	x	x	x	x	x	x
24	Chemicals and chemical products	2233	9.0	306789	6.9	148782	8.1
25	Rubber and plastic products	x	x	x	x	x	x
26	Mineral products	560	2.3	78899	1.8	2988	x
27	Basic metals	22	0.1	1773	0.0	x	x
28	Metal products	2230	9.0	256899	5.7	37940	2.1
29	Machinery and equipment	3521	14.3	772219	17.2	532742	29.0
30	Computers and office machinery	x	x	x	x	x	x
31	Electrical machinery	451	1.8	53938	1.2	16737	0.9
32	Communication products	x	x	x	x	x	x
33	Medical and precision equipment	777	3.1	106861	2.4	82233	4.5
34	Motor vehicles and parts	448	1.8	67743	1.5	36813	2.0
35	Transport equipment	4650	18.8	748493	16.7	469414	25.5
36	Manufacturing n.e.c	965	3.9	90240	2.0	36032	2.0
37	Recycling	16	0.1	1524	0.0	68	0.0
	Unclassified	3582	14.5	402477	9.0	60365	3.3
	Total	24700	100.0	4477100	100.0	1838489	100.0

When looking at the recent development of R&D spending in the Turku region, we can see that investments have more than doubled in just five years. The biggest increases in R&D spending have been in the private sector, where the spending has grown from €152 to €352 million. The development in the education sector has also been remarkable, being €100 million in 2000. Private sector covers three quarters of all R&D spending while the public sector only accounts for only 3.2%[9]. Compared with Tampere region, which is a similar size, the R&D spending in Turku region is significantly lower, being roughly two thirds of the figures in Tampere region[10].

[9] Most of the funding in the education sector (universities etc.) comes from the public sector and therefore the effective amount of publicly funded R&D is much bigger..

[10] When looking at industry specific statistics, it seems that this difference is mainly explained by the rapid increase of R&D expenditure by the ICT industry in Tampere in the 90s.

Table 8. R&D spending in the Turku region in 1995 and 2000 (Source: Statistics Finland)

Million Euro	Total	Companies	Public sector	Education sector
1995	220	152	10	58
2000	466	352	15	100

Percentage	Total	Companies	Public sector	Education sector
1995	100.0	69.1	4.5	26.4
2000	100.0	75.5	3.2	21.5

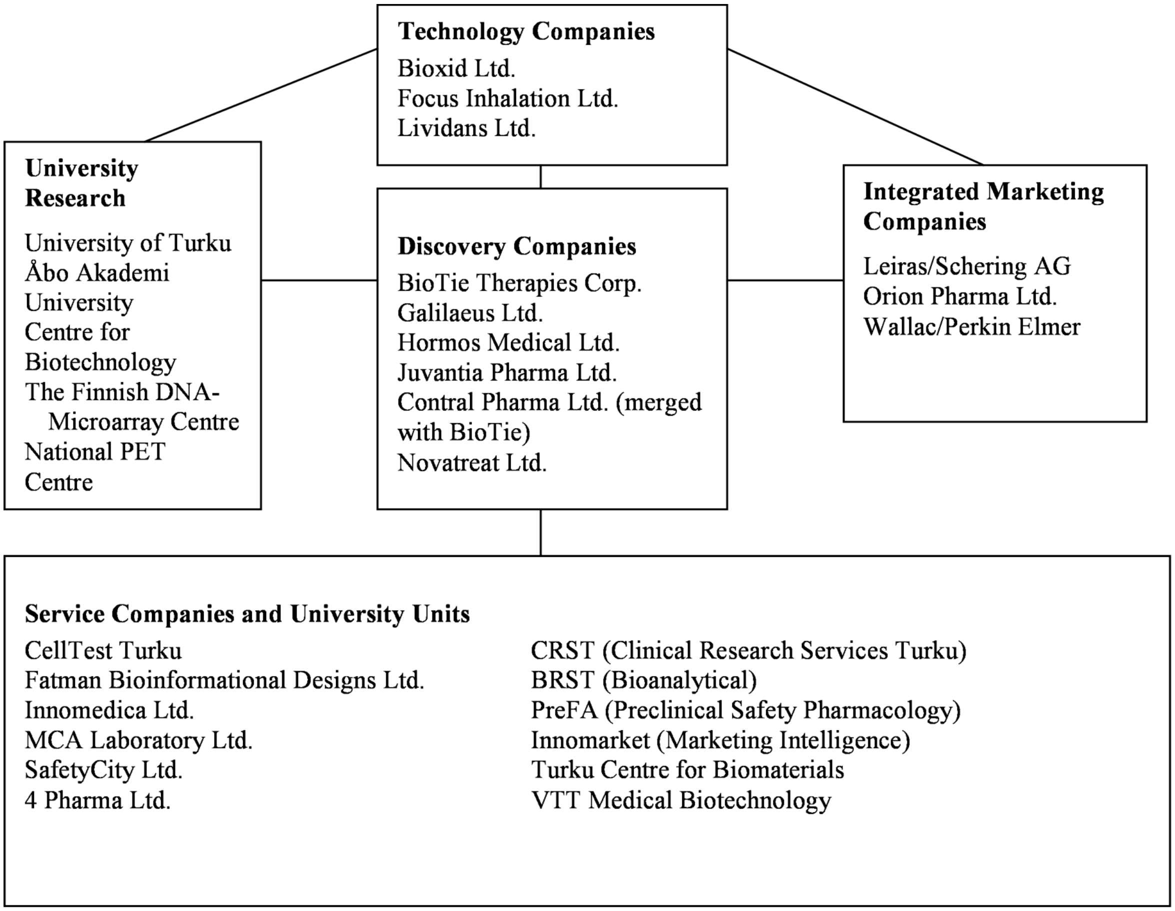
1.4 The leading biotechnology firms in the region

Turku region has expertise especially concentrated in biopharmaceuticals but also in diagnostics and the food industry. The field of biomaterials has also evolved recently but is still developing. These fields are also recognised in the Turku region Centre of Expertise program. In addition, there is an increasingly strong group of service companies from testing to marketing developed around the core companies.

Pharmaceuticals and therapeutics

As we discussed earlier, the pharmaceutical industry is especially strong in Turku. There are two large pharmaceutical companies present, Schering and Orion, both of which do R&D in Turku. There are also quite a few smaller drug discovery companies like BioTie Therapies, Hormos Medical and Juvantia Pharma. Together with the universities and service companies, this sub-field forms a relatively tight network of drug discovery and drug development. Most of the smaller companies have appeared during the last ten years and the number of companies has increased rapidly.

In the figure below, we show the drug discovery and development actors in both the public and private domain.



(*Source: BioTurku in Finland, Superior Know-how Chain 2002*)

We describe briefly the profiles of some of the leading large and small bio-pharmaceutical firms. Some of this information is taken from company brochures and websites.

Schering

Schering Oy is an independent part of the global pharmaceutical Schering Group that employs 26,000 people around the world. The collaboration between the Finnish company Leiras and Schering began in the 50s. In 1996, Schering bought Leiras Oy. In 2003, Leiras Oy and Schering Oy joined forces and were combined into one company operating under the joint name, Schering Oy. The annual sales of Schering Oy were €206 million in 2002 of which 80% was exported. The annual R&D budget is about €30 million (2002).

The company's R&D focus is mainly on family planning and hormone therapy, medicines for bone diseases and polymer technology. Strategic areas in its Finland base are gynecology and andrology, multiple sclerosis, diagnostic imaging, cancer therapy as well as dermatology. Especially the fields of gynaecology and andrology are strong in Finland. The most important products and technologies in these fields are the polymer-based drug delivery technology Delvivo and its current applications in gynecology: the hormonal intrauterine system Mirena, the contraceptive implants Norplant and Jadelle. There are also treatments for bone metabolism (Bonefos).

Schering Oy has actively invested in both R&D and in co-operation with the universities. In addition to R&D activities, there is also a significant amount of production in Turku with 300 working in drug manufacturing and the Turku plant is one of the leading manufacturing facilities within the whole Schering group. All in all Schering has about 900 people working in Turku and it is the biggest life sciences company in the region.

Orion Pharma

Orion Pharma is the core business division of the Orion Group. It contributed 30% of the group's net sales for 2002 but as much as 63% of the operating profit. It is also the leading drug company in Finland with 11% market share. Orion Pharma's operations are carried out in four business areas: core therapy areas, specialty products, animal health and active pharmaceutical ingredients (produced by a sub-unit Fermion) (Orion Group Annual Report 2002). The core therapy areas focus on central nervous system disorders, cardiovascular diseases and critical care and hormone therapies and include products like Comtess and Comtan (Parkinson's disease), Simdax (for severe heart failure), Indivina (menopausal hormone replacement therapies), Precedex (for sedation of patients in intensive care) and Fareston (for breast cancer). 83% of the net sales came from human specialities and 33% of the sales came from proprietary products.

Orion Pharma is involved in both stages of commercialisation of therapeutics, since it develops, manufactures and markets pharmaceuticals. The company still has a strong position in the domestic drug market but with the increasing competition in Finland, the company is now increasingly targeting global markets. International operations already account for over 60% of the total net sales and new drugs from its own research account for an increasing share of the company's net sales. The main location of the company is in Espoo but there is also R&D and manufacturing in Turku, Kuopio, Hanko and Oulu in Finland, and in Kvistgård, Denmark. In total the amount of personnel in the company is about 3000 (2500 in Finland) of which 900 are working in R&D. In Turku there are approximately 600 people working for the company.

Orion Pharma's product and research strategies focus on central nervous system disorders, cardiovascular diseases and critical care and hormone therapies. The company is investing heavily on new drug development. In Turku, construction investments for 2002 and 2003 related to the R&D functions will total approximately EUR 15 million.

BioTie Therapies

BioTie Therapies is one of Turku's upcoming dedicated discovery and development companies, with a focus on dependence disorders, inflammatory diseases and glycobiology. The company has an extensive product portfolio with products in all phases of clinical development.

The company's R& D pipeline is based on opioid receptor, VAP-1 (Vascular Adhesion Protein-1) receptor and integrin technologies, sulphated polysaccharide and multivalent carbohydrate technologies. The company was created through a merger of BioTie Therapies Corp., Contral Pharma Corporation and Carbion Inc. in October 2002. BioTie's shares are listed on the Helsinki Exchanges. The number of employees was well over 100 at its largest but has decreased to 68 (May 2003).

Hormos Medical

Hormos Medical develops novel, patented pharmaceuticals for certain hormonal based diseases and particularly those related to aging. Targeted indication areas include osteoporosis, Alzheimer's disease, menopause, andropause and certain cancers.

Hormos Medical Corp. is a Finnish biopharmaceutical company specialising in the discovery and development of pharmaceutical products for the hormonal prevention and treatment of certain diseases, particularly those related to aging. The discovery and research activities of the company are currently focused on SERM-research, SARM-research and HSD enzyme research.

Hormos Medical's core competence lies in its in-depth study and understanding of tissue-specific steroid hormone effects on the molecular and cellular level. Hormos Medical takes the advantage of using the core competence for the discovery and development of new generation hormonal therapies. At this point the number of personnel is 55 (April 2003). Like in many other small companies, the number of personnel has declined during the last year because of tightening financial markets, particularly of venture capital funding resulting from the economic slowdown in the US

Diagnostics

Diagnostics is a field that is growing fast as a consequence of new technologies. With modern diagnostics it is possible to detect many diseases and medical conditions more quickly and with greater accuracy due to the sensitivity of new, biotechnology-based tools. Good examples of these are tools for testing blood, cancer tests and pregnancy tests. Molecule research and gene technology are important fields in the process of developing easier, faster and more accurate diagnostic tools.

Diagnostics is also getting more closely related to drug development. There is a need to develop a more holistic treatment. There is a need to analyse individuals before developing a drug or deciding a treatment. This field, "theragnostics"), brings diagnostics and pharmaceuticals more closely together.

PerkinElmer-Wallac

Wallac Oy develops, manufactures and markets analytical measuring devices, software and reagents for the research and development of drugs and diagnostic systems for clinical diagnostics and mass screening. It is part of the American PerkinElmer Life Sciences unit of the PerkinElmer group. Wallac had about 550 employees and the annual turnover was €100 million in 2001. The original Finnish company, Wallac, has operated in Turku for 50 years and has had a big influence on the development of diagnostics research and manufacturing in Turku. Wallac has trained many professionals who are now working elsewhere. It has also been very active in establishing co-operation with the university earlier. Recently the collaboration has been less frequent.

There are a few other diagnostics companies in the region. Many of these smaller diagnostic companies are either spin-offs from Wallac or related to it in some ways e.g. Arctic Diagnostics, whose founder was a long-time R&D manager in Wallac. There are also some small companies that are spin-offs from the university like Innotrac Diagnostics that supplies diagnostic systems and reagents mainly for hospital laboratories.

Biomaterials

Biomaterials is the smallest area in biotechnology in the Turku region. Biomaterial applications are widely used in both medical devices industry and in drug development but also, for example, in environment technology. In drug development the use of biomaterials can be connected to dosage of medication and the ways in which medicine is used. Biomaterials are also an important technology in medical and dental implants and replacement of body parts.

As opposed to other biotech fields, there are no big companies in biomaterials to spearhead R&D spending. Instead, most companies are small university spin-offs that have mainly been established in the 90s. One example of a more developed firm is Sticktech, a firm that specializes in developing and producing glass fiber reinforcement technology for dental care.

Food industry

Food production is the oldest field of biotechnology and well represented in the Southwest of Finland. Biotechnology has been used in manufacturing food products for thousands of years. Bread, alcoholic beverages, vinegar, cheese and yogurt, and many other foods owe their existence to enzymes found in various micro-organisms, like yeast. In the modern food industry biotech is used by providing new products, lowering costs and improving the microbial processes. One controversial but very large field in food biotechnology is gene technology used in modifying organisms.

The food industry is a huge employer in Turku region. Although the profitability of the industry has been lower than in many other industries and has had to face increasing foreign competition , biotechnology and especially functional foods, have been seen as a way to improve the industry's competitiveness. So far there has not been much technological progression in this field. According to a previous study, the importance of functional foods is still very small for the companies, Raisio Group being an exception (Orava et al 2001). Several reasons can be seen behind this slow development. First, the food industry seems to be much more conservative than the pharmaceutical industry in venturing into new fields. Second, there is less experience in long term R&D in the food industry compared with pharmaceuticals. The field of functional foods is also more demanding than, say drug development, because with food all the regulations are much stricter than for drugs, which are ingested less regularly and in smaller quantities. The field of "nutriceuticals" aims to combine therapeutic properties to food products.

Raisio

The Raisio Group was established in 1939 by Finnish farmers. Its first production unit was a flourmill, but over the years, the company has expanded into many other areas of agricultural product processing, and it can claim to be ahead in this field of knowledge. Today the product range includes margarines, grain products, potato products, animal feeds, malts (Raisio Nutrition), paper chemicals (Raisio Chemicals) and functional foods (Raisio Life Sciences). The Raisio Group's headquarters are in Raisio, close to Turku. The Group employs some 2 700 people, of which about 42% are based abroad. Today, Raisio has production units at 25 locations in 13 countries. In 2001, the Group's total turnover was €822.9 million. The parent company, Raisio Group plc, has been listed on the Helsinki Stock Exchange since 1989.

The company has tried to concentrate resources in in-house R&D recently. There are 200 R&D personnel most of them (120) in Raisio Chemicals. Life Sciences are the latest field in the company's activities and so far the smallest unit. Of the total R&D expenditure of €18.3 million (2001), 2.3 million went to life sciences.

The company's only commercialised life sciences product is a stanol ester called Benecol, an ingredient that lowers serum cholesterol levels. It is developed from the surplus sitosterol of the chemical pulp industry. While Benecol is probably the best known functional food product in Finland it has faced great difficulties in commercialization. There were challenges in getting the product to the US market as the company lacked knowledge of the regulatory environment for functionalistic foods in that country (Tulkki et al 2001). After a slow start Benecol is now used in many kinds of products like margarines, yoghurts, ready foods, milk and snack bars. Raisio is now trying to expand its field of functional foods to new ingredients to manage heart health, diabetes and allergies, but these ingredients are still in the development phase.

1.5 The institutional set-up for innovation in the region[11]

We suggest that the institutional setup for innovation is defined by the "local innovation system". On the supply side are located the institutional sources of knowledge creation in the regional economy, which usually means higher education institutes (HEI) like universities and different private or public research institutes. Closely linked to these are the institutions responsible for training and the preparation of highly qualified labour. The demand side of the system subsumes the productive sector — firms which develop and apply the scientific and technological output of the supply side in the creation and marketing of innovative products and processes. Bridging the gap between the two are a wide range of innovation support organizations, those which play a role in the acquisition and diffusion of technological ideas and know-how throughout the innovation system or provide support through necessary infrastructure and resources. Moreover, the national and international organisations and institutions can have a very important role in the innovation system. In Finland the role of national institutions in particular, is very important.

The institutional setup for innovation in Turku covers several local and national level actors. The demand sector consists of a few medium sized companies and many young and small companies. On

[11] In keeping with the LIS study, we use broadly the following definition for Local Innovation Systems:
"..spatial concentrations of firms (including specialized suppliers of equipment and services and customers) and associated non-market institutions (universities, research institutes, training institutions, standard-setting bodies, local trade associations, regulatory agencies, technology transfer agencies, business associations, relevant government agencies and departments, et al) that combine to create new products and/or services in specific lines of business."

the supply side there are three universities, a polytechnic and industry R&D units. Supporting knowledge transfer, financing and interaction there are a variety of public or semi-public development organisations but also a lot of private and public knowledge intensive business services. In the following section we represent some of the local organisations supporting innovation activities and research in Turku. The national level institutions and higher educational institutes (HEI) are presented in the following chapters.

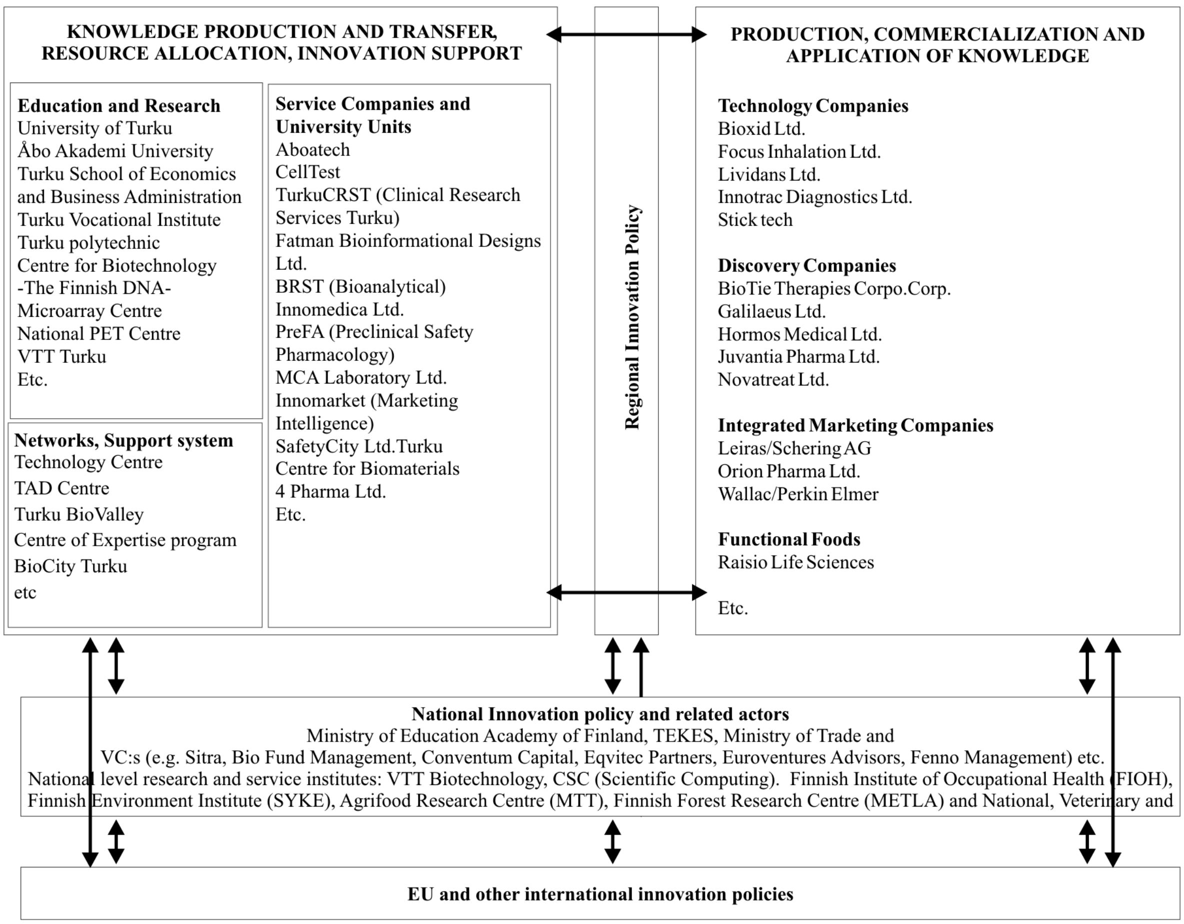


Figure 3. The regional innovation system for Biotechnology in Turku.

Turku Science Park, BioTurku and Turku Bio Valley

Turku Science Park is the hub of biotechnology innovation for Turku and is laid out in a small square kilometer area abutting the city downtown area. It extends from three universities at one end of the city, to encompass a middle region of the "Cities" (BioCity, PharmaCity, DataCity and others) of several life science and ICT buildings to the Turku Bio Valley corporation and onward to the other end of Turku with PE Wallac Life Sciences, the dominant diagnostics company. In all, the Turku Science Park (TSP) is one of the largest Nordic efforts of its kind, with "BioCity" constructed in 1992, "PharmaCity" more recently, and Turku Bio Valley Ltd, established as a company by the Turku City Council in 1999. It has a mandate to coordinate the entire bio cluster of the Turku area and provide specialised production and product development facilities on specification by companies. Novatreat and Focus Inhalation are two companies who have made use of such production/manufacturing arrangements.

The goal of the TSP, through organisations like Turku Bio Valley, is to provide support for the entire innovation chain, from invention to production, through the "branded" concept, or shared vision of a BioTurku, a new conceptualisation of a high-tech Turku region.

BioTurku is said to comprise the entire bio-chain, and the schema is envisioned as in the figure 3 above: Although the BioTurku concept is supposed to encompass more than pharmaceutical know-how, the figure describes this particular sub-component of the local biotech capability.

The rabbit-warren architectural frame and nature of BioTurku encompasses a dense setting of corporations, university laboratories, public sector S&T presence, venture capital agencies as well as common restaurant and café facilities. Some of the firms are spin-offs of ideas from academic researchers.[12]

From an organisational standpoint, joint seminars hosted by Bio Valley and the Turku Technology Centre, as well as those hosted within BioCity itself, all serve to bring BioCity and adjacent other "Cities" (ElektroCity, EuroCity, DataCity) inhabitants closer together. Some of these initiatives are funded by Tekes.

BioCity Turku

BioCity Turku is a cross-departmental and cross-University umbrella organisation of academic research on cell and molecular biology and biotechnology. The partners in the collaboration are the University of Turku, the Åbo Akademi University, the Turku University Central Hospital and the National Public Health Institute. BioCity Turku belongs to neither of the universities, but has its own board with representatives from both of them and also from industry. The task given to BioCity Turku is to structure collaboration, resource sharing and infrastructure development in research and education in the area of life sciences.

The BioCity Turku research community consists of over 50 research groups with over 500 people working in different fields. There are four major research programs within BioCity Turku: the Centre for Reproductive and Developmental Medicine, Turku Immunology Centre, research program for Systems Biology and Research program for Receptor Structure and Function. BioCity has received two nominations as a Centre of Excellence. Its facilities include cDNA microarray services, peptide synthesis/analysis services, sequencing facilities as well as imaging techniques on site.

The administrative key people in the organisation are the Scientific Director of BioCity Turku, the Chair of the Board, the Director of the Centre for Biotechnology, and the Coordinator. The figure below captures the structure and organisational links between the various arms of BioCity Turku.

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[12] Arctic Diagnostics, started by Prof. Erkki Soini, is a good example. His office is in BioCity and he is both professor as well as head of the firm. In addition, because of his very long tenure in the medical diagnostic equipment business, particularly at PE-Wallac, he also continues to have fulfilling and long-standing relationships with other firms - many of which have been started by researchers formerly at Wallac, Orion or Farmos, the other old Turku firms.

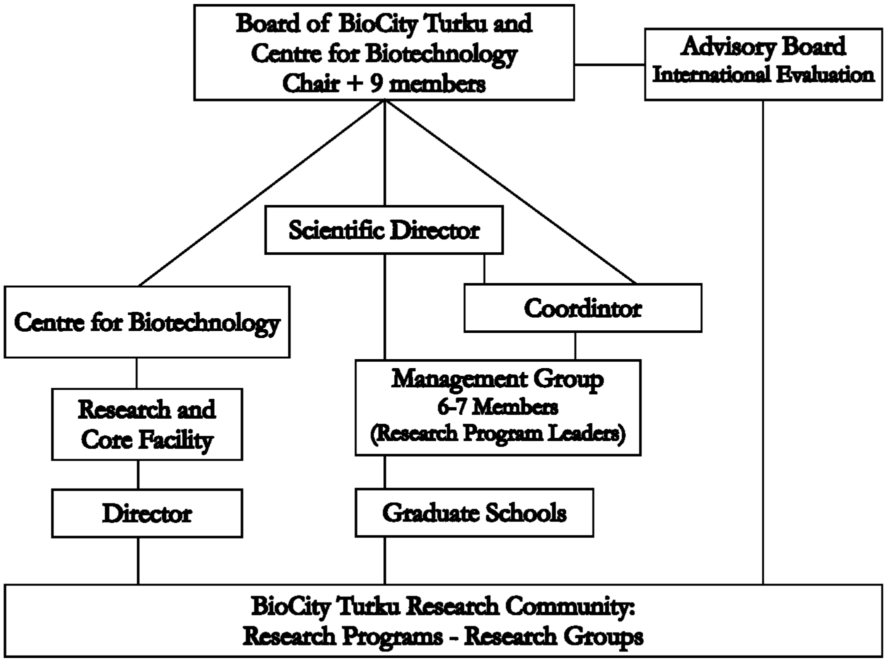

Figure 4. The organisation of BioCity Turku research network (Source: BioCity Turku http://www.biocity.turku.fi/).

Turku Centre for Biotechnology[13]

The Centre for Biotechnology is a dedicated university research unit that was established in co-operation between Turku and Åbo Akademi Universities. The Centre provides technical expertise and coordinating services for academic and industrial projects in several central areas of biotechnology. Large-scale equipment, in particular, has been installed at the Centre to create "core facilities" for biotechnological research. The CBT was established in 1989 to facilitate biotechnology and biomedical research as well as to enhance scientific interactions between research groups across departments and within two universities. This concept has proved efficient and helps in optimizing the use of resources. The Centre has also provided a forum for active interactions between academia and industry. Such interactions have resulted in a number of biotech companies, which are based on scientific discoveries in academia. The Centre is also a part of the wider BioCity Turku research network.

Today the centre has three major functions: research, training and education. It acts as a centre for expertise and services in the area of biotechnology and emerging sub areas of technologies and research. It is also involved in facilitating interactions and discussions between academia and industry.

The following main research groups function within the Turku Centre for Biotechnology: Their lead researchers are also mentioned.

1. Regulation of Neuronal Survival by Protein Kinase Signalling (Eleanor Coffey)

[13] Some materials here taken directly from the websites of the respective organisations

2. Syndecan Research Group (Markku Jalkanen) 3. Signal Transduction Group (Päivi Koskinen) 4. Cell Invasion Group (Veli-Matti Kähäri) 5. Molecular Immunology Group (Riitta Lahesmaa) 6. Protein Crystallography and Structural Immunology (Tassos Papageorgiou) 7. Map Kinases in Cancer Cell Signalling (Jukka Westermarck)

(Source: Turku Centre for Biotechnology. http://www.btk.utu.fi/Research_Groups/research_groups.html)

The Centres of Expertise program

The Ministry of Interior began to support the development of technology in cities (previously regional funding mainly to peripheral regions) through Centre of Expertise programs (CEP) in 1994. At that time, eight different Centres of Expertise were named and the South-West Finland Centre was one of them. The first program was deemed successful and the second program period started in 2000. The idea of the program has been to pool local, regional and national resources to develop the selected internationally competitive fields of expertise. The idea of CEP is to provide basic state level funding and matching it with local funding to provide different kinds of new initiatives to increase interaction between industries and innovations systems (R&D, education and services).

One key function of the CEP is the identification of promising core areas for R&D. In Turku currently three out of four 'spearhead' areas are targeted to biotechnology (medicine, diagnostics and biomaterials). This has meant that new people and more money have been available to organise the development of co-operation in these areas. In Turku this has translated into a new organisation especially targeted to co-ordination and development, and that in each area (pharmaceuticals, biomaterials and diagnostics) there is a person dedicated to co-ordinate co-operation.

The program financing has been used as a tool to create new co-operation forums and establish new service organisations. The main difference with, Tekes for example, has been that no actual end product has been necessary. Instead, building new networks and start-up money for new projects and organisations is itself the goal. In biomaterials, for example, a joint Biomaterials Centre of the University of Turku and Åbo Akademi University has been set up, providing services for quality control and commercialisation. In diagnostics the main objective has been to establish a more continuous co-operation model in helping to establish new enterprises, especially those who find applications for biotechnology. In pharmaceuticals, the CEP has been used as a way to establish new interaction but especially as seed money to establish new service units like the Clinical Research Service Center (CRST) in 1995, the Quality Control Unit in 1995, "Safety City" (toxicology research services) in 1997 and Prefa (research on side effects and interaction with other compounds) in 1997. Moreover, the CEP has been active in improving training and education activities in the region.

The Centres of Expertise Program serves to play an important role in building up capacity at these different locales - most explicitly at the university and in BioCity laboratories, such as the MediCity research laboratory. The CEP also hosts some seminar series and training sessions to bring closer to each other the pharmaceutical, diagnostics, food and biomaterials groupings of the biotech cluster in Turku. This seems to have worked only to a limited extent because although there is a common core of scientific and technical expertise among these groups of researchers, they have very different research applications and commercialisation needs. Finding a common platform has been difficult whether in education, marketing or in networking.

VTT Turku

More recent developments include the location of the public research institutes, VTT Centre, the Technical Research Centre of Finland (said to be the largest in the Nordic countries) in the Turku PharmaCity building, along with companies like BioTie, Hormos, Juvantia and others. VTT biotechnology has wide experience in contract research. The entire institute comprises 300 people and is located currently in Espoo. Its “Industrial Biotechnology” research program was one of the 26 2000-2005 Centres of Excellence program designates, and concentrates on 4 areas: protein production, metabolic pathway engineering, molecular recognition and enzyme technology.

The real estate industry and the origins of BioCity.

High-tech cluster development is often described as arising from combinations of efforts (or single-handedly) from industry, university or government domains. Rarely does it claim its origins in the real estate industry. Turku’s real estate businesspeople have in fact played an important role in galvanising Turku’s biotech boom. First, it appears that they were driven by images of success stories for real estate returns in the construction of the Cambridge, UK and other European technology parks. Early ideas for Data City and then BioCity were already being discussed in the mid 1980s. Thus, just before the worst of the recession hit Turku, they suggested a similar scenario of building biotech facilities locally. A friend of Erkki Soini (who is one the pioneers and influential scientific and industrially-affiliated names in Turku) in the real estate business saw an opportunity and suggested it, even persuading the City government that the time was right for City involvement in the project. The City agreed to put in investments to secure up to 50% of the space, with the proviso that constructions pass a certain progress milestone by a specified date. This meant that the building industry was motivated to put in money –with no guarantees of return at that stage- with the understanding that the City would also do the same. Thus, fortunately, before the worst of the recession hit Turku, the facilities were already built and available. Had a few more months lapsed, it seems unlikely that the BioCity project and facilities would have been constructed at all, given the worsening economic climate.

In addition to people like Erkki Soini and the real estate builders, another important galvanising effect for the City’s involvement was an Academy of Finland report at the time that cited other Finnish cities for expertise in the life sciences, but suggested that Turku was diverse and applied, interpreted locally to represent a lack of focus. This implied that Turku needed to garner its forces across disciplines and build visibility. (Subsequently, in 1996, an Academy of Finland initiated international group of experts in molecular biology and biotechnology ascertained that, indeed, Turku had done well, which has been seen locally as vindication of their efforts to build visibility for existing expertise-and not that the expertise itself had to be built).

What BioCity served to accomplish was to create a physical and conceptual environment where biologists, chemists, medical researchers, physicists and mathematicians, and a range of technicians, were able to operate across (a) departmental (b) university (c) disciplinary and (d) physical boundaries. Core facilities – particularly recently acquired micro-DNA array equipment, crystallography machines and so forth, created an area where people had to be trained together, new students were brought into an atmosphere of shared technology, and the curriculum for teaching was accordingly revamped to reflect increasing multidisciplinary work. One example of cross cutting work that has since arisen from BioCity – specifically from the MediCity researchers - has been to look not at the area of research i.e. lymphocytes, for example, but instead at a specific problem - how do you measure separation between lymphocytes (an important and troubling cell trafficking problem). This problem-solving approach has then led to a discussion with medical physicists on an adjacent floor of the facilities, which otherwise appear to have been seen more as skilled technicians rather than fundamental scientists in their own right. A solution was found which served the purposes of the research and new possibilities for collaboration across other vexing problems have since arisen.

1.6 Extra-regional institutions and networks for innovation

While the local innovation system was finding it way forward, a corresponding set of institutional consolidation has occurred nationally. The national innovation system plays a big role in the development of biotechnology industry in Finland. Most of the financing for the universities and the companies come from public sources and there are several dedicated national programs to support biotechnology. Some sources even see that biotechnology will be the fourth pillar of the Finnish industry in the future (Schienstock & Tulkki 2001).

The national innovation system in Biotechnology covers several institutions and organizations, many of which are located in Helsinki region. The most important of them are the ministries, the Academy of Finland and the Finnish Technology Agency TEKES. The biggest public sources of finance for biotechnology are the Ministry of Education, the Academy of Finland, the Ministry of Trade and Industry and TEKES.

The universities gain their funding from three primary sources: budget funding, earmarked funding, and competitive funding. The budget funding by the Ministry of Education for biotechnology research in 2001 was 3.94 M€ million for the University of Turku and 1.22 M€ for Åbo Akademi. In addition the Ministry of Education and Academy of Finland provided 39 M€ of biotech funding to sources like research, researcher posts, researcher training, Centres of Excellence and international activities in Finland in 2001. This money goes to a great extent to biocentres like BioCity Turku. Moreover, TEKES provides 22.6 M€ of competitive funding to Universities and Biocentres nationwide. (Biotechnology in Finland). The table below represents the division of the Academy of Finland and TEKES funding for Biotechnology in 2001.

Table 9. The division of Academy of Finland and TEKES funding for Biotechnology in 2001 (Source: Biotechnology in Finland).

	Academy of Finland	*%*	*TEKES*	*%*
Turku	7804	20,1	9626	42,6
-BioCity Turku	*5879*	*15,1*	*5188*	*22,9*
-University of Turku	*1176*	*3,0*	*4094*	*18,1*
-Åbo Akademi	*749*	*1,9*	*344*	*1,5*
Helsinki	19642	50,6	8133	36,0
Other regions	11368	29,3	4852	21,5
Total (Universities and Biocentres)	38814	100,0	22611	100,0

Important tools for the research in the field of biotechnology are the graduate schools, Centre of Excellence funding and the Academy professor posts. In 2001 there were for example 20 Graduate Schools with 280 student positions schools in areas connected with cell and molecular biology and biotechnology in Finland. Seven of these schools were co-ordinated by the UTU or ÅA. Of twelve biotechnology related academy professors two are working in Turku (in BioCity). In biotechnology, there are 18 different labs or departments that were granted a Centre of Excellence (CoE) status. Two of them are in BioCity.

In addition, several national level research organisations are related to biotechnology industry. The most notable of these is VTT Biotechnology, which now has started a unit in Turku. Other applied institutes related to biosciences are CSC (Scientific Computing), the Finnish Institute of Occupational Health (FIOH), Finnish Environment Institute (SYKE), Agrifood Research Centre (MTT), Finnish Forest Research Centre (METLA) and National, Veterinary and Food Research (EELA).

For the financing of the companies, there were 51 venture capital companies in Finland in 2002 of which 46 are private and 5 public (Biotechnology in Finland). Of these 22 (18 private and 4 public) invest in life sciences. The most important of these is Sitra. Although the public investors are a minority, in terms of volume they account for 40% (Sitra alone supports 35%) of investments.

International Turku?

We should make a distinction between the academic, commercial and civic life of Turku in analysing to what extent the city is becoming an international, and not just Finnish, hub for biotechnology. On the one hand, the scientific community has historically had very strong international links. The Finnish benchmarking surveys put Turku, as with many other Finnish cities, high on the list of academic centres in terms of the number of publications in internationally peer-reviewed journals, as well as the extent of international co-authorship in any single publication. Furthermore, scientists in Turku appear to travel abroad frequently to attend conferences and present papers (this is increasingly so for select students as well. Both Functional Foods and MediCity students present ongoing research abroad, and apprentice in laboratories abroad as well, usually for a year during their Ph.D.s).

Moreover, local academics tend to be relatively well connected to their peers elsewhere. Particularly in the medical field, Turku appears well-known elsewhere and does not seem to experience any difficulty in getting foreigners to come and present their work. However, it does have problems in getting foreign researchers to come and work in Turku for any significant length of time (other than as students). The foreign student community derives primarily from Eastern Europe and Asia (Chinese, Indians, Pakistanis mainly) and there is some worry that for even those groups Turku is only an intermediate stopping point.

In terms of commercial links, there have been strong historical links to Sweden and to a lesser extent to other Baltic Sea countries. Some former Soviet republics have also re-emerged as desirable destinations. So far the re-establishment of these links is still in an early stage. In the formation of regional policy, ties to Sweden, Germany, Russia and the Baltic states have appeared especially important.

2 The transition process of the industry

2.1 How the industry got started in the region

The background of the biotechnology industry in Turku and in Finland can be traced to the development of the domestic pharmaceutical industry, which was born in the late 19^{th} century. The period from 1889-1925 highlights the beginnings of the Finnish pharmaceutical industry, from the establishment of its first company to creating a capability in generics manufacturing. This period does not appear to have been known either for endogenous technological or scientific breakthroughs, nor for innovative manufacturing.

The first important turning point for the city of Turku occurred in the 1940s, when both Farmos and Leiras companies, started research and development bases in Turku. One of the companies had a founder from the region who was familiar with advances in public domain research communities of the universities; another situated itself there primarily to exploit a relationship with the universities.

Overall, the decades from 1925 to the 1980s were somewhat uneventful from an innovation standpoint. The strategy of Finnish companies was primarily to acquire foreign licenses to sell foreign technology-generated drugs to the domestic market and thus was a primarily marketing relationship. This was driven in large part by a national ideology of self-sufficiency for drug supply, even though not much was yet being invested in being independent of the foreign technologies. The 1970s on the other hand heralded the advent of more global relations. There was a move to greater trade with other countries and for the first time in recent history, brought a need to increase R&D investments to provide distinctive exports as well as combat superior imports. It also brought a period of stable and profitable generics sales volumes to Russia, a long-time historical trade partner.

If the 1970s saw new opportunities through greater trade and the expansion and exploitation of the massive Russian (and broader Soviet) market, the years between 1989 and 1994 were to herald significant threats to Finnish pharmaceuticals and the second major turning point in the direction of technology capability. In the 1980s, Farmos succeeded in creating the first Finnish drug for breast cancer along with analgesics and tranquillisers for veterinary use. From 1989-1994, tumultuous times ensued. There was not only the loss of Russian generic drug markets with the fall of the Soviet Union, but Finland found itself battling a massive economic recession. 1994 heralded the actual Finnish accession to the European Union, spurred in part by the belief that some economic relief would be found in a larger European identity. This had at least two significant technological implications: firstly, joining the EU brought a new institutional framework of the product patent regime, while the loss of the generics Russian market simultaneously drove down easy profits for Finnish pharmaceutical companies.

But regional, pan-European changes were exacerbated by global restructuring in the pharmaceutical industry, with a significant rise in global mergers and acquisitions within the pharmaceutical industry, resulting in notable effects on the Finnish pharmaceutical cluster. In the 1980s, Orion Corporation, a Finnish company from Espoo, and Huhtamäki Ltd. aggressively bought out most other companies. Despite the Espoo location, Orion had many product research projects ongoing in Turku. Leiras was subsumed into the Huhtamäki Pharmaceuticals Company in 1986. Farmos and Orion both merged in 1990, and in 1992, Leiras became a separate legal entity once again and parted ways from the Huhtamäki Corporation. It was then bought by the multinational company Schering (now Schering-Plough). While these developments changed the nature of the therapeutics segment, diagnostics was not immune. The Finnish firm Wallac, with a long history of collaborative work in the Turku area in diagnostics, and with strong links to individual university researchers, was bought by US-based Perkin Elmer Inc, itself EG&G formerly. Thus, Finnish companies in Turku, also affected by the restructuring, were bought by global multinational companies and spent the early 1990s consolidating and narrowing their research portfolios, while laying off researchers. The result was an increased number of start-ups and spin-off companies in the Turku area, developed within a changing intellectual property environment. The loss of access to in-house R&D facilities, forced many of the now-independent researchers to strengthen their ties to the university to keep a flow of free, public-domain information feeding their knowledge pool in the creation of new products and processes.

Turning points for the Turku pharmaceutical industry:

1889-1925	Start of Finnish pharma industry, Generics manufacturing, mass production
1940s	Farmos and Leiras start bases in Turku
1925-1980s	Companies mostly acquiring foreign licenses to sell domestically.
1970s	Move to greater trade. More R&D investments but greater generics sales to USSR
Late 1980s	product patents adopted in many other countries. Anticipation of EU membership
1989-1994	Recession, loss of USSR generics markets, M&A in pharma in global pharma industry, joining EU, shift to EU product patent regime, Turku starts BioCity
1994-2002	EU entry, further focus on R&D, consolidation of drug development R&D projects in Turku firms, layoffs, biotech start-ups and spin-offs arise, Turku pushes to develop a nationally recognises biotech base.

2.2 The transition and rise of biotechnology

Finland industrialised relatively late in Europe and was institutionally less market-driven than many Western European countries. Indeed, the State's involvement in the economy is still substantial, particularly in science and technology. Dominated by older industries such as shipbuilding, food processing, construction, metal work and textile and shoe manufacturing, Turku has been hard pressed to redefine itself as one of Finland's "high-tech" miracles. It also has not had a Nokia-type success story to prop up the local economy. Studying how Turku has come to be one of Europe's promising emerging biotech clusters is also a way to identify what institutions and their transformation led to this renaissance. Unlike stories in many other emerging biotech regions, where other high-tech industrial capabilities also exist, Turku's story emerges as one of redefinition and regrouping around a broadly defined set of food, pharmaceutical and agricultural expertise.

The period from 1990 to 1999 proved to be decisive for Turku. Unemployment in the city rose from 4.2% in 1990 to 22.1% in 1994. The food processing industry alone lost 21% of its labour force, with implications for new approaches to biotech within the food industry in more recent years. Despite its best efforts through combined public and private strategies, Turku unemployment in 1999 was still 17.4% compared with the Finnish average of 10.2% in the same year.

Turku was not alone in facing an economic shock in the 1990s. The fall of the Soviet Union, a long-time market for Finnish, and Turku goods, particularly for processed foods, shoes and textiles-staples of Turku output, as well as the recession that hit all of Finland at once, shaped the destiny of Turku in a unique way through the rest of the decade. Thus, while other cities had rebounded to different extents, the industry mix and the particular dependence of the Turku area on the Russian markets set the stage for needing a new identity for the city's industries

The silver lining however, was that despite these downturns and external shocks, the global restructuring climate in the pharmaceutical industry had left Turku with Finland's highest concentration of therapeutic and diagnostic firms and 2 new multinational companies (Leiras/Schering-Plough + PerkinElmer Wallac), along with a residual sizeable, but vulnerable, food industry. When there was a need for trying to find a new growth area and looking at the local knowledge base, "biotechnology" was the obvious candidate.

The preponderance of large companies like Orion and Schering in Turku already accounts for more than half of Finland's pharmaceutical industry and the same applies to the diagnostic industry with the huge impact of Perkins Elmer Wallac Life Sciences. The smaller emerging companies, a 1990s phenomenon, are Finland's biotechnology poster child(ren)- BioTie Therapies Corp., Hormos Medical Corp. and Juvantia Pharma Ltd, of which BioTie became the first Finnish biotech firm to go public and list on the Helsinki stock exchange. BioTie is also distinctive in being started by a former academic and head of the Centre for Biotechnology, Markku Jalkanen.

The driving organisations and actors behind Turku's upward trajectory in biotechnology have been its historical medicine, biology and chemistry bases. These, with intersections with the pharmaceutical and diagnostic firms drive the gradual economic success of Turku firms. Overall, because of the long-term relationships with university researchers established by mid-size domestic and foreign pharmaceutical companies within Finland, (such as PE Wallac- an acquisition of the Finnish diagnostics firm Wallac, by US-based Perkins Elmer Life sciences group), the industry-academic connections function relatively well.[14] In addition, there has been an organisational proliferation of "new" types- hybrid entities such as BioCity Turku, Centre for Biotechnology and MediCity, both coming out of the university domain, but heralding new forms of inter-university co-operation as well as new intersections with the private sector.[15] While there has been an effort to include more traditional industries such as shipbuilding, metal work and manufacturing, it is clear that the preponderance of focus has been on a redefinition of the image of Turku as a high-tech hub.[16]

In addition, we propose that the localisation of capability and the focusing on a life science identity has also played out through a transfer of institutions. An experiment with information technology through "Data City" in Turku between 1986-'89, a dedicated area for IT, was followed by "Bio City" in 1992. Furthermore, the national Centres of Excellence Program created further impetus for local initiative, and concentrated resources and gave recognition to local lead researchers. National programs through TEKES also forced a greater localisation through bringing local industry and researchers together through financial and market incentives of various kinds. The *combin*ed effects were productive; more Finns abroad returned to Finland, and many from Turku were only too glad to be able to return home and find R&D opportunities available after stints in the best foreign laboratories. The following list highlights this institutional "stickiness" that drove localisation in Turku.

Table 10. Factors related to institutional transfer

Transfer of sectoral institutions and learning	**Transfer of national to local program initiatives**	**National programs that induce greater interaction between local firms and universities**	**The circulation and return of skilled personnel**
Data City (1986-89) -> Bio City (1992)	"Regionalisation" through directed funding and the Centres of Expertise Program	Diffusion programs of one university department with many local companies	Brain gain and model adoption from world-wide hubs for biotech research

Direction of increasing localisation and progressive institutional transfer, both laterally and vertically

[14] Stressing this dynamic linking old pharmaceutical firms with the local universities, one respondent said, "key founders and key people in these pharmaceuticals whether on Board of Directors or in advisory capacities, have been professors. In the 1970s there was a university backlash to make research "pure", but in Turku it never seemed to cut off the very significant ties to the three main companies. So in Turku there were hundreds of people in R&D, mainly in bio-sciences linking University with industry."

[15] The City of Turku has often been accused by residents and non-residents alike, of having come to the policy push late, but has recently shown organising zeal and a financial initiative to take on long-term vision-planning for Turku's new identity as a high-tech hub of biotechnology. The Foundation for New technologies as well as the South-West Finland Biotechnology initiative have also been ways to fuel adaptations and acquisitions to newer technologies and establish the larger Turku region-including IT-centres like Salo, to integrate a broader "corridor" effect in high technologies.

[16] Also, see more details of Turku's organisational construction in Bruun et al (2001)

Ironically, despite Finland's image as an IT and telecommunications hub, an important factor in Turku's renaissance has been the relative *absence* of IT-related skills and industry which has led to the need for a concerted effort to foster its life-sciences research and commercialisation. The absence of engineering departments in the Turku city area (except for Chemical engineering at the Åbo Akademi which has been relevant to biotech) is often stated by academics, policy makers and entrepreneurs alike as the reason why no IT-boom occurred in Turku, unlike elsewhere in Finland.

Turku University with 16, 200 students and Åbo Akademi with 7,000 students each provide the basis for the skilled local labour.[17] Both are driven by science and technology but highly resource constrained at a time when the Finnish state is pushing universities to seek external sources of funding from non-governmental sources. TEKES has been particularly forceful in making the case for increased university-firm interaction, leading both firms and university researchers to ask whether this is an optimal strategy for either in the long-term if universities do more applied work.

Accession to the EU has also had a downside to Finland. EU laws prevent European companies from developing an alternate process for manufacturing a drug until the expiry of the patent i.e. product patents exist. There is thus no "easy" money to be had for Finnish firms while they build capability. Instead, they too, often mix R&D and service capabilities to earn revenues and build learning alliances. They have lost much of their drug manufacturing markets, while not having realised their full drug discovery potential.

We can classify five sets of institutions central to Turku's biotech focus. They are:

1. Older mid-size pharmaceutical companies
2. Universities: BioCity Turku (Centre for Biotechnology) and MediCity
3. National government - especially Tekes and Sitra
4. City of Turku
5. City, Regional and National Government (FNT and SWB projects)

2.3 Technological change and building the competence base

Turku's capabilities through its companies and its university expertise in the pharmaceutical sector have evolved in a fashion similar to what occurred in the U.S. or Western European countries earlier in history. Experience began on both the research end of the value chain as well as manufacturing competence in the middle and marketing at one end. However, the sales and marketing end has not been a strong suit of Finnish firms internationally and with the domestic market being small, they are being forced to go global rapidly. In the therapeutics sector, scientific and technological expertise emerged predictably from medicinal chemistry in the random screening of targets, while in parallel,

[17] Importantly for the pharmaceutical industry, the University hospital continues to build up a formidable force in basic research as well as clinical study and testing services. It also provides an important source along with the medical faculty of the university, of validation of early drug target research in the private sector. The business school has also been important, with 2,000 students, creating an increasingly focused curriculum, which can provide new impetus to S&T initiatives in Turku. The Polytechnics contribute more than 6000 students; the Turku vocational institute has 4,500.

industry made money off manufacturing different versions of the patented drug market right up until the 1994 EU accession. The 1994 EU membership created a window (in most countries about a decade) where serious efforts were put in place by companies to increase R&D to take on the pharmaceutical product patent regime.

When the molecular biology revolution occurred in the 1970s, Turku had its technological outpost in the San Francisco Bay Area and in other areas like Southern California (La Jolla, for example), where Turku Ph.D.s and doctors did their postdoctoral research work in some of the best laboratories. They witnessed firsthand the birth of commercialised biotechnology in the US and the many pathways through which academics became involved in the business of medicinal biotech. This appears to have been particularly important for a few lead researchers who subsequently came back to Turku and became intricately involved in the setting up of both the Centre for Biotechnology, as well as a few start-ups which have been very promising. The postdoctoral years in the U.S. in the early 1980s gave these academics ideas about developing their own proprietary technologies and how to commercialise them and/or how to work with industry in a constructive way, even if choosing to remain in academia themselves.

While the predictable 'graduation' from medicinal chemistry to molecular biology focus was ongoing in therapeutics, driven mainly by M.D. Ph.D.s (i.e. doctorates with medical training), thus bringing to the fore longstanding medical expertise in Turku in addition to its chemistry base, a similar domain shift was ongoing (if a little more slowly) in the food industry. Here, very large companies like Raisio, with global ambitions, already had under their belt experiments in sweeteners like Xylitol and later cholesterol-lowering foods like Benecol, which became global products. The food chemistry expertise at the university appears to have been instrumental in the rapid growth of the company, which also boasted an impressive in-house R&D focus. Perhaps more in food than in medicine, there seems to have been less resistance overall to working with industry, since PhD students themselves in food chemistry (and now functional foods), are exposed to industry early on in apprenticing through their educational years. Raisio and other food companies have also benefited from genetic advances, being able to tailor-make foods to a greater extent, while also developing a much more sophisticated understanding of delivery and uptake properties of the human body.

Thus, from the 1980s onward, the food industry - particularly that segment involved in nutriceuticals, or functional foods, has been gravitating towards the therapeutics segment of the pharmaceutical industry. Although the institutions through which they commercialise the innovations look very different, both industries now have similar segments dealing with similar products. For example, Raisio has a third important wing called Raisio Life Sciences, while companies like Hormos Medical also has a wing dedicated to nutriceuticals. From a policy standpoint, the current use of modern biotechnology in both these sectors, moving from a platform of older biotech (for example chemistry and enzymology in both the food and pharmaceutical industries), has provided a "branding" within a newer, high-tech mould of diverse sectors, some with greater employment potential than others, making it easier to "sell" the image of the new, high-tech Turku to the public and policy makers alike.

However, the food industry seems to be quite conservative about adapting new technologies and it remains to be seen whether these initiatives will remain within large, established companies like Raisio, or become a sector trend. Therefore, new policy measures have been taken to integrate the food industry more into the biotechnological development. A good example of this is the new Functional Foods Forum (a research and development center, which was established 2001.

Thus combinatorial chemistry, genomics, proteomics and other sub-segments of the "new" biotechnology have provided a strategic regrouping of older competence into shared policy instruments across disparate sectors, allowing an otherwise fragmented, small grouping in Turku to accumulate size and visibility on a national, even international scale. They also provide both national agencies like Tekes and the Academy of Finland, as well as city councillors, a way to take advantage of economies of scale across sectors when planning for manufacturing plants, research consortia or international marketing assistance with the number of potential participants increased, and with some common (although as yet minimal) research programmes defined. In this way the term 'biotechnology' can also be seen as a policy instrument to activate and combine different resources emerging from different domain histories.

2.4 Current competitive standing of the industry in the region

Turku, like many other emerging biotechnology centres around the world, finds itself facing some pressing problems. These challenges are particularly present in the biopharmaceuticals, a capital intensive industry dominated by large multinationals. While collectively Turku seeks to identify itself with certain niche expertise, it also wishes to be seen as having strengths in many different areas so as to build visibility. From a firm's standpoint, this translates to positioning along the global pharmaceutical "value chain".

We can envision the generic pharmaceutical value chain as having drug discovery (and all its components) at the left-most end of the value spectrum and the marketing and sales end on the right most. These two extremes have taken on a different character after the 1970s' molecular biology breakthroughs and the subsequent mergers and acquisitions within the industry throughout the 1980s. This was primarily generated by a shift in the dominant technology of the pharmaceutical field, from random screening to targeted drug discovery that emerged from bioengineering after the 1970s revolution. What once used to a right-moving value chain, i.e. with the highest value-added component being marketing and sales, with the entire labour component being absorbed into pharmaceutical companies, has since the 1980s emerged as a labour specialisation with high value added at both extremes of the chain: both drug discovery on the left and marketing and sales on the right. Although sales and marketing still tends to be the big money-earner, the shift in labour specialisation has resulted in an interdependency between two types of organisations, particularly exemplified by the U.S. example: small, dedicated biotech firms (DBFs) with proprietary technology platforms engaged in drug discovery (and occasionally development) and on the other end, mid-size to large pharmaceutical companies with many more functions vertically integrated and significantly more revenue-rich than the smaller DBFs. While many large pharmaceuticals also comprise a corporate R&D function engaged in drug discovery, it is still more profitable (and often faster) to license candidate molecules from smaller dedicated drug discovery firms.

Within this division of labour as seen in the U.S., Turku firms must find a position along the value chain. With Turku no longer a manufacturing hub after the recession, and with generics manufacturing no longer having a strong historical base within Turku (although certainly within Finland), Turku pharmaceutical firms are differentially spaced along the value chain. On the one hand, there are the small DBFs (Juvantia, Hormos, BioTie), all using biotechnology tools for probing candidate molecules for therapeutic uses at the left hand extreme. In addition, there are firms like Focus Inhalation, more into looking at new/novel Drug Delivery Systems (NDDS) for existing drugs. Such firms use a proven concept within the drug discovery domain, but make inroads into specific delivery problems vexing the industry. In their case, how best to deliver externally (mechanically) but also internally (biologically) the powdered inhaled drugs targeting asthmatics, among others. Since their inception, an encouraging sign is that smaller companies, particularly in diagnostics and materials, have emerged from the initiatives of individual researchers or research groups at the universities either assisted by technology transfer companies like Aboatech or independently (such as Sticktech, Innotrack and Arctic Diagnostics).

In addition to such companies, the therapeutic segment also comprises competence within Turku university hospital where the clinical studies and some clinical trials are conducted on patient populations, most of which are voluntary. However, Turku does not yet have indigenous companies that have a well-established international reputation in clinical trials and studies. One recent attempt to change this has been to develop “Safety City” and other service companies spun-off from university facilities as independent companies, which provide this services function. However, most Turku firms thus far still give their therapeutics for trials to international firms like Quintiles for large-scale testing.

The strict regulatory standards that firms now face by the US FDA and European regulators to show the efficacy of their clinical trial results means that it is technically challenging and more capital-intensive, to say the least, for new local firms to establish themselves in this service segment.

Moving further rightward along the value chain, Turku has few small firms positioned in the marketing and sales segment. Not unexpectedly, the larger pharmaceutical (therapeutic) players like Orion, Farmos and Leiras (now of Schering-Plough) are the ones with well-established networks both inside and outside Finland. Thus smaller firms are still dependent on licensing out candidates, as in the U.S. model, to organisations further right on the value chain.

However, an important difference with the U.S. inspired value chain is that for the population as a whole, (indigenous companies and not multinationals situated locally), neither the right hand nor the left hand extreme are secure positions. The drug discovery firms are now emerging with technological and financial hardships. The technological difficulties revolve around generating new tools and new products and developing intellectual property of sufficiently high value to keep operations going and to grow to a larger scale. This involves, but is not limited to, buying the latest technologies, attracting specialists in certain sub-segments of the research who many not be available locally, and in establishing joint ventures with foreign firms at the cutting edge so that technology transfer to the latest finds can take place. From the financial standpoint, these firms are finding it increasingly hard to tap still-nascent private venture capital, and finding it increasingly frustrating to satisfy conditions for public sector funding which invariably mean participating in collaborations with university researchers and multiple other firms. The interviews indicate that this doe not often lead to fruitful outcomes for any of the firms, and appears to mainly benefit the university academics at the cost of wasted time and resources for firms. With the U.S. economy, particularly high-tech and biotech stocks doing poorly in 2002, investor confidence has been sapped and tapping international capital appears to have become time-consuming and dispiriting.

With neither secure positions at either end of the value chain and Orion being the only Finnish firm at the right hand extreme, Turku firms as well as Turku policy makers, find themselves faced with the question of where along the value chain - or at multiple points - should they place themselves. Should they strategically develop competence at specific segments and go head-to-head with the U.S. and other European firms (particularly European ones from Germany, Sweden and the U.K.) or should they pick a range of competencies to develop so they might diversify and reduce risks?

What Turku firms have in making this decision are (a) local resources - the expertise in the universities and in the CEP, VTT and other public-sector inspired competence centres (b) local skill set (c) other product firms and their competence base (d) local services base. From a resource theory driven angle, one might imagine that the choices become optimised given the local setting. But of course, the resources could also be outside the local area. Turku firms seem to have to decide between being local and establishing a global presence. This often means choosing between staying small locally or growing larger through multiple international sites. For one firm, this has meant, evaluating whether they have "run out" of local resources for a given research direction, and whether they will need to look overseas to establish links which are more substantial (and researchers abroad who are more willing for whatever reason) to dedicate to a specific research interest of the firm. From an international validation standpoint as well, whether it is for the validation of a specific biomaterial, or for the validation of a target molecule, non-local researchers play a significant role. It is not clear yet, if this means more international links or that the firms move abroad as they get closer to the manufacturing stage in their development.

Unlike even some later industrialisers such as Singapore or India, Turku cannot fall back on the strategy of lowering costs in the long-term, nor (as is the case of India) on the size of the domestic market for making volume sales.[18] Unlike Singapore, it cannot compete on manufacturing capability in the pharmaceutical segment either (even if it once could) either on the basis of economies of scale in any single plant, or through multiple plants, or through attracting foreign companies by sheer density of manufacturing companies. Furthermore, as mentioned earlier, it has yet to produce an indigenous firm that can conduct clinical trials on a scale and at a cost comparable to the large clinical trials service firms today. On the marketing and sales end, it depends heavily on multinational firms for licensing or sales agreements. In this sense, it is similar to Singapore, which is trying to work its way to other segments (rather than manufacturing alone), but which is stymied because its indigenous firms are too

[18] These comparison countries are used since one of the authors, Srinivas, is currently studying how the pharmaceutical industry has developed in these countries.

young, and its larger firms are predominantly multinationals, who are uncertain long-term partners to the city and to local firms. Unlike India, which also has significant pharmaceutical abilities, it does not have the absolute numbers of skilled people to venture into entirely new segments or work its way into integrating across the multiple segments of the value chain.

Thus, from the city perspective, the most likely trajectory is to continue to foster its small companies and help them grow, while setting itself up for the possibility that they may ultimately take flight and move elsewhere in their desire to establish an international presence. From a strategic policy perspective, avoiding the 'taking flight' outcome will mean at least two things: first, that although local companies may eventually relocate elsewhere for sales and marketing, they may retain their R&D and core-competence focus in Turku. Second, to at least retain the volume of firms present in Turku, and hopefully to grow that volume, Turku needs to attract in new firms or have new ones sprout locally. In particular, to attract firms from elsewhere (Leiras is now moving an increasing number of functions to Turku, and global clinical trial firms are also considering tie-ups with the university hospital), Turku needs to sell the competence of its universities and its services base. While this may not mean directly advertising competence, it may mean that a strategic university policy needs to emerge that addresses the long-term knowledge base for Turku. Thus, either to retain local firms or to attract in outsiders, the university begins to take on greater relevance, not simply as a source of knowledge and ideas, but as an active partner in building the local biotech base.

3 The role of technology in transition

3.1 The rise of modern biotechnology

In this report, biotechnology refers to a broad range of life sciences (biosciences) and their utilization in medicine, primary production, industry and services. **B**iotechnology can be defined as a set of powerful tools that employ living organisms (or part of organisms) to make or modify products, improve plants or animals, or develop micro-organisms for specific uses (Biotechnology for the 21st Century, 1995). OECD defines biotechnology as "the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."

Biotechnology can be divided into three bases. Early 1st phase biotechnology includes traditional animal and plant breeding techniques, and the use of yeast in making bread, beer, wine and cheese. Second phase biotechnology can be seen as starting from the 1940s, when biotechnology was introduced in modern industry. Modern or third phase biotechnology includes the industrial use of recombinant DNA, cell fusion, novel bioprocessing techniques, and bioremediation. This phase can be seen starting from the seventies, when new tools for modifying the genetic structure of a living organism were introduced (see Tulkki et al 2001, 14).

What is interesting from the research point of view is that the new advances in the biosciences have led to the blurring of boundaries between historically separate disciplines. Biological sciences interact with other fields like medicine, chemistry, informatics and physics, which has meant that there has been an increasing need for interdisciplinary research. The restructuring of science has also brought different industries closer to each other. Medicine has integrated into the broader field of life sciences, but biotechnology is not only limited to life sciences. Many of the new technologies developed for molecular biology research, such as high-throughput DNA sequencing, protein structure determination or gene expression analysis on "DNA chips", are also used in ecology, agriculture, forestry, and the biotechnology and pharmaceutical industries (Biotechnology in Finland, 2002).

From the R&D point of view biotechnology is a very demanding set of tools or "field". Research in the biosciences demands rapidly evolving and expensive methods and instrumentation. Because the cost of R&D is so big it puts special emphasis to funding, both in university research and company R&D. Biotechnology also often requires very time-consuming experimentation with expensive materials and equipment. Many of the innovations are based on basic research, which means that the time from the innovation to markets is very long.

From this point of view, biotechnology as a field differs very much from information and communication technologies (ICT), where a new company, especially in software, can be started with a very little amount of capital and where the time from innovation to markets can be very short – sometimes even months. From a managerial perspective as well, biotechnology differs from ICT. As ICT industry can mainly be seen as a new field with new organisational culture and a field that is easy to enter, advances in biotechnology are turning older industries like food industry into "high tech", which can place many challenges (Brännback et al 2001, 9).

It has been estimated that only one out of ten of the biotechnology firm succeeds in bringing a product to the market. This means that biotechnology is a risky industry and this has to be taken into account by policy makers and venture capitalists alike when supporting the industry. For the same reason there have been many recent mergers and small companies try to spread risks by having several products in the pipeline.

By most accounts, there are two primary indicators, which define an industry as high technology: R&D spending and patent approvals.[19] With these indicators, biotechnology is by far the most R&D intensive of all major non-defence industries. R&D spending per employee is usually almost ten times as big in biotech companies compared with all industries and much bigger than in ICT industries for example (Brännback et al 2001). In biotechnology, the importance of patents is also very big.

Genomics for example is making drug development more focused, cheaper and makes it possible to make more 'tailored' drugs for targeted groups of patients; for example, the new biochip technology with the capacity to do testing at a fraction of the cost of traditional screening. Prices of the drugs are mainly driven by drug development costs. Traditional drug discovery methods for medicinal chemistry are being displaced by combinatorial chemistry where thousands of compounds can be screened for each gene target in a search for the perfect drug. At the same time it is possible to target specialized

[19] Admittedly, these two indicators are highly context-dependent. Some countries may have investments in "high-tech" domains, but have relatively little to invest in patenting or R&D. Thus, having little of either indicator does not mean that the field of involvement is not "high-tech", but that the best examples of such a field are characterised by high numbers in both indicator categories.

drugs for people with different kinds of genotypes. This is one of the main reasons why the diagnostics industry is getting closer to pharmaceutical industry as there is an increasing need to diagnose patients for individualized treatment.

This "new way" of developing drugs has been one key factor that has given the small companies the possibility of entering a the field previously dominated by large players. The new integration of different disciplines and the increasing importance of publicly generated scientific knowledge have increased the need for Big Pharma to collaborate with universities and small start-ups or specialized companies. Previously the competitiveness of many bigger companies was based on imitation, generics and a concentration of various niche markets. Internal specialization is more difficult now, when knowledge from so many fields is required. At the same time especially the pharmaceutical industry has concentrated and these large MNCs are increasingly concentrating on distribution and marketing.

This increasing interdependence between small discovery companies and large MNCs suits both sides. The small companies get resources, tools and a distribution channel as the big companies can increase their R&D productivity, spread their risks related to expensive R&D and have access to new knowledge and new innovations. All in all, in biotechnology, success demands working collaboration at many levels in order to link different competencies and resources in many levels of research and the industry.

3.2 Linking competencies in Turku-the challenge and success

There has been something of a struggle in Turku to link various competencies within the university and in the private domain. University administrators have not directly been involved in this effort (unless they themselves are biomedical researchers, for instance). In general, the effort to link the various groups has been driven in part by the national programs like Tekes and CEP, which have attempted to consolidate the vast groupings of expertise in Turku broadly seen as therapeutics, diagnostics (both pharmaceuticals), functional foods and biomaterials. In general, the functional foods and biomaterials, and to a lesser extent diagnostics groups, feel the national attention is primarily focused on pharmaceuticals (which to some extent is true, if the policy and city literature is anything to go by). This is ascribed to the effect of the U.S. markets, where blockbuster drugs and huge valuations of pharmaceutical (therapeutics) and small biotech companies has created a public awareness of the industry and generated policy-maker support. Diagnostics and biomaterials thus find it understandably difficult to integrate into efforts to promote Turku as a biotech hub when the efforts are primarily focused on therapeutics. The CEP and Tekes efforts appear to now be changing direction. Recent attempts at the local level through Bio Valley and others are now also geared towards developing all elements, particularly with recent gains made by biomaterials and functional foods. As elsewhere, the future of functional foods is still uncertain vis-à-vis regulation. One supportive future market where relatively comprehensive and clear regulation exists is Japan, where functional food items are well accepted in the market

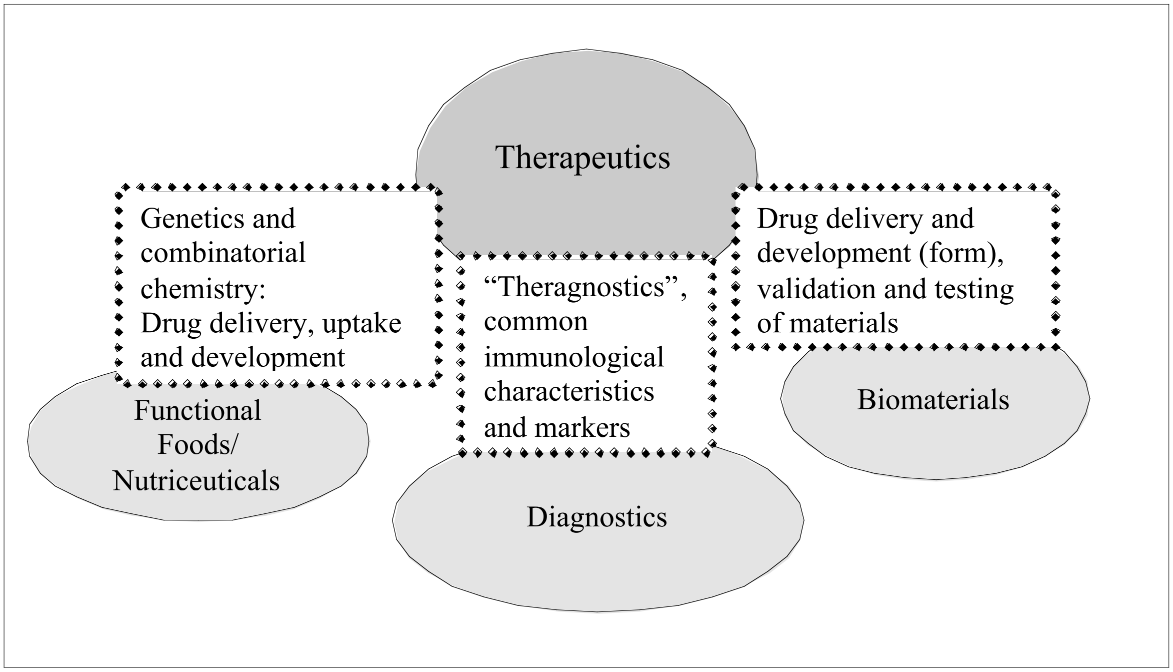

Figure 1. The therapeutics dominated group of competencies in Turku

The efforts to link across expertise in the four main segments: therapeutics, diagnostics, biomaterials and functional foods is challenging because not only are the technologies used in these industries only loosely connected, the fields are also institutionally divergent the closer they get to the market, where separate industry institutions and commercial linkages become important. For instance, at the early stages of exploratory work, there could, in principle, be links established and common interests between therapeutics researchers in drug delivery, and those in biomaterials (looking at actual materials through which delivery could occur). However, the eventual applications diverge and are regulated by different bodies, meet different market criteria and emerge through significantly different validation procedures and networks.

Furthermore, to a large extent, the therapeutics market is driven by the global dynamics of mergers and acquisitions in a way that does not presently exist for biomaterials companies, where many of the important organisations are still small and medium firms, not the behemoths of the therapeutics segment. Another example of divergence is within the pharmaceuticals itself, where the therapeutics segment and diagnostics may share common research interests in immunology – one for constructing appropriate drugs, one for building diagnostic equipment. However, rapidly, their interests diverge because of the technical variations in application, with the diagnostics researchers heading much more rapidly into instrumentation, prototyping and engineering specifics based on the immunology findings and driven by the dynamics of diagnostic markets leaders, usually separate mid-size and large companies such as PE-Wallac. A third example is that of common early links between chemistry groups in pharmaceuticals and those in functional foods, which are later driven in the value chain by entirely different sets of market and regulatory institutions, one in the health care, the other in the food industry.

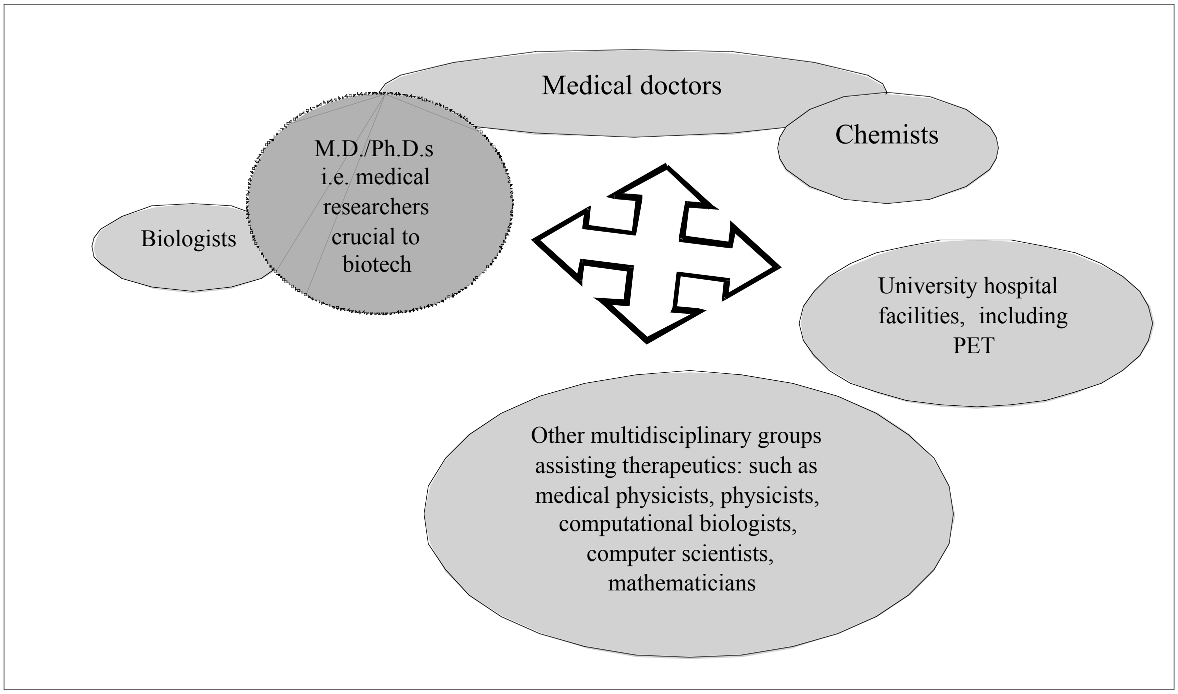

Figure 5. Turku's therapeutics competence: Knowledge assets across subject/sector domains

Despite the difficulties in linking scientific competencies, there is also a challenge in Turku to acquire and link small companies with big MNCs. In addition to small home markets there are only few multinationals present in the region, which means that the small companies have to head for the global markets and identify accessible and valuable global networks from the beginning.

3.3 Spatial clustering and proximity effects

There are many studies referring to the positive effects of spatial clustering and throughout the 20th century researchers of different fields have been interested in why and how industry agglomerations emerge, and in what ways location close to similar or related firms contributes to the competitiveness of an individual firm[20]. Malmberg & Maskell (2002) have summarised the literature in the way that we can find at least four factors that affect spatial clustering. The traditional *analysis of spatial clustering* tries to analyze the advantages that firms get by locating close to each other (localization economies). Three different mechanisms traditionally identified:

1. Reduced costs for producing and maintaining a dedicated infrastructure and other collective resources
2. Well-functioning markets for specialized skills

[20] Obvious contributors to this dynamic field of enquiry are amongst others Marshall (1890), Weber (1909/1929), Myrdal (1957) and more recently authors like Scott (1988, 1998), Amin & Thrift (1994), Storper (1997), Porter (1990, 1998) and Krugman (1991).

3. Reduced interaction costs for co-located trading partners

Recent analysis of spatial clustering is based on the idea of knowledge and innovation. A fourth factor is introduced:

4. A localized cluster of firms that form a basis for the local milieu that may facilitate knowledge spillovers, learning and adaptation[21].

Although a shared infrastructure and supplier and service network have an important role, in a high tech industry like biotech the role of knowledge becomes especially crucial. We can find several reasons related to knowledge and expertise that link innovation capability to space.

- **New knowledge**. New knowledge is usually difficult to codify and therefore difficult to transfer. It is best transferred through repeated and frequent face-to-face contacts. Innovation is therefore facilitated by geographical proximity.
- **Knowledge exchange**. Knowledge exchange can happen through knowledge spillovers. On the other hand, most actors are unwilling to share crucial information when there is a danger that it can end up in the hands of the competitors. Information exchange usually happens with known and trusted clients and customers. This may also be the case with long-term co-operation with the universities and research institutions.
- **The availability of a high level workforce** is a very important requirement for innovation. Labor mobility is lower (especially in Europe) than the mobility of other resources and tends to concentrate in certain regions.

From the perspective of spatial clustering, Turku faces many challenges. The size of the local cluster is quite small and lacking parts of the support system especially in private biotechnological services. At the same time, there are hints of the limitations in the local supply of high level labor force and skilled research staff. For now, most companies have seen no big problems in the supply of skilled labor but lately more staff has been recruited from Oulu and Helsinki. Most of the companies are also small and the cluster as a whole lacks the kind of corporate engine that is found in the ICT sector with Nokia. Mid size companies like Leiras-Schering and PE-Wallac serve this function partially but their links to smaller firms are limited and in that sense the agglomeration of biotechnology companies in Turku does not present very strong functional clustering. [22]

For many smaller companies, the location in Turku is still crucial as most of the core competencies and expertise is concentrated on local human capital in the companies and university research groups. Although individual researchers move abroad frequently, as a whole the mobility of labor is quite small and in this sense the industry seems to be geographically sticky. As a result of this, the internationalization strategy seems to be mainly based on partnerships and side offices abroad.

[21] A broad field of models explaining the relationship between innovation and territorial organising of functions have been developed especially during the last two decades. These approaches include such as industrial districts, milieux innovateurs, new industrial spaces, local production systems, regional innovation systems.

[22] While this has implications for strict appropriability arrangements through patents, we do not explore this subject here.

We show below a hypothesised link between two different types of proximity (which we see to be broader and richer than spatial proximity alone) and the learning behaviours that they potentially generate.

Table 11. Proximity and learning in the Turku biotech community

The type of proximity	Learning type	The facilitating features of proximity
Spatial proximity	Between local initiatives across sectors/technologies: Data City and Bio City Between people within the biotech community	Local proximity allows failures and successes to be incorporated into next initiative. Safety in numbers, ease of contact, shared resources and lowered costs, scale building for national and international visibility[23]
Organisational proximity	Between organisations: Dual roles for locals	Circumventing formality, linking people, linking disciplines, influencing policy, finding new markets for R&D

There is a generally shared belief in Turku that in a small city with limited resources and limited size there is a need to compensate for the lack of urbanisation and knowledge diffusion presumed to be found in bigger metropolitan areas by actively building a working innovation environment. The spatial dimensions of this, as evidenced by the networked architecture of the buildings, also seem to assist the process.[24] It is extremely encouraging to see that the fairly small but active network of individuals appears to have had a big effect not only on improving the competitiveness of new pharmaceutical companies but also on mobilising new policy activities to support the local cluster's development. The company researchers and executives know each other personally and the interaction has helped in some ways to share experiences, as there is 'no need to reinvent the wheel'. On the other hand, concern has also been expressed by a variety of interviewees that the local network of active individuals is too small and that too much of the burden is laid on few key individuals. In this way a strengthened position of

[23] An interviewee summarised this, saying "“The best thing so far, as of today, is the cooperation between City of Turku and the Universities of Turku. This has created the buildings and has made it possible to invest in this type and level of equipment. Without this type of cooperation, this would never have happened. It's also getting closer and closer all the time."

[24] "…it doesn't matter where you are - if you don't waste your energies fighting, you can "do beautiful things". In the early 1980s all the fights were very destructive. The new physical structures have helped a lot and the newer generation [of people]."

the City of Turku and new organisations like Bio Valley may help to institutionalise the development activities, which previously were more likely to have been sustained by individuals.

4 The role of universities in the innovation process

4.1 The long road to build the local knowledge base

The data collected in this study and in previous studies from Turku clearly suggest that the universities have had a strong role in supporting the innovative capacity of the biotechnology related industries. The question is what form this support and leadership takes in building the "local innovation system". Biotech related research and education has a long history in the region. Especially the University of Turku but also Åbo Akademi have been important in providing educated workforce for the local companies and in conducting internationally recognised research. The local history of collaboration between universities and companies has been relatively strong. In Turku there also seems to have been less resistance in the university to applied research and co-operation with companies. It is a widely shared view, that co-operation was already quite normal in Turku at a time when in other universities and in the Ministry of Education (especially in the 70s) co-operation with industry was viewed as not acceptable or actively harmful to the cause of the university.

The oldest of the local expertise is in the food industry, where food processing (manufacturing) and food chemistry have worked closely together since early 70s.[25] Companies like Raisio, Alko and Suomen Sokeri had all co-operation with universities during the time. The pharmaceutical industry began nationally in the early part of the 20th century, and the Turku presence was properly established with the creation of Wallac and Farmos in the early post WWII period. In addition, synthetic and polymer chemistry expertise has existed in various forms for the last 40-50 years, which has given rise to Turku's present biomaterials fortunes. In sum, none of the areas of expertise or knowledge appears to be entirely new, and only therapeutics and diagnostics have been most directly affected by the molecular biology revolution of the 1970s.[26] While functional foods is now emerging as a core area of its own, its technological home still lies heavily in the food chemistry arena-comprising aroma chemistry, lipid chemistry, biochemistry and prebiotics and probiotics of functional foods.

In this sense, "older" biotech has merged with newer forms, and the strengths of the last 50 years still define current competencies and reputation. For instance, Åbo Akademi is known for its organic and inorganic chemistry expertise and the university's link to chemical engineering groups (the only engineering department in the Turku area). Again, this is a classic case of past expertise coming to bear fruit in a "newer", high-tech mode. These departments which had early on established a reputation with industry by working on relatively mid-tech problems (by today's standards) with a mid-tech industry (such as forestry products, in wood processing and pulp and fibre chemistry), now find themselves

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[25] The department of food chemistry at the University of Turku was established in 1970 and most of the professors have been working in the industry. Also 13 of the 27 graduated Ph.Ds are employed in the industry as of 2002.

[26] This was captured in the statement by one interviwee: "Well the business side is diverging. At invention stage, they are getting closer and closer. The real biological invention contains both applications and opportunities."

with new opportunities in a convergence of fields many of which have since gone "high-tech" in biomaterials, functional foods, diagnostics and therapeutics.

Thus, from a policy standpoint for building rapid competence in completely new areas, the implications are somewhat sobering. It has taken up to half a century for local presence and experience to develop in these biotech sub groupings. These more traditional industries have adapted to newer technologies over time and more detailed analytical questions must thus examine the rate and quality of adaptation, rather than the idea that biotech Turku was built from nothing since the Finnish recession.

4.2 Older companies and their university oriented push

As mentioned earlier, Turku developed, somewhat luckily, as a base for Leiras (of the Schering-Plough group), and Farmos (later fused with Orion), both in drug development, while Wallac was acquired by Perkins Elmer to become PE Wallac for the diagnostics industry. Thus, Turku went from a city with an early concentration of therapeutics and diagnostics to one explicitly driven by the dynamics of two multinationals (Leiras and PE Wallac) and one large domestic company (Orion).

It would be misleading to say that these companies were the prime movers of the early drive to create a biotech base in Turku, but it is certainly true that they were far more directly involved as organisations than the university as a whole. For them, the link to universities functioned well and served company purposes.[27] PE-Wallac, in particular, seems to have institutionalised many of its interactions with university researchers, and this culture seems to have been copied or at least supported, by researchers within other companies such as Orion and Leiras. The diagnostics business, and the importance of PE-Wallac within the industry, were certainly important factors in this internal culture driving later industry-university links in Turku, but it is equally true that this internal culture was driven by the initiative of motivated individuals within PE-Wallac. Individuals with histories in big pharmaceuticals as well as big food or other older industry clusters have pushed the boundaries of university links. These people have been as likely to be institutional drivers as have organisations.[28] For instance, researchers like Prof. Erkki Soini, formerly a long-time senior researcher in PE-Wallac, always kept links to university research, having come from there himself. During his 20-30 year tenure at PE Wallac, he actively coordinated with university departments because he had a vision of what joint research could accomplish, and believed this at a time when few others had such a vision. Thus his views were uncontested. When he returned to the university as a full professor, having decided that he could pursue some types of research more effectively in the university, he was also able to obtain some cheaper services through university facilities for the company he has since established.

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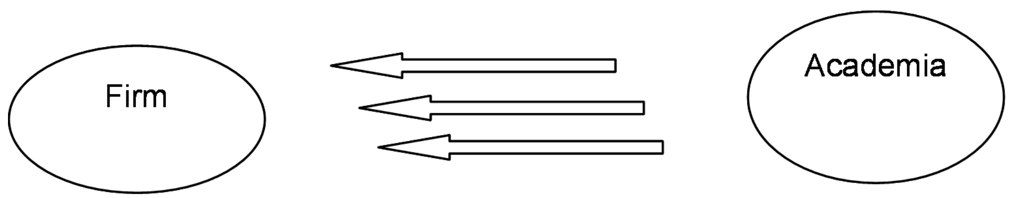
[27] One said, "Here its very easy for me to talk to research universities or Tekes and call directly and suggest ideas and ask if this is feasible. In the US you don't have this type of close connection. If you go to universities, you may not get past a room like this, but here you can do it quickly- there is a broad selection of capabilities-human resource or technical.

[28] As one interviewee said, "The university was not the prime driver, but scientists were."
Another succinctly captured that people and personal links, are at the heart of the process:" I have never been able to negotiate with institutes, universities, companies, I always negotiate with people there and you need to know them, their capabilities and their limitations."

4.3 Tekes-induced networking: University-Industry R&D collaborations under a microscope

For the purposes of our research findings, Tekes has also been instrumental in forcing university and industry cooperation. This has not been without its teething problems well past infancy.

Tekes finances university-industry co-operation basically with two different models. The first one is what we call the "1-to-1" mode of co-operation, where university unit works directly in co-operation with one company. The other model, which has been emphasized recently, is what we dub here the "one-to-many" model. This model is the dominant way of participating in the technology programs. Below is the summary of experiences of these models in Turku biotech community. "Academia" in the figure refers to university departments with one or many faculty members involved. Our research findings are summarised in the boxes below.

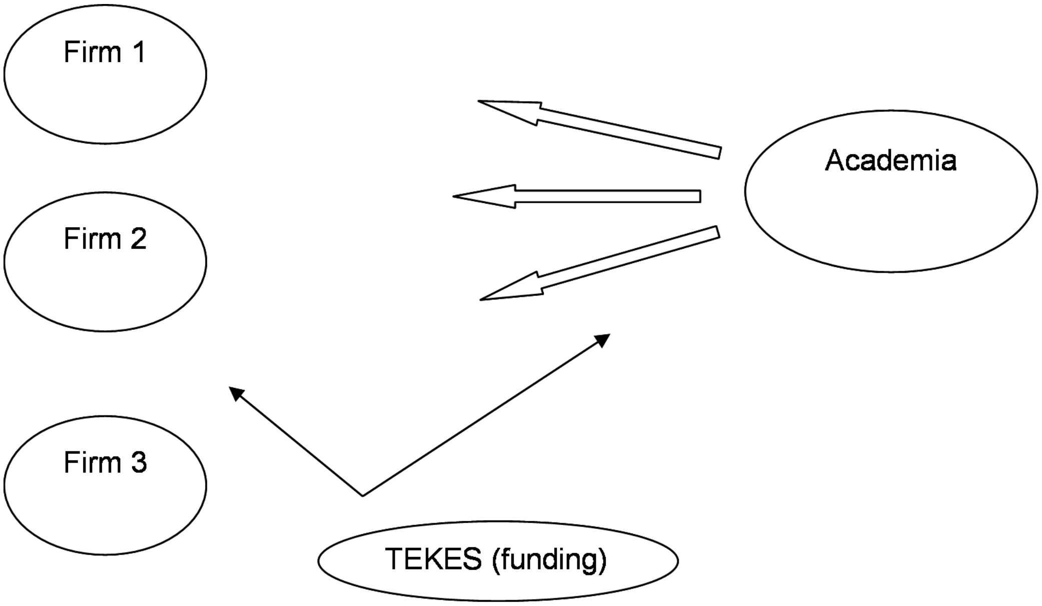


1-to-1 Model of collaboration

(Single academic department or individual, single firm)

Result: Overall levels of firm satisfaction are high, university department/researchers gets funded, research output benefits firms, particularly small ones, which do not have large in-house R&D operations.

The other model links single research groups or departments in the university to multiple firms.



1-to-many Model of collaboration
(Single department or research group works with multiple firms in exploratory and problem-solving research.)

Result: Overall levels of firm satisfaction are low, university departments/researchers get funded but research output does not seem to help firms.

The schematic is shown to demonstrate an underlying tension within the academic and industry research communities. While public domain knowledge is increased and disseminated through collaboration of this type, it also places strictures on academic research. While private companies can gain from public knowledge, this knowledge is diluted when too many companies strive to partake from the findings since potentially easy appropriability of each other's research becomes an issue. Thus, while 1-to-1 is desirable from the point of view of the companies, it is unattractive to Tekes which seeks to extract the maximum public good from its funded projects.

Part of the difficulty in universities emulating with industry what companies have consistently done in their links to university, is perhaps that industry researchers seem clearer about what the relevance of "pure" versus "applied" work is in medicine and biotechnologies related to medicine, in the therapeutics and diagnostics side. For companies, collaboration can be attractive under the 1-to-1 model. But even in this case, universities find the relationship problematic. Part of the challenge surrounding universities emulating what companies have done in building links with the other party, may be explained by the fact that private sector researchers seem to be able to articulate more clearly the distinction between "pure" and "applied" research in medicine and pharmaceuticals. These researchers appear to distinguish more clearly than their university counterparts when something is distinctly in the "problem-solving" domain and when it is purely exploratory *but seem to value both depending on the context.* They appear frustrated by the university researchers who seem unable or unwilling to follow this division and appear to value exploratory work only.[29] This appears to have made problematic their models of collaboration. In the bid to ensure that universities are not forced to do too much "applied" work, university researchers and administrators seem to have been over-cautious about their liaisons with industry. The fundamental motivation to work with industry appears to have been funding sources, rather than interesting technical programs. Thus, Tekes initiatives to get industry and universities closer together seems to have benefited universities more through the funding they secure through such programs, rather than benefiting industry much at all, or through providing strategic focus to universities for how the collaborative research could benefit the university.

While the initiative to link up with industry may not exist formally within the university, it has existed strongly on the parts of individual researchers, who have been important players in galvanising academia, industry and policy makers alike, into recognising the importance of biopharmaceuticals (and more broadly, biotech) for Turku. In a small city like Turku, these individual initiatives are not without their resonance, and key individuals (despite the lack of strategic support from their own institution) can become important drivers in their own right for later organisational and institutional change city-wide

However, companies like Leiras seem to be less directly involved in interactions with university researchers locally and, possibly in accordance with being multinational now, develop academic links outside Turku whenever needed. Increasingly, PE-Wallac also dictates policy from Boston, not Turku and the universities locally seem to have lost a little of their prominence. Thus, globally oriented companies may be harder pressed to articulate why historic links to a city like Turku continue to be valuable in the future.

If we had to pinpoint what the larger companies have contributed towards the local constellation of innovation, it has been as a source of people with ideas and past interactions with the university. While the interactions with academia may have been institutionalised to different degrees within the different companies, what all the companies effectively passed on was a tradition for hiring in university researchers, or for having in-house corporate researchers with an open attitude to working with universities.

A particularly important local driver of this in-house innovation, which then spilled over to the city, was the mergers and acquisitions that drove the global pharmaceutical industry (particularly therapeutics) in the 1980s. By the mid-1990s, Turku companies' drug development focus was under scrutiny. Both Leiras and Orion drastically consolidated projects under drug discovery and development and cut back significantly both on projects and the number of personnel who were involved. The idea was to prune and streamline operations to become more globally competitive.

[29] The concerns of more academically inclined researchers were voiced thus: : "In Finland its almost getting to the point where I am worried about the ability to do basic research - even the Academy is funding applied work-and there's becoming a dearth of basic research in the medical sciences."

What this resulted in was scores of researchers, highly talented and experienced individuals, whose core projects had been terminated, despite promising initial forays, and who decided to start their own companies with these ideas as the basis. While the founders were former employees of the Leiras or Orion, often co-founders or shareholders were academic researchers with whom they had links. In the case of Orion, the company distanced itself from departing researchers and seems to have had a difficult transition with intellectual property disputes with researchers who later founded their own companies. Leiras seems to have also had something of a turbulent local history as far as IP goes, but seems to have become less adversarial with the smaller companies once they started up. In particular, the disputes for both companies and the approach they took to the newer companies centred on the original technologies on which the companies were founded. Two important local companies in drug development were born from these companies: Juvantia and Hormos.

The smaller biopharmaceutical companies have all been start-ups with one exception, Galilaeus, which has been a spin-off of Leiras, where the parent company appears to have recognised its changing role and was nurturing the smaller company. In diagnostics and biomaterials most of the companies are university start-ups.

Thus, in general, the growth of companies in Turku appears to have been largely driven by the start-ups arising from the pruning of the large company research focus. The overall growth of the biotech base in Turku seems to have been predominantly private sector driven (pharma companies and real estate) more than public driven - although the initial impetus through funding for BioCity came from the Turku City Council. The university appears to have lagged in all of this, except to have to some degree foreseen the importance of joint facilities and collaboration between the two universities. Yet again, this seems to have been fuelled more by anxieties about funding cuts and needing to build scale in research resources, than a vision for the future biotech base in Turku.

However, a newer role for the university may be emerging, with smaller start-ups opening up new channels of communication with the university, having been themselves cut off from the large internal corporate R&D of the parent companies. As the SMEs do not have international connections, resources and diverse capabilities of the big pharmaceutical companies, they need to lean on external sources like the universities. According to our findings, multiform interaction between university research units and small companies is evident in Turku. Thus, a mutually fruitful cooperation with smaller companies could emerge in the long-term. However, smaller companies also face serious financial and product deadlines and have less space for leisure, infusing their collaborations with universities with some urgency. If local universities cannot provide vision and strategy that is useful to local firms, then the latter are likely to look elsewhere for such alliances.

An external factor of considerable importance in the inspiration and evolution of Turku biotech seems to have been comparisons made by locals, and by national policy makers, of the differences of Turku with Helsinki. The delayed local introduction of VTT is a case in point. Some local researchers in both corporate and university circles seem to think it was a deliberate attempt by Helsinki and Oulu to keep the VTT centre away from Turku.

4.4 Other institutions of importance

Although the local knowledge base in the life sciences and in chemistry and chemical engineering is very strong in Turku there are many connections to other Finnish universities and international institutions of higher learning as well. The companies have many connections to universities and R&D:s abroad, but since the original innovation is often based on local research, these connections tend to be more complementary by nature.

When looking at the most important institutions supporting the development of biotechnology research and innovation activities in the companies, specifically three national level public organisations, the Academy of Finland, TEKES and Sitra stand out. The Academy of Finland and TEKES have been very influential in supporting research and education in the universities and the collaboration between the universities. Sitra has been crucial in providing financing for the new start-ups and is still the most important source of venture capital for smaller biotech companies in Turku. These are reviewed briefly here.

The Academy of Finland: Financing for biotechnology research

The Academy exists within the Ministry of Education and operates as an expert group advising and channelling resources for research funding. Its focus is on the academic system, through which it aims to finance high-quality research primarily in basic and pure sciences and the humanities. It also finances individual projects, programs, the Centres of Excellence program and allocates money for academic posts and training positions. The Academy granted biotechnology research about 27million EUR in 1997, 32 mill EUR in 1998 and 41 million EUR in 1999. (Biotechnology in Finland 2001, Finnish Bioindustries)

Life 2000 is a 13.8 mill EUR research program with 37 running projects on biological functions and is jointly funded by the Academy and Tekes and is dedicated to the use of new research methods and the results of basic research in the life sciences. It funds 150 researchers for three years and many hundreds more will be involved (without direct Academy Funding) in the projects. There is a commercialisation element to its focus as well (where the Tekes interest begins), and aims to promote the use of important research findings in biotech production, pharmaceuticals, as well as forestry and agriculture. There is a funded portion of Life 2000 also dealing with the ethical and socio-cultural elements of life-sciences research. The focus areas are neuroscience functional genome research, developmental biology, ethical and socio-cultural dimensions, biophysics and bioinformatics.

In addition, the Academy of Finland had also launched a Gene research program nationwide, with some work ongoing in Turku. This program ended in the year 2000, but provided a way for various expertises across the country to network and build visibility.

The Genome Research Programme 1994-2000

"The Genome Research Programme for 1994-2000 was launched jointly by the Academy of Finland's Natural Science Research Council, the Medical Research Council, the Research Council for

Agriculture and Forestry, and the Research Council for the Environmental Sciences. In the new organization of the Academy of Finland Research Councils responsible for the Programme are Research council for Health and Research Council for the Environment and Natural Resources. One of the aims of the programme is to combine the work and expertise of research groups working in different fields. This will produce sufficiently large networks and teams in Finland, which will improve expertise and competitiveness in those rapidly advancing areas of genome research that are of major scientific importance.

> *"Information about cellular functions obtained using molecular biological and biotechnological approaches forms the basis for modern biological research. The exceptionally rapid progress made in this area of research is expected to continue and to result in the 1990s becoming the decade of genome research. In the future, the achievements of genome research will benefit basic and applied research in both the biosciences - medicine, zoology, botany, and microbiology - and traditional biotechnology. The results can be applied in the near future in several fields, such as medicine, pharmaceutical industry, agriculture and forestry, industrial biotechnology, food industry, and wood processing.*
>
> *Support for high-level genome research in Finland is essential if the Finnish scientists in this field and in the related industry are to be internationally competitive. It is easy to envision that biotechnological research and the results that it has generated by the end of the decade will form an important basis for new technology industry in Finland.""*
> *(Source: http://www.utu.fi/research/celgenmol/genome/genintro.html)*

Tekes: R&D funding for industry university co-operation

Tekes is the National Technology Agency and acts as the main R&D financing agency in Finland. Biotechnology has emerged as one of the key areas where Tekes is becoming involved, financially and institutionally. We have already discussed the agency's importance in propelling universities and companies together, for better or worse. In addition, the increased interaction is developed under a Tekes-driven umbrella of four important technology programs exist in the life sciences (out of 50 existing Tekes technology programs). These are:

I. Drug 2000 (biomedicine, drug development and pharmaceutical technology, with 51 academic research projects grouped under five themes of (a)target identification and validation (b) targeted therapy and novel treatment methods (c) chemistry (d) in vitro and in vivo screening methods and (e) pharmaceutical development. Drug 2000 has an annual budget of 17-25 million EUR.
II. Diagnostics 2000, which works in cooperation with the Finnish in Vitro Diagnostics Industry Cluster (FIVDIC), a company initiated organisation. There are four areas of work: (a) Infectious

diseases (b) degenerative diseases (c) Method development and (d) DNA Diagnostics. Diagnostics 2000 has an annual budget of 10 million EUR.

III. Innovation in Foods, which focuses on links between food and health, particularly focused on how food science can reduce risks in digestion, heart disease and cancer and the promotion of new food technologies. There are four main areas of work: (a) Gut health (b) plant-based substances promoting health (c) separation and encapsulation techniques and (d) commercialisation process management. It is a four-year program with a total budget of 50 million EUR.

IV. NeoBio-Novel Biotechnology, which aims at both the development and utilisation of modern biotech methods in research and product development. It is aimed at multiple industrial sectors.

(Source: Tekes and Biotechnology in Finland published by Finnish Bioindustries, also at www.finbio.net)

Tekes also jointly funds Life 2000 with the Academy of Finland.

Sitra: Public venture capital

Sitra, the Finnish National Fund for Research and Development, is an independent public foundation. It was established in 1967 for the 50th anniversary of Finnish independence, with the Bank of Finland, and acts under the direct supervision of the Finish Parliament, making it quite unique institutionally in the world. It works primarily by boosting research for innovation, and organises strategic training programs in addition to providing venture capital money, particularly where private capital financing is weak or unavailable. Since Finnish capital markets are yet weak, particularly for venture capital finance for biotech areas, Sitra has played a particularly important role in helping smaller firms in Turku.

In total, Sitra's Corporate Funding is involved as a shareholder in about 100 companies in information technology, industrial production and the life-sciences. Its specific involvement relevant to Turku, is its life sciences investments of being a shareholder in about 50 companies nationwide in pharmaceuticals, diagnostics, chemicals, functional foods, biotechnology and "e-health". Its particular focus is on commercialisation of technologies and thus also invests directly in technology transfer companies themselves. Sitra invests additionally in international venture capital funds and this keeps a window open to linking up companies it invests in to these types of fluid international transfers. Its PreSeed program is of particular relevance in Turku, where private capital is channelled to early phase companies. This has been particularly important for drug discovery companies, which are cash-hungry and may have few investors in an immature financial market because of the high risks involved. However, money is not available for clinical trials, and some discovery and development companies appear to have found it difficult to raise money for this challenging and long-drawn out process.

5 Conclusions

We began this research by asking what the determinants were of the concentration and rise of the "new" biotech concentration, particularly in biopharmaceuticals, in the city of Turku and also enquired into whether local universities have been catalysts in this change.

The origins of

We find that the evidence demonstrates clearly that the process of creating the "new" high-tech biotechnology atmosphere in Turku has been a concentrated effort of several players –"the old industry", the local government and national public support organisations It has also been important that "new" participants have emerged- academics turned entrepreneurs, venture capitalists and smaller firms. Despite the fast growth of the industry in terms of new firms and new jobs, the knowledge base of the region has been developed over a much longer period of time and through a confluence of knowledge and skills built across multiple disciplines, sectors and larger companies. Technological innovations have also existed before "BioTurku" was born, but newer institutional arrangements and external economic scares have driven concentrations of skills and resources closer together.

The rise of Turku should thus be seen as building on older capabilities, recently driven forward by new organisations and institutions that have come about due to resource constraints, external economic shocks and fundamental changes in the global pharmaceutical industry. BioTurku has arisen, therefore, more as a reconsolidation of expertise across sectors under a new banner of "biotech", which has in turn, allowed new configurations of innovative actors to link up and create new technological services and products as well.

From a government policy perspective, the tale is cautionary. It suggests that despite all the statements to the contrary, this is not a story of "new" technological capabilities and thus cannot be easily replicated by other aspirant locales into another biotech driven "Silicon Valley" overnight. However, there are some promising implications of what has occurred. It suggests ways in which external economic impacts and national industrial and S&T policies could be strategically turned to a city's advantage in re-amassing existing capability and building new strengths with the help of local activity. It also suggests ways in which a new label "biotechnology" has been crafted to fit in with local strengths to build a new vision for the nation and the city structured around varied industries. National policies that recognise local excellence and that attempt to build scale across the small country, have allowed local initiatives to dynamically grow by linking to national (public) programs at various "levels" of innovation.

The role of the universities

In general, the universities in Turku could be said to be more generators of ideas and knowledge, rather than strategists for technological or institutional innovation. Thus, firms that have found the universities to be useful have been those that have themselves either identified core groups at the universities that could assist in the firm's research areas, or those firms that have benefited from knowledge areas developed at the university even without direct collaboration. There were no obvious examples of university-initiated projects to work with industry which have not had as their basis a financial or technical resource constraint. This is an important findings and fundamentally challenges the way we normatively think of what the regional development role of universities should be. The reality appears to have been that the universities were themselves unlikely to be pioneers in venturing off-campus unless resources (financial or infrastructural) forced them to. The State, at national level, has also been crucial to bringing firms and universities closer together, although the specific models used by Tekes to generate this interaction may need modification if the collaboration results are to be useful to participating firms . However, the role of the State, particularly through innovation-related policies, is likely to keep increasing until some point is reached whereby universities see a clearer path to direct collaboration with the private sector or more appropriate technology transfer institutions are strengthened that link the two.

The Turku University and Åbo Akademi each provide the basis for the skilled local labor.[30] Both are driven by science and technology but highly resource constrained at a time when the Finnish state is pushing universities to seek external sources of funding from non-governmental sources. TEKES has been particularly forceful in making the case for increased university-firm interaction, which has ?some questions from both firms and university researchers, as to whether this is an optimal strategy for either in the long-term if universities do more “applied” work. While EU membership has brought global contacts, new markets and greater funding, accession to the EU has also had a downside to Finland. EU laws prevent European companies from developing an alternate process for manufacturing a drug until the expiry of the patent. There is thus no “easy” money or time to be had for Finnish firms while they build capability.

There are many challenges ahead for university-industry relations. Some of them are listed as follows:

- Departmental dynamics: the creation of BioCity and MediCity as collaborative research organisations
- Adapting to newer IP regimes and legal codes and the IPR ownership questions in the future
- Multidisciplinary work – how to increase interaction between the disciplines
- Cultural traits and past histories of two universities – conservative university structures may cause slow response to new challenges
- The position in terms of national institutions
- Engineering or humanistic traditions?
- The future of financing and basic resources

[30] Importantly for the pharmaceutical industry, the University hospital continues to build up a formidable force in basic research as well as clinical study and testing services. It also provides an important source along with the medical faculty of the university, of validation of early drug target research in the private sector. The business school has also been important, with 2,000 students, creating an increasingly focused curriculum, which can provide new impetus to S&T initiatives in Turku. The Polytechnics contribute more than 6000 students; the Turku vocational institute has 4,500.

Future Challenges in Turku

National and international invisibility in the eyes of policymakers and industry seems to be a big challenge both in terms of attracting a skilled workforce and in generating inward investment.[31] For now most of the growth has been based on the local research and education system with Finnish VCs and the national policy tools supporting the development. There is a competition with Helsinki and other big biotech regions in northern Europe. By far the most dominant strategies for solving this have been specialization and forming networks with other technology centres both in Finland and in close areas abroad.

There are also substantial local pressures on the sector to succeed. The Finnish experience from the high ICT growth, especially in the late 1990s, gave rise to similar expectation about biotechnology. The city of Turku has made considerable investments in infrastructure and in many public development strategies biotech is seen as a new major employer to substitute for job losses in the declining industries.[32] These tensions are most clearly shown in the different views of branding the industry as R&D based versus manufacturing based which would bring employment. Especially in pharmaceuticals the common view by the industry is to concentrate on R&D. This 'policy gap' is a potential source of disappointments and may lead to diminishing policy support in the future. On the other hand, some people see that too much attention is given to pharmaceuticals to the exclusion of other fields that can actually generate manufacturing jobs in fields such as medical equipment and diagnostics.

Pressures for speed to market from global regulatory institutions are one potential threat as a small concentration like Turku has very little resources to follow the changes efficiently. Also the differences in the regulations and scientific ethics between regulatory organisations in Europe and US give a lot of trouble to SMEs.

The small size of the regional economy and the biotechnology related industry means that there are many gaps in local expertise. Many central scientific areas supporting biotech are underdeveloped. There is also a shortage of high level services and people with specialized legal expertise, entrepreneurial and management skills and marketing skills. Besides the limited amount of specialists in business management there is also a small local labour market to hinder the recruitment and retention of skilled research staff. There seems also to be a need for more career opportunities for post-doctoral researchers in the universities. Also many foreigners seem to regard Turku as a temporary stop on the way to somewhere else.

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[31] An interviewee said, while describing the need for policies to make Turku more visible, "They (policy makers) need to think of things like spousal hire, diversity of the labor force. There is a loss of postdoctoral researchers because of this, the focus is too narrow here and may mean more jobs are not possible."
Another said, on needing to boost Turku's and Finland's visibility, ""Still, for scientists, Finland is a pretty unknown place. They still think we live in igloos or something. We need to do this sort of marketing all the time. When I was in the US many years of course ago, there was a secretary who was serious when she said are there phones in Finland? She wasn't joking."

[32] A manager in the Turku area said "Turku had three shipping yards plus clothing factories, now has one shipyard and one factory. They have lost almost 20,000 jobs, and these jobs don't come back."

As regards to research, there is growing concern about the situation of basic research funding, especially among the companies but also in the universities. Government cuts in university basic research funding and the concurrent more applied focus of public research funding has lead to a situation where it is easier to get financing for applied research.

The size of the firms and their position in the value chain is also a risk to the survival of the industry. A small company size is problematic especially in drug development, where the development times are slow and there is no certainty of success. Small dedicated drug discovery companies have to fight for financing and the risks that come with having a narrow set of therapeutic candidates in the pipeline.

A small domestic market is a challenge especially for small companies. Companies are forced to target global markets from the beginning, which brings increasing managerial, informational and financial complexities in terms of finding partners, establishing markets and connecting to global information sources.

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Appendices

Kimmo, have deleted column with dates as they are incomplete

Appendix 1: Biotechnology related innovations in Turku Region

PRODUCT/NCE (OR IN CLINICAL TRIALS) INNOVATIVE FORMULATION OR PROCESS	Type of innovation	Company sub-group relevant for biotech
Xylitol	Health-promoting sweetener (Food industry)	Huhtamäki/Leaf
Benecol	First product worldwide to include cholesterol-lowering stanol ester	Raisio Life Sciences
		Perkins Elmer Life Sciences (Wallac)
		Perkins Elmer Life Sciences (Wallac)
Levonova/Mirena	Intra-uterine contraceptive system (Innovative formulation)	Leiras
Bonefos (clodronate)	Cancer therapy	Leiras
		Farmos ((before the merger with Orion)
		Farmos (after the merger with Orion)
Ospemifene (FC-1271 a) (Phase II)	To prevent and treat postmenopausal osteoporosis	Hormos Medical
Finrozole (Phase II)	To treat male obstructive urinary dysfunction	Hormos Medical
	Prevents and treats male osteoporosis and cardiovascular diseases	Hormos Medical
HM-101, HM-144, HM-2002, HM-3000 (all in Phase I)	Prevents and treats male osteoporosis and cardiovascular diseases, Alzheimer's disease, breast cancer, risk-lowering of certain cancers **respectively**	Hormos Medical
Somatostatin receptors	Treatment of vascular wall re-stenosis and chronic allograft rejection	Juvantia
Adregenic alpha-2 receptors	Treatment of neurodegenerative, psychiatric and cardiovascular	Juvantia

	disorders	
Neuropeptide receptor FF	Chronic pain treatment	Juvantia
VAP-1 antibody therapy program	Treatment of inflammatory diseases	BioTie Therapies
BioHeparin	Production of non-animal derived heparins	BioTie Therapies
		Sticktech
Fareston (toremifene)	Treatment of breast cancer	Orion Pharma
Comtess (Entacapone) and Eldepryl (selegiline)	Treatment of Parkinson's disease	Orion Pharma
Simdax (Levosimendan)	Short-term intravenous treatment of acutely decompensated heart failure	Orion Pharma
Precedex (dexmedetomidine)	Sedation in intensive care	Orion Pharma
Divina/Indivina	Hormone replacement therapies	Orion Pharma
QuikRead	Diagnostics of inflammation by measuring the C-reactive protein concentration in whole-blood	Orion Diagnostica
Uricult	World's leading dip-slide method for demonstrating urinary tract infections (been on the market for 30 years)	Orion Diagnostica
Taifun Technology Platform	Multiple dose powder inhaler for more efficient drug delivery to the lung.	Focus Inhalation
Wet suspension technology with ultrasound processing	Used to produce highly homogenous and stable powder formulations	Focus Inhalation
Streptomyces strain from production of daunomycin group of antibiotics	Cancer chemotherapy	Galilaeus
Two-photon fluorescence excitation TPX-technology and uses latex microparticles as solid phase	Single-step assay, separation-free, high sensitivity, positive signal response, sensitivity is independent of volume. Particularly well-suited for high-throughput screening and highly cost-effective	Arctic Diagnostics
Multiparametric Assay System ((MPA-Technology) based on TPC technology	Fully automated is simpler, smaller and cheaper than existing automatic assay systems.	Arctic Diagnostics

Source: From company reports

Appendix2: Finnish Technology Policy

Milestones of Finnish technology policy

1979 National technology committee
1982 Council of State resolution on technology policy
1983 Founding of Tekes
1984 Technology programmes started
1985 EUREKA started
1986 OECD assessment of Finland's science and technology policy
1986 EU framework agreement on research co-operation
1990 Report of the technology programme committee
1991 Finland becomes a member of CERN
1992 Finland the chair country for EUREKA
1992 Founding of Finland's EU R&D secretariat
1993 Ministry of Trade and Industry: National industrial strategy
1994 EEA agreement intensified research co-operation with the EU
1995 Finland becomes a member of the EU
1995 Finland becomes a member of ESA, the European Space Agency
1995 Funding of energy technology transferred to Tekes from the Ministry of Trade and Industry
1996 Government decision to increase R&D funding
1997 Founding of Employment and Economic Development Centres
1999 Finland's R&D funding over 3% of GDP
1999 Finnish Presidency of the EU

(Source: Tekes)
http://www.tekes.fi/eng/rd/milestones.html

Increasing R&D investments of GDP (Gross Domestic Product)

1985	1.55 %
1990	1.91 %
1995	2.29 %
1997	2.72 %
1998	2.89 %
1999	3.19 %
2000	3.37 %
2001	3.59 % (estimate)

Relation 60 % / 40 % between the private sector and the state.

Appendix 3: The Universities

Turku University

Turku University was founded in 1920 and today graduates 16, 670 students, of which 1,080 are at Master's degree level and it also serves 130 Doctorates a year. Its financing is largely state-generated, with Direct state budget funding at 67 %, Chargeable services 12 % , jointly funded research 10 % , Academy of Finland 7 % and other 4 %.

It offers a vast spectrum of departmental subjects. In particular, of special relevance to the biotech efforts in the city, are in the Faculty of Mathematics and Natural Sciences:
(a) Department of Biochemistry and Food Chemistry
(b) Department of Chemistry
(c) Department of Physics
(d) Department of Mathematics
(e) Department of Information Technology
(f) Department of Biology
and in the Faculty of Medicine
(g) Institute of Biomedicine
(h) Institute of Microbiology and Pathology
(i) Institute of Clinical Medicine
(j) Institute of Dentistry

Åbo Akademi

In the year 1918 Åbo Akademi University was founded with three major departments: Arts, Mathematics & Natural Sciences and Political Science, which was the first of its kind in the Nordic countries. The sole engineering base in Turku was established two years later in 1920 with the Faculty of Chemical Engineering. In 1927, the Åbo Academy School of Economics and Business Administration was established., which complements today's third university in Turku, the School of Business and Economics. One reason why Åbo Akademi has had a longer history of working with the private sector in biotechnology and other areas, and a culture different from Turku University vis-à-vis industry, can be seen in both the existence of the chemical engineering school as well as the source of its funding. From its inception in 1918, just after WWI, right uptil 1964, the university was entirely financed by private means. This changed in 1964, when a new law was passed in Finland, which guaranteed state support for Åbo Akademi University; in part recognizing its national status as representing the entire Swedish speaking minority population of Finland (about 6%). In 1981, the source of financing and the institutions surrounding research, commercialisation and links to industry all changed with Åbo Akademi University becoming a state university and coming under the national government's purview, and professors becoming de facto state employees.

While Åbo Akademi undoubtedly has a unique position in hosting the only engineering department in the Turku region, it does not graduate PhDs, but only students with the Master of Science in Technology in both Chemical Engineering and Computer Engineering.

ÅA particularly specializes in five core areas:

1. Applied chemistry: biocompatible materials and glasses; combustion chemistry; catalysts and catalytic processes; chemical sensors; process and environmental analysis, biopolymers and polymer synthesis.
2. Process Engineering: advanced process control of energy and raw-material-saving processes; bioprocess engineering; process and production optimisation; control theory; drying technology; fluid dynamics.
3. Pulp and Paper Science: wood and paper chemistry; grinding and delignification of wood; process-water and environmental chemistry; paper chemistry, technology and converting.
4. Software engineering: Formal methods for system design; computer supported system verification; object-oriented system analysis and design; parallel and distributed systems.
5. Embedded systems: asynchronous VLSI design; hardware/software codesign; programmable protocol processors; model-checking; object-oriented design of real-time systems.

In addition, for research in biotechnology and informatics, close collaboration and university support goes towards independent institutions such as the Turku Centre for Biotechnology, headed by Dir. Riitta Lahesmaa, the Computing Centre, headed by Dir. Stig-Göran Lindqvist, the national PET-Centre, headed by Dir. Juhani Knuuti, the Turku Centre for Computer Science, headed by Dir. Ralph Back.

(Source: http://www.abo.fi/aa/engelska/inbrief_2002/)

The Turku School of Economics and Business Administration

It was founded in 1950 by an impetus from the local business community. As was the case with Åbo Akademi, it began its life as a private institution maintained by the Foundation of the Turku School of Economics. This changed in 1977, when it became a state institution. The Foundation continues now to support it by channelling State and other funds. It has approximately 2000 students currently registered.

Its departments are

1. Accounting and Finance
2. Management
3. Marketing
4. Economics
5. Languages
6. Business Research and Development Centre
7. Finland Futures Research Centre

Its core areas of expertise in both research and teaching are:

1. Business Studies
2. Information Management in Enterprises

3. Economics (particularly International Economics)

It also hosts specialised areas of expertise, such as European studies, SMEs and entrepreneurship, Internationalisation and Logistics and Futures studies.

In addition, it hosts a Business Research and Development Centre, which in turn comprises (a) The Pan-European Institute (b) The Small Business Institute (c) the Media Group and the (d) The Finnish Institute of Real Estate Economics.

The Local Innovation Systems Project

The Local Innovation Systems Project, an international research partnership based at the Industrial Performance Center (IPC) at MIT, is addressing a central issue now confronting industrial practitioners and economic policymakers throughout the world: How can local economic communities survive and prosper in the rapidly changing global economy?

Our particular focus is on the role of innovation – in products, services, and processes – in promoting productivity growth and competitive advantage at the local and regional levels. National and local governments around the world, as well as other institutions with an interest in economic development, are greatly interested in creating and sustaining local environments that are attractive for innovation. Firms, too, recognize that their innovation performance is affected by their location.

The policy debate has been dominated by a few outstandingly successful centers of technological entrepreneurship, notably including Silicon Valley and the Boston area in the United States, and the Cambridge region in the U.K. But most locales do not have clusters of high-technology ventures of such scale, nor are they home to research and educational institutions with world-class strengths across a broad range of disciplines. Many, on the other hand, do have distinctive industrial capabilities and vibrant higher educational institutions, and some of these locales have been quite successful in harnessing new technology to revitalize their economies or even to reinvent themselves as centers of innovation and competitive advantage.

The Local Innovation Systems Project is investigating cases of actual and attempted industrial transformation in more than 20 locales in the United States, Europe, and Asia. Our research is aimed at developing new insights into how regional capabilities can spur innovation and economic growth. We seek ultimately to develop new models of innovation-led industrial development.

We are currently completing the initial year of a projected multi-year study. In the first phase of research, we are investigating the roles of universities and other public research institutions as creators, receptors, and interpreters of innovation and ideas; as sources of human capital; and as key components of social infrastructure and social capital. Later phases of our research will explore the process of enterprise growth and the ability of different locations to attract and retain innovating firms. We are also investigating different approaches to individual and institutional leadership in locally-based systems of innovation.

The founding research partners of the Local Innovation Systems Project consist of an interdisciplinary team of faculty, graduate students and research staff at the MIT Industrial Performance Center, together with their counterparts at the University of Tampere and the Helsinki University of Technology in Finland, the University of Cambridge in England, and the University of Tokyo, Japan.

Current research sites include several locations in the United States (Boston, MA; Rochester, NY; Akron, OH; Allentown, PA; Youngstown, OH; New Haven, CT; Charlotte, NC; and the Greenville-Spartanburg area of SC), Finland (Helsinki, Turku, Oulu, Tampere, Seinajöki, Pori), Japan (Hamamatsu, Kyoto), and the United Kingdom. Additional research is being carried out in Ireland, India, Taiwan and Israel.

At each location, teams of researchers from the partner institutions are studying innovation trajectories and developing comparative case studies of growth and transformation in several industries, mature as well as new, including polymers, ceramics, optoelectronics, industrial machinery and automation, auto/motorsports, medical equipment, biotechnology, and wireless communications.

The outreach activities of the Local Innovation Systems Project will include the preparation of discussion papers and books, executive briefings and informal workshops, international conferences, and executive education and training programs for policymakers, research managers, and industry executives.

Current sponsors of the Local Innovation Systems Project include, in the United States, the Alfred P. Sloan Foundation and the National Science Foundation, Tekes (the National Technology Agency of Finland), the Cambridge-MIT Institute, and the University of Tokyo.

For further information, please contact the Project Director, Professor Richard Lester (617-253-7522, rklester@mit.edu).