Focus on biotechnology

Issues related to R&D in biotechnology - Denmark in a comparative perspective

The Danish Institute for Studies
in Research and Research Policy
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Introduction

It is widely recognized that the world of science has been reconfigured over the last decades. Internally, disciplinary boundaries are loosing influence on scientific conduct as knowledge is increasingly being produced within the context of application. The organizing principles of knowledge production tend to be determined not by the codes of practice relevant to a particular scientific discipline but by a specific application. Externally, the traditional boundaries between science and society deteriorate since scientific problem solving very often is oriented towards societal problems. Science is increasingly expected to contribute to society; or in other words: the market for scientific knowledge has demonstrated an increasing demand for specialized and applicable knowledge and it is vital for the practitioners on the supply-side to meet the demands. To be competitive, knowledge production must fulfil needs; not necessarily economic ones, but social needs in a broader sense as expressed by the demand-side of the market.

The science-society relationship is in a process of integration. The scientists engaged in knowledge production are not uniformly representing a common institutional centre - the university - but represent a variety of institutions and companies within the public as well as the private sector. The networks of cooperation increasingly transcend the sectorial barriers, since the initiating force of research is not exclusively intra-scientific dynamics but also the need for social problem solving that will draw together the specific competencies needed, independent of the institutional affiliation of the scientists possessing these competencies.

Knowledge production within the context of application is - in turn - knowledge production within a context of implication. Research aiming at solving social problems will affect social life, either directly as scientists interact with society and citizens or indirectly when scientific knowledge is used as a platform for policymaking, marketing initiatives or different forms of interest articulation. Research-based technological developments or future prospects affect the way we work, the way we recreate, our understanding of life and death, and the way we relate to other people. In summary, the dynamics of science-society integration implies that knowledge production will increasingly affect the lives of ordinary citizens.

The new mode of knowledge production involves new standards and procedures of quality assessment. Knowledge produced in the context of application is not merely - or even primarily - assessed by scientific standards such as the stringency of logic or methodology, but also by the societal relevance or 'social robustness' of the research results. The quality of knowledge production is dependent on the likelihood that it does in fact fulfil its purpose of solving social problems. Quality control is to an increasing degree performed by politicians and laymen, since they are as capable of evaluating the political implications of science as are scientists, who have traditionally been upholding the quality of research within the system of 'peer reviewing'.

Modern biotechnology is a field of research that very well exemplifies the new production of knowledge. Research within this field is conducted within a variety of institutional settings, including the universities, government agencies and private companies. There is a profound political awareness of biotechnology and a will to manage and regulate in terms of launching science policies and publicly financed research programs. Private companies are strongly engaged in biotechnological research, and there are comprehensive venture capital interests, as the potential profits from future production are high. The networks of cooperation integrate scientists from the various institutions, and biotechnology does transcend the traditional scientific disciplines. International statistics show that research related to the field of biotechnology is being performed within all of the traditional main fields of R&D including the social sciences and the humanities.

Thus, the scope of biotechnology is wide-ranging, since it not only involves knowledge production regarding biology and technology, but also a range of considerations regarding ethics, law and social practices. The actual and potential impact of biotechnology on society is substantial. In a long-term perspective biotechnologies will clearly affect areas such as health care, agriculture, environment, energy production, crime fighting and a vast number of additional areas. In the process society will have to take stands regarding the legitimacy of the new technologies and the regulation of these technologies and find appropriate ways of expressing the citizens' attitudes towards this field of research.

Due to the extended integration of science and society within modern biotechnology, this field of knowledge production is not only interesting to the core practitioners of biotechnology - scientists within the natural sciences - but indeed also to social scientists. The contributions in this report are all concerned with biotechnology as looked upon from the perspective of the social sciences. Under the heading 'focus on biotechnology' each of the presentations addresses social issues related to biotechnology. The report is the outcome of a seminar where a number of social science studies of biotechnology were presented.

The presentations fit into three thematic clusters. The first cluster of presentations is concerned with definitions and perceptions of biotechnology. Karen Siune presents the formal definitions of biotechnology used in different national and international statistics, stressing the social embeddedness of the divergent formulations. Using large-scale surveying and in-depth interviewing Niels Mejlgaard and Jesper Lassen respectively present results regarding the perception of biotechnology amongst citizens. Gitte Meyer and Peter Sandøe describe the perception of biotechnology amongst scientists, based on the results of a research project on the communication between scientists and the public in Denmark about modern plant biotechnology. Maja Horst describes the media coverage of health care related biotechnology, focusing particularly on the media's perception of controversial stories.

The second cluster of presentations is concerned with economic aspects of biotechnology, or more narrowly, with the behavior of private companies within this field of research. Based on a study of the evolution of the biotechnological industry in USA and Denmark, Jesper Norus identifies different entrepreneurial strategies within the sector. In his presentation, Henrik Troelsen focuses on the cooperation between venture capital firms and the biotechnological firms and describes the strategic and financial aspects relevant in order to create a sustainable competitive advantage. Rasmus Nelund assets the importance of the structure of the surrounding context for the strategy and organization of the biotechnological firm, based on evidence from a comparative study of the biotechnological industry in the Medicon Valley and Rhône-Alpes regions. Finally, Mette Mønsted offers a description of research management within the small biotechnological firms, stressing the importance of networks in creating an organizing set-up or infrastructure within and between firms.

The third cluster of presentations is concerned with the measurable - and non-measurable - impact of biotechnology on society. Peter S. Mortensen provides a description of the state of the art regarding obtainable indicators of knowledge production within biotechnology, both in terms of measures of input and production and measures of output and impact. Comparing three different 'isles of innovation', Ulrich Hilpert & Dietmar Bastian analyze the role of international networks and skilled labor for the economical effects of the biotechnological sector. Peder Olesen Larsen examines the requirements that must be met by the public sector, in order to provide for a successful and socially beneficial biotechnological research effort. Finally, Anthony Arundel suggests that the economic impacts of biotechnology are likely to be substantially less than its impact on environmental and quality-of-life conditions, thereby stressing the need for developing indicators for the non-economic impact of biotechnology on society.

Finally, Andrew Jamison provides a general description of the approaches applied by social scientists to the development of new technologies. While approaches to 'technoscientific politics' tend to portray the processes of technological developments either in economic terms, focusing on the welfare benefits of innovation, or in sociological / social constructivist terms, focusing on the social and environmental implications of new technologies and the need for public participation, neither of these are fully able to grasp the complex processes of cultural appropriation of biotechnologies. Jamison stresses the need for including the insights of the cultural sciences such as anthropology and linguistics in science studies.

What is it we care about?

Karen Siune - The Danish Institute for Studies in Research and Research Policy, DK

In the discussions about biotechnology there is a lot of verbal as well as written references to biotechnology, but very seldom there is included in the discussion a clear definition of what biotechnology is, nor references to what it is perceived as.

Among statisticians it is a well known fact that definitions of the object we try to measure is absolutely necessary, and this presentation will focus on different definitions used by individual OECD countries. The presentation will end up with a reference to the definition agreed upon at the OECD ad hoc meeting on biotechnology.

Box 1

Definitions of biotechnology In this presentation a number of different definitions will be shown.
The emphasis in the different definitions is different, some refer to:
• *Science and Industry*, others to
• *Science and Society*, and the latest to
• *The knowledge society.*

As referred to in box 1, there is a clear differentiation between definitions that emphasize the society perspective in form of references to relationship between science and society or refer to the specific society labeled as the 'knowledge society' and those definitions that refer primarily to science and industry. Those definitions that refer to goods and services are classified in this presentation as being of the type with reference to science and industry. The definitions used by OECD and the European Federation of Biotechnology refer both to services and to products or goods.

Box 2

The integration of science and industry
OECD*Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services.*European Federation of Biotechnology*Biotechnology is the integration of natural sciences and engineering sciences in order to achieve the application of organisms, cells, parts thereof and molecular analogues for products and services.*

Box 3

The integration of science and society
Denmark *Biotechnology is the integration of natural sciences and engineering sciences in order to develop and produce organisms, cells, and molecular analogues for the combating of disease, environmental improvement, food production, energy production, and industrial production.*

The Danish definition presented in box 3 refers to industrial production but at the same time it refers to societal aspects such as environment, and with the inclusion of this aspect the definition change from pure industrial orientation towards the integration of science and society albeit the majority of the definition is concerned with industrial production.

Contrary to the orientation presented in that definition the definition presented by New Zealand refers primarily to "improving quality of life". And the same approach is presented in the Australian definition, which refers to technological application "useful to mankind".

Box 4

For the good of the people…
New Zealand *The application of scientific and engineering principles to the processing of material by biological agents and the processing of biological materials to improve the quality of life.* Australia *Biotechnology means any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use. Biotechnology is simply the use of micro-organisms, and plant and animal cells, to produce materials such as food, medicine and chemicals that are useful to mankind.*

In OECD at ad hoc meetings in 200 and 2001 within a working group attached to NESTI (The National Experts on Statistical Indicators) the discussion has dealt with the possibility of finding a definition that could be used as a basis for collecting data for statistical comparisons. The single definition agreed upon at the 2001 meeting in the ad hoc group is shown in box 5. This definition refers to 'knowledge, goods and services' and in this way it embraces all the above mentioned aspects: the industrial production of goods, the new economy-perspective of services and refers to knowledge as well; and the last item transfers the definition to the class of definitions that does not only focus on the industrial or economic aspect of biotechnology.

Box 5

Provisional single definition – OECD

- The application of S&T 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.

(OECD, 2001, Ad hoc study group)

But the single definition presented in box 5 did not, albeit it included so much and so many aspects of biotechnology, give enough specification to what biotechnology actually is, so in addition to the single definition a list based definition was added. The additional list based definition is shown in Box 6.

Box 6

Additional list based definition

- DNA (the codings): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering
- Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein engineering, proteomics, hormones and growth factors, cell receptors/ ignalling/pheromones
- Cell and tissue culture and engineering: cell tissue culture, tissue enginering, hybridisation, ellular fusion, vaccine/immune stimulants, embryo manipulation
- Process biotechnologies: Bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurization, bioremediation and biofiltration
- Subcellular organisms: gene therapy, viral vectors

It is obvious from a reading of the processes included in the additional list, that it is or at least may be functional for producers or for researchers working with biotechnology, but it is also obvious, that it can never be used in social discussions of biotechnology. In social discussions it is expected that there will be references to examples of biotechnology, but no one without expert knowledge will be able to apply the list based definitions, so the conclusion is, that it might prove relevant for statistical purposes. And the conclusion is also that it includes what we care about, but it does not necessarily improve social understanding of biotechnology and nor can it be expected to make discussion of biotechnology as a social issue easier. But it does give clear indication of what can be included under the heading “biotechnology”. So that is what we care about.

Public perceptions of biotechnology - survey results

Niels Mejlgaard - The Danish Institute for Studies in Research and Research Policy, DK

The subject of this presentation is public perceptions of biotechnology and it describes the results of a large-scale survey, conducted at the end of 2000, on perceptions of and attitudes towards biotechnology within the Danish population. It examines the Danes' over-all interest in science and research; their interest in and perceptions of biotechnology; and their attitudes towards this particular field of research. The impact of social determinants on perceptions and attitudes regarding biotechnology will be examined and some methodological problems connected to measuring perceptions of biotechnology will be mentioned.

Box 1

The Survey

- Sample size: 1398 respondents; face-to-face.
- Representative of the Danish population in terms of distribution on gender, age and geographical location.
- November 2000.
- Comparability: AFSK 1997, EB 1996 + 1999, Borre 1989.

The survey was conducted by The Danish Institute for Studies in Research and Research Policy and the survey population is representative of the Danish population in terms of age, gender, school education, and geographical locality. It encompasses a total of 1398 respondents.

Interviews were performed face-to-face, and the questionnaire was designed in a fashion that ensured comparability between this survey and previous surveys on public perceptions of biotechnology on a national as well as international level.

Box 2

Perceptions of biotechnology

- Interest in science and research in general
- Awareness of biotechnology
- Immediate associations to
- Expectations towards
- Knowledge of
- Attitudes towards

The term 'perceptions' is used in a broad sense to cover the entire spectrum of public interest in, understanding of, thoughts about, expectations towards, knowledge of and attitudes towards the research area. The venture point is a description of the over-all level of interest in research amongst Danish citizens, with special attention to the development in interest over the last decade. Subsequently results are presented with regard to the Danes' awareness of science and research in general, in order to estimate the relative importance of biotechnology compared to other fields of research.

The main focus is on perceptions of biotechnology in particular. Respondents' immediate associations to biotechnology are categorized and the distribution on five main categories is described. Remarks will be made regarding the methodological difficulties implied by measuring perceptions and regarding differences between different categories of citizens as to their associations to modern biotechnology.

Finally the presentation offers a description of expectations and attitudes towards biotechnology amongst Danish citizens. It is demonstrated that public attitudes towards biotechnology depend not only on social variables such as sex, age and education, but also upon cognitive factors such as knowledge, trust in scientists and perception of risk.

The interest in research in general has continuously increased over the last decade amongst the Danes. Table 1 shows the distribution of self-reported interest on four categories ranging from 'not at all interested' to 'very interested'. The percentage of respondents declaring themselves 'very' or 'somewhat' interested in research has increased from 51 in 1989 to 75 in 2000.

Table 1 Interest in research - Self-reported interest in research, per cent

	1989	1997	2000
Very interested	16	19	24
Somewhat interested	35	38	51
Slightly interested	35	32	21
Not at all interested	13	10	4
Don’t know	1	1	0
Total	100	100	100
N	1512	1397	1397

Men and well-educated tend to be more interested in research than other categories of citizens, but analyses of the survey results from 1997 and 2000 reveal a levelling of interest in research between different groups within the population. In 2000 the average interest in research is relatively high and homogeneous among both women and men, well educated and less educated, and different age-cohorts (Siune & Mejlgaard 2001a).

The relatively high general interest in research is an important precondition for public involvement in debating research policies and the development of new technologies. The level of interest in research is traditionally emphasized in quantitative approaches to the Public Understanding of Science.

When confronted with words such as 'science' and 'research' a range of specific research fields and broader terms come to the mind of Danish citizens. In 1997 there was a tendency to express perceptions in broad terms such as 'scientific investigations' or 'new knowledge', whereas in 2000 a significant share of respondents chooses to express perceptions in connection to research in terms of specific research fields such as 'medical research', 'biotechnology', or 'environmental research'.

Figure 1 shows the distribution of perceptions on a number of categories for 1997 and 2000. It is noticeable that perceptions regarding 'biotechnology' or 'genetic engineering' have increased from 11 to 25 pct. over the three-year period. Unprovoked, 1 out of 4 respondents mentions biotechnology - or a related term - when asked what comes to mind when thinking about science and research in 2000. This is a rather high proportion of respondents, and it brings biotechnology into the second highest position regarding the distribution of perceptions of science and technology. Biotechnology is only outranked by 'medical research' that has a unique position in the minds of the Danish citizens. Medical research is also the research area that the Danes are most interested in and the area that the majority is in favour of prioritising in terms of increasing the public financing of research.

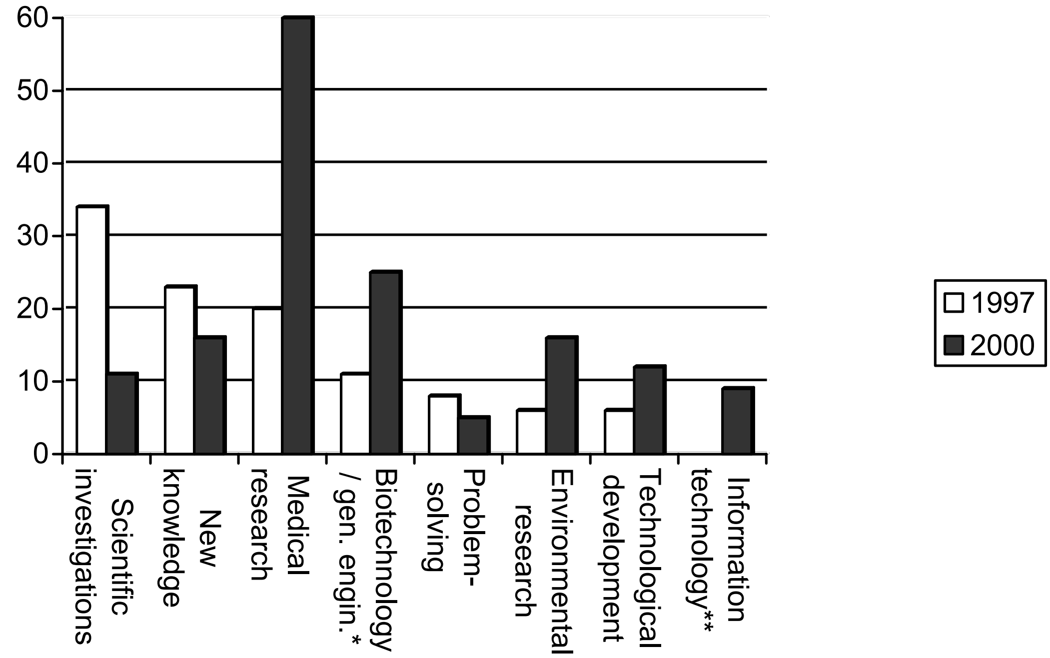

Figure 1 What is 'science' and 'research'? - Awareness of biotechnology

There is a statistically significant correlation between gender, age, and educational background on the one hand and perceptions of science and research within the area of biotechnology on the other. In 2000, women are more likely to think of biotechnology, when asked about perceptions of science and research, than are men. Young people are more likely to mention biotechnology than the elder, and the well-educated mention biotechnology more often than the less educated.

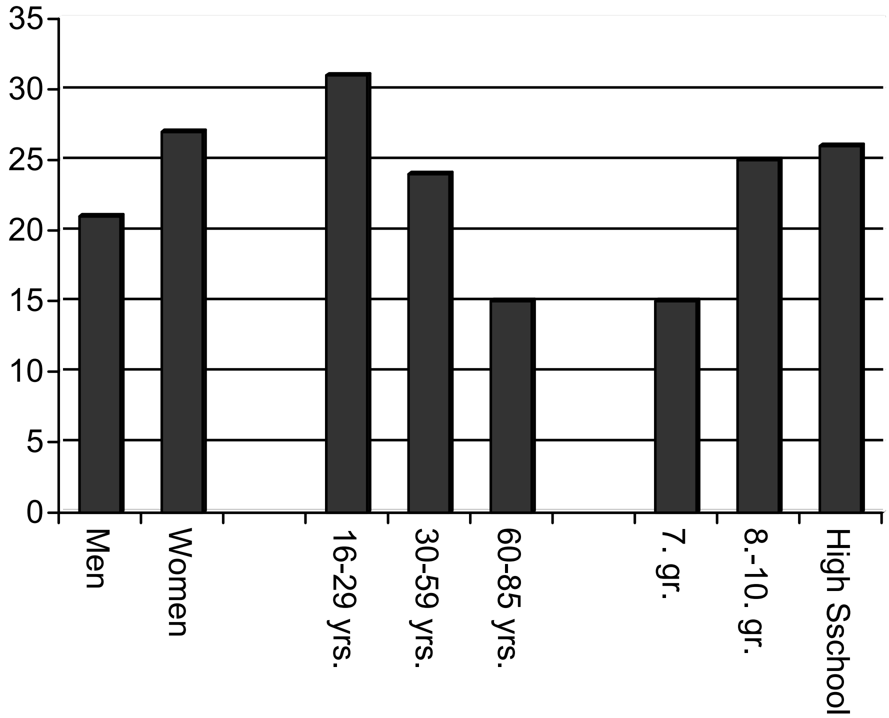

Figure 2 Young well educated, women

Taking the analyses one step further, we now examine the Danes' perceptions not of science and research in general, but of modern biotechnology in particular. In the 2000 survey we asked respondents to express their immediate thoughts when thinking about modern biotechnology. The answers were distributed according to a preclassification of five categories, originating from the Eurobarometer surveys on biotechnology, and to the extent that answers could not reasonably be fitted into the categories, they were categorized as 'other'. The categories have been applied rather narrowly to respondent answers, resulting in a relatively large proportion of 'other'-answers. As a general methodological remark, it is surprising that respondent answers have fitted so neatly into five categories in the Eurobarometer surveys. In the 2000 survey even a very inclusive application of the categories would have left a number of answers that in no way fitted into the preclassification.

The distribution of answers is shown in figure 3, where the black bars represent the results from the 2000 survey.

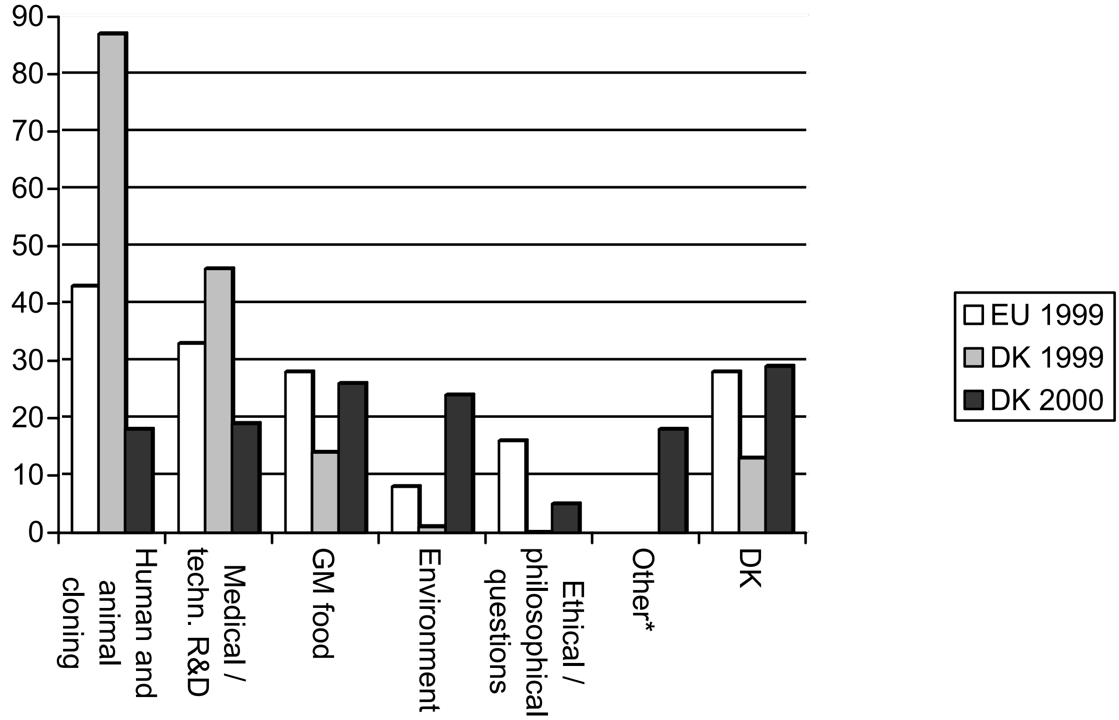

Figure 3 What is 'modern biotechnology'? – And what is 'genetic engineering'?

In the figure the white and grey bars represent results from the Eurobarometer survey 52.1, conducted ultimo 1999 in 15 states. The white bars illustrate the distribution of perceptions in the entire survey population, and the grey bars represent the Danish fragment of the survey population.

Comparing the Danish figures in 1999 and 2000 respectively illuminates remarkable differences. In 1999, 87 pct. of the Danish citizens thought of 'human and animal cloning' when asked about immediate perceptions of biotechnology, whereas the corresponding figure in 2000 is only 18 pct. People who think of 'medical research or scientific progress' are also strongly over represented in 1999 in comparison with 2000, whereas the share of respondent answers in the remaining three categories are higher in 2000 than in 1999. It is equally remarkable that only 13 pct. of respondents have no perceptions of biotechnology in 1999, whereas 29 pct. fit into this category in 2000.

In order to understand this apparently substantial development in perceptions of biotechnology in Denmark, a media surveillance has been performed for both survey periods, covering the time spectre from one month prior to the starting date for data collection up until the end of the survey period. Even though the contents of the articles are obviously not the same in the two survey-periods, the content analysis finds no substantial evidence suggesting that cloning as a subject of public concern is of more importance in 1999 than in 2000 (Mejlgaard & Siune 2001b). In order to explain the fundamental difference between the 1999 survey and the 2000 survey in perceptions tending towards cloning, the focus will thus be shifted towards the exact phrasing of the question posed to respondents in 1999 and 2000 respectively.

In the 2000 survey respondents were asked to answers the following question: *'Please tell me what comes to your mind, when you think of modern biotechnology in a broad sense?'*. In 1999 the exact same words had been used, but subsequently the sentence *'that is including genetic engineering'* had been added. In the Danish edition of the 1999 Eurobarometer-questionnaire used for the Danish segment of respondents, the words 'genetic engineering' were translated into 'gensplejsning' (gene splicing) which is a rather slim expression compared to 'genteknologi' (gene technology), which would have been an alternative Danish translation of 'genetic engineering'.

Taking into account that there was no particular focus on cloning in the media at the time of the 1999 survey, the massive intensity of associations regarding human and animal cloning amongst the Danish segment of respondents suggests that the phrase 'gensplejsning' sets in motion a line of associations in the direction of 'cloning'. In 2000, where respondents were asked of their thoughts regarding biotechnology in general, and the subsequent sentence *'that is including genetic engineering*' was excluded, there was a levelling between the categories of perceptions.

This comparison between the distribution of perceptions in 1999 and 2000 indicates that the way in which perceptions are operationalised is decisive for the result of the inquiry. It is unlikely that 87 pct. of the Danish population - everyone but three persons when excluding the respondents with no perceptions - should conceive of biotechnology in terms of cloning, unless they were exposed to a specific stimulus. It is somewhat more likely that 87 pct. of respondents think of cloning when guided by the word 'gensplejsning', and it must be emphasised that the 1999 survey in fact was measuring perceptions of genetic engineering rather than biotechnology.

Split ballot questions on expectations to biotechnology / genetic engineering respectively in the Eurobarometers through the 1990's are indeed suggestive of the importance of distinguishing between the words 'biotechnology' and 'genetic engineering' and the results presented here underscore the need of linguistic clarification in measuring perceptions.

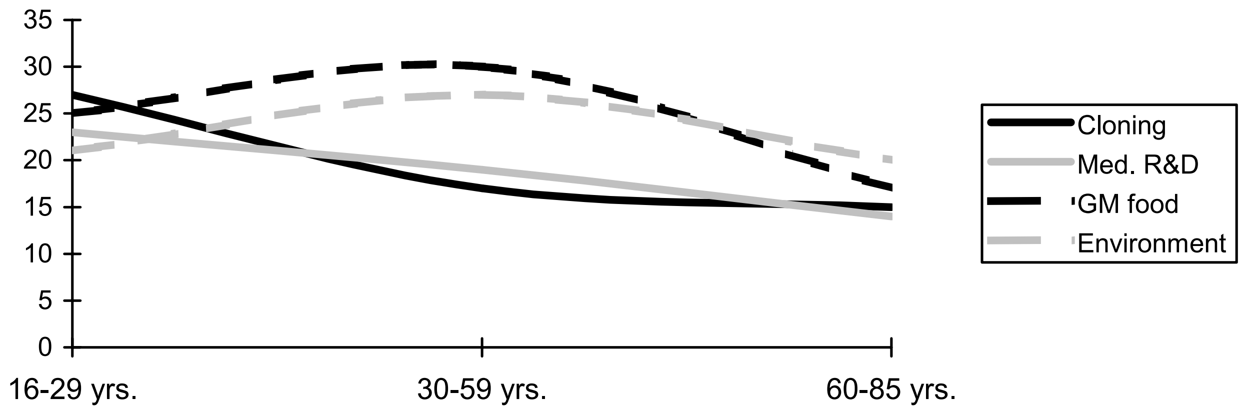

Figure 4 Age and perception of modern biotechnology, per cent

The difference between male and female respondents is marginal. There is a minor tendency towards a stronger emphasis on 'human and animal cloning' amongst women, but the general impression is that there is a relatively homogenous distribution of men and women on the six categories of perceptions. Age has a larger impact on perceptions of biotechnology than gender. Figure 4 shows the distribution of perceptions amongst the young, the middle-aged, and the elder. The categories 'other' and 'ethical / philosophical questions' are excluded.

The young have relatively homogeneously distributed perceptions of biotechnology. Each of the four categories is mentioned by 21 to 27 pct. of the young respondents. Amongst the elder the span is the same, but generally perceptions are fewer, with the categories being mentioned by 14 to 20 pct of this age group.

Amongst the middle-aged perceptions are less homogeneously distributed. Special awareness is given to 'genetically modified food' and 'the environment', whereas 'cloning' and 'medical research - technological development' rank somewhat lower in the minds of this age-group.

A number of recent studies suggests that public assessment of biotechnology R&D varies according to the application of the specific research area - within the biotechnology field - in question (Durant *et al*. 1998; Thulstrup 2000). There is generally a sceptical attitude towards biotechnology in food production, whereas the level of support for the application of biotechnology in areas of genetic testing and the production of new medicines and vaccines is relatively high.

The results of the 2000 survey are in accordance with these earlier findings. Respondents were asked, to which extent they expect modern biotechnology to help create a better life, distinguishing between medical biotechnology aiming at developing new medicine and treatment on the one hand, and animal and vegetable biotechnology aiming at creating new and better food on the other.

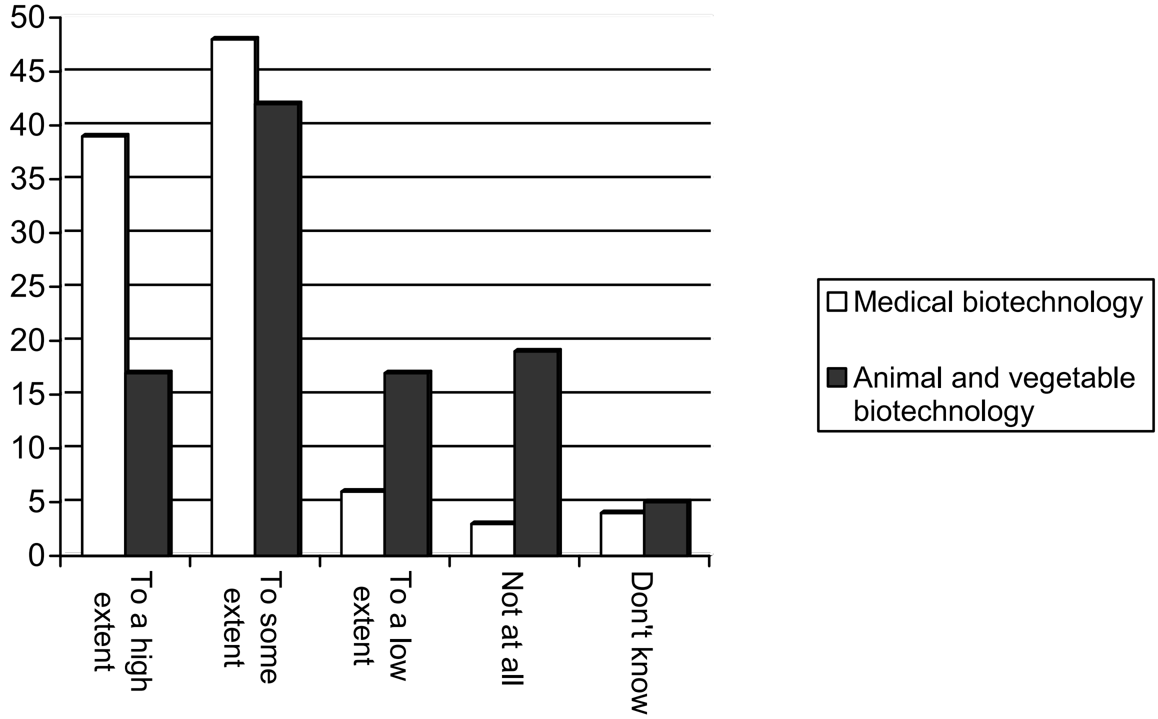

Figure 5 Expectations - Does modern biotechnology help create a better life?; per cent

Figure 5 shows the expectations of the Danish population regarding biotechnology in the sphere of medicine- and food production respectively. The general level of expectations is decisively in favour of medical biotechnology. 87 pct. of the respondents expect of medical biotechnology that it will 'to a high extent' or 'to some extent' help create a better life, whereas expectations towards biotechnology in food production are lower.

Men hold higher expectations towards biotechnology in both fields than women. As mentioned earlier, women generally think of biotechnology somewhat more than men when confronted with words such as science and research, but at the same time their expectations are more sceptical.

The somewhat paradoxical relationship between a relatively high level of awareness and a relatively low level of expectations is also characteristic of the expectations of the respective categories of educational background towards biotechnology. The well educated, who have a higher level of awareness of biotechnology, have more sceptical expectations than the less educated regarding the potential benefits of biotechnology.

In general the social background variables gender, school education, and age have a limited predictive capacity in relation to expectations towards biotechnology. The causal relations are statistically significant, but the differences between men and women, different age groups, and different levels of school education are still limited.

Conversely, the variable 'self-reported interest in research' proves rather interesting in relation to expectations towards biotechnology. A high level of general interest in research correlates with a high level of expectations towards biotechnology, with reference to both food production and medical research.

Reconstructing an additive index of support for biotechnology from the 1989 survey gives an indication of the development of attitudes towards biotechnology within the Danish population. Over the last decade there has been a moderate decline in support for biotechnology in Denmark, as illustrated in figure 6.

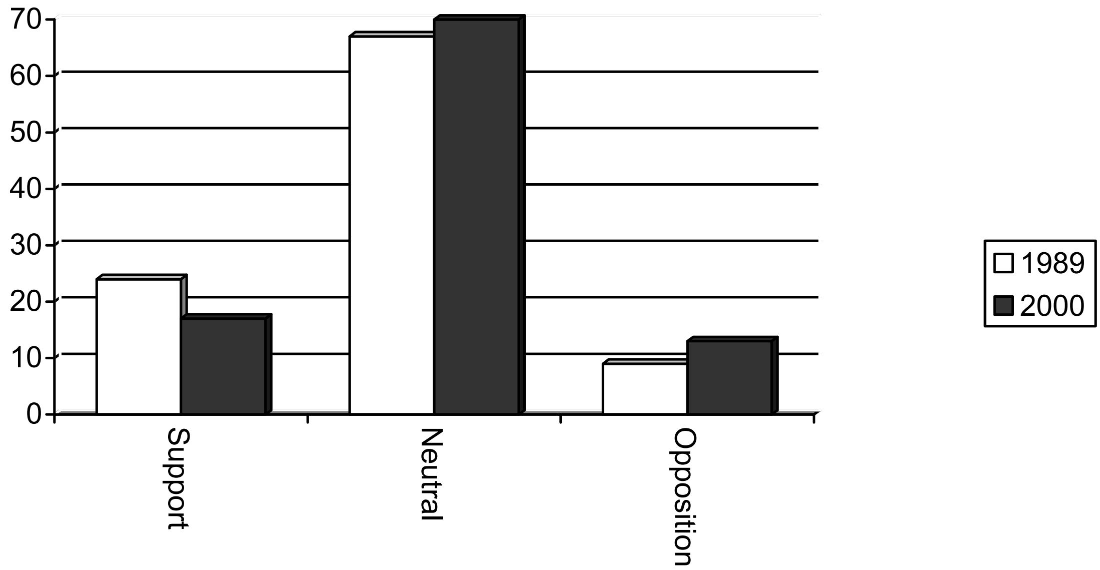

Figure 6 1989-index of attitudes towards biotechnology; per cent

Within the theoretical framework of what could be termed 'a model of mobilization', it could be hypothesized that over time attitudes towards a new technology such as modern biotechnology would tend to divide into both stronger support and stronger opposition rather than converge into consensual positions. The Eurobarometer results support the thesis that a higher level of knowledge of biotechnology tends to drag attitudes towards the extremes of either a high level of support or a high level of opposition.

Comparing the Danish 1989 and 2000 distribution of attitudes towards biotechnology this is not the case. The share of respondents within the 'neutral' and 'opposition' categories has moderately increased, while support has decreased. The general tendency of change in attitudes is thus in disfavour of biotechnology.

Men are generally more supportive of biotechnology than women. Table 2 shows that the support for biotechnology has declined amongst both men and women over the last decade, but the tendency is predominant amongst women, thereby reinforcing the difference between men and women.

Table 2 Gender and attitudes towards biotechnology; per cent

	Men		Women		Total	
	1989	2000	1989	2000	1989	2000
Opposition	8	10	11	16	9	13
Neutral	62	66	72	73	67	70
Support	30	24	17	11	24	17
Total	100	100	100	100	100	100
N	726	686	783	705	1509	1391

Regarding the attitudes towards biotechnology within different age groups, figure 7 shows that young people are more supportive than elder. The figure also reveals that support for biotechnology has declined the most amongst the elder between 1989 and 2000. This development intensifies the difference in attitudes between the young and the elder, just as the difference between men and women is accentuated.

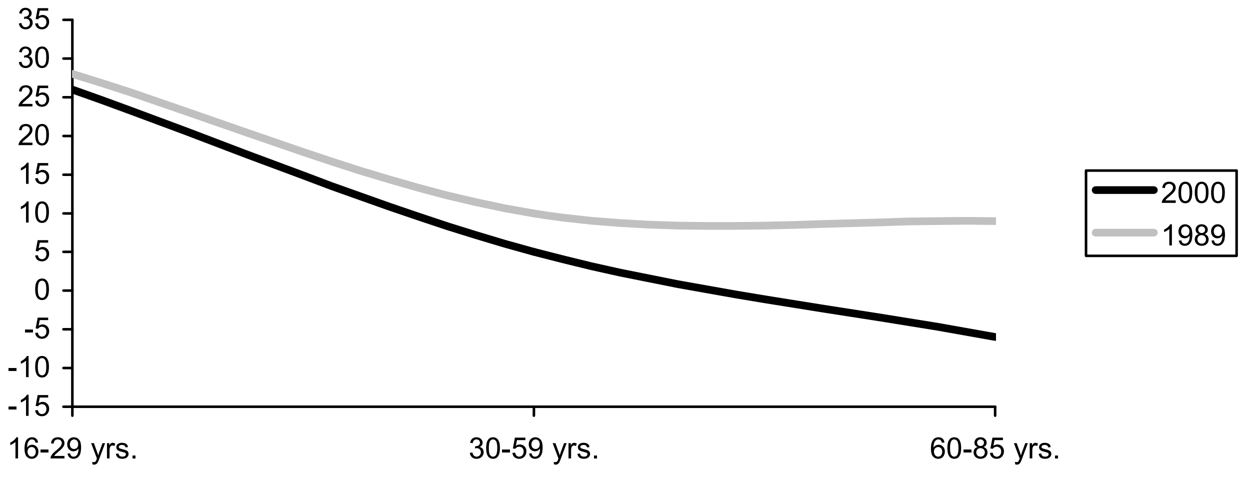

Figure 7 Age and attitudes: Support – opposition (per cent point difference)

It is relevant to examine the relationship between perceptions of modern biotechnology and attitudes towards biotechnology. It has already been shown that expectations towards biotechnology depend on the specific research area in question, with expectations being higher regarding the benefits of medical research than of food production. Figure 8 shows that, on average, people who perceive of biotechnology in terms of medical research are more supportive than respondents who associate biotechnology with GM food.

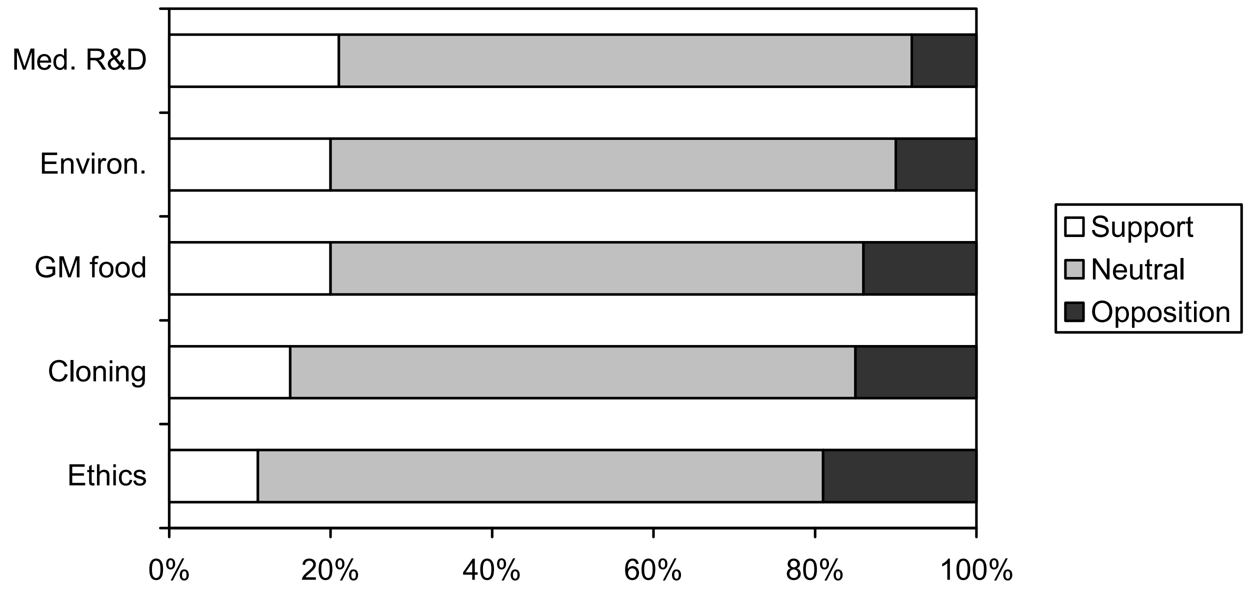

Figure 8 Perceptions of and attitudes towards modern biotechnology; per cent

GM food is the area within the field of biotechnology that Danish citizens in 2000 most frequently mention when asked about perceptions of modern biotechnology. GM food is a subject of concern and interest in Denmark, which is also reflected in a relatively high level of both media coverage and research effort. It is interesting that among the respondents who perceive of biotechnology in terms of GM food there is the lowest share of 'neutral' attitudes towards biotechnology. Respondent answers indicate that an awareness about GM food provoke strong opinions regarding biotechnology in general.

Respondents who perceive of modern biotechnology in terms of 'human and animal cloning' or ''ethical / philosophical questions' are the least supportive of biotechnology in general, whereas perceptions of biotechnology in terms of 'medical research - technological development' or 'the environment' lead to the highest level of support for biotechnology in general.

The Danish citizens' confidence or trust in scientists within the field of biotechnology is strongly correlated with attitudes towards biotechnology. Table 3 shows that citizens with no confidence in scientists are very likely to be negative towards biotechnology, whereas a high level of confidence generates a positive attitude towards biotechnology.

Table 3 Confidence in scientists in biotechnology; per cent

	No confidence	Not much confidence	Some confidence	Much confidence	Total
Opposition	42	32	10	6	12
Neutral	54	64	72	65	70
Support	4	4	18	29	18
Total	100	100	100	100	100
N	26	161	880	275	1342

Likewise, the public perception of risk has a strong impact on the general attitudes towards biotechnology. If a person emphasises the potential risks caused by modern biotechnology, he or she is less likely to hold positive opinions about biotechnology in general than someone who is less attentive towards the risks caused by biotechnology. This negative correlation between risk-awareness on the one hand and positive attitudes on the other is intuitively comprehensible. But even if the negative correlation is no surprise, the profoundness of the correlation accentuates the need for integrating cognitive factors such as 'risk-perception' and 'trust in scientists' as explanatory variables in a model of opinion formation regarding public understanding of modern biotechnology.

Table 4 Risk willingness and attitudes towards biotechnology; per cent

	Risk adversion	Neutral	Risk acceptance	Total
Opposition	19	11	4	13
Neutral	72	71	59	70
Support	9	18	37	17
Total	100	100	100	100
N	452	768	170	1390

Ever since The National Science Foundation performed the first systematic surveys on public understanding of science in the 50s, special attention has been paid to producing valid measurement of citizens' level of 'objective knowledge' of science and research. In the first decades of the empirical research programmes the dominant expectation of scientists and politicians involved with science policy was to find a relationship between a high level of knowledge on the one hand and a positive attitude towards science on the other. The political presupposition regarding the public support for science suggested that any lack of support could bed explained by a lack of information or knowledge about scientific practices or research results. Within the theoretical framework this relationship between knowledge and support - or lack of support - is known as the 'model of deficit', and in several ways the model of deficit has set the agenda not only concerning the empirical work within the field, but also regarding the political initiatives within this policy-area.

The Eurobarometres on public understanding of biotechnology from 1996 and 1999 encompass nine questions aiming at measuring the respondents' level of factual knowledge about modern biotechnology. Building an additive index based on those questions enables us to divide the respondents into categories according to their level of factual knowledge. Figure 9 suggests that the Danish segment of respondents is generally well informed compared to the average European citizen. During the three-year period from 1996 to 1999 the average score on the knowledge-index has even increased moderately from 5,7 to 5,9 amongst the Danish respondents, whereas the European average is 4,8 both years.

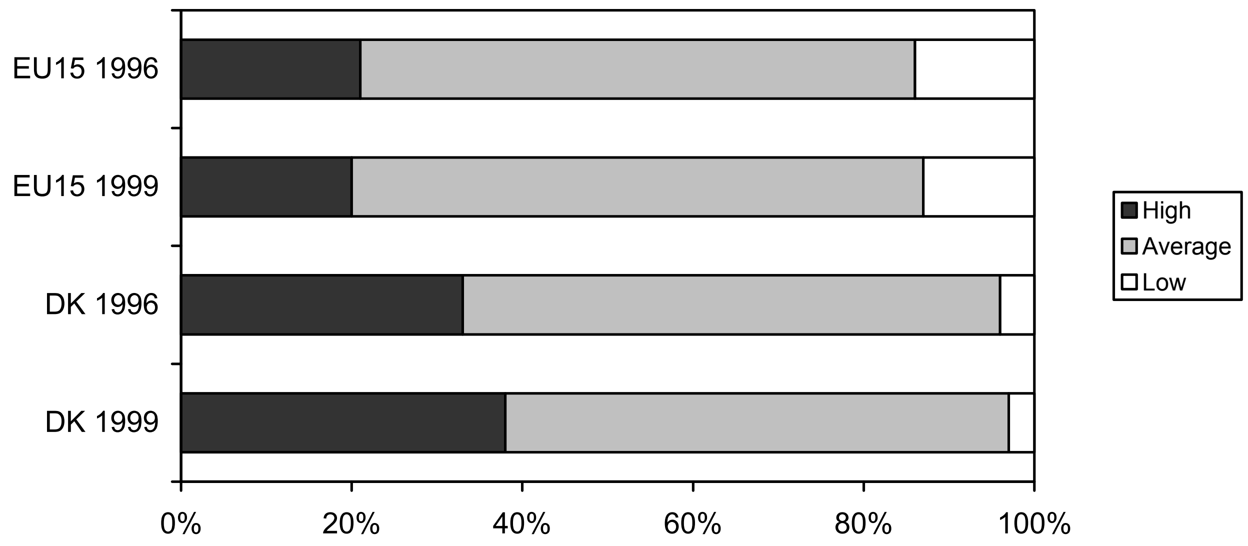

Figure 9 Level of factual knowledge of biotechnology; per cent

The Eurobarometres suggest that knowledge is in fact related to attitudes. First, respondents with a high level of factual knowledge are most likely to hold strong opinions about biotechnology; positive opinions as well as negative ones. This does not correspond with the model of deficit that would have expected only positive attitudes to increase as knowledge increases. Secondly, when excluding those respondents who have no opinion about biotechnology, there is in fact a positive correlation between knowledge and attitudes. This means that, when looking only upon those persons who have an opinion regarding biotechnology, there is some validity to the model of deficit.

Thus, the model of deficit cannot be rejected when looking upon the relationship between knowledge and attitudes in an isolated manner. But it must be emphasized that factual knowledge is not the prime explanatory variable in regard to attitudes towards biotechnology. Further, even if knowledge has a direct positive impact on attitudes, it also has a positive impact on risk-aversion, which, in turn, has a negative impact on attitudes on towards biotechnology. In other words, the model of deficit must be sophisticated in terms of including intermediate variables that are affected by the level of knowledge and affect attitudes towards biotechnology. Figure 9 demonstrates the indirect impact of knowledge on attitudes as a consequence of the impact of knowledge on trust in scientists and risk-perception.

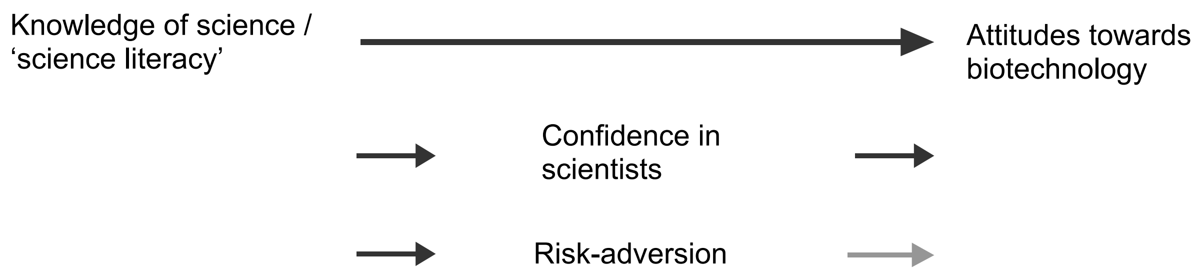

Figure 10 Knowledge, risk and confidence

The figure shows that confidence in scientist increases as knowledge increases. Increased confidence in scientists has a positive impact on attitudes towards biotechnology. Correspondingly, risk-aversion increases as knowledge increases, which means that people tend to be more sceptical and less willing to accept risks the better informed they are. When risk-aversion increases attitudes towards biotechnology tend to be more negative. In sum, the net effect of increased knowledge is difficult to estimate, since the indirect impact on attitudes is neither exclusively positive nor exclusively negative.

It is revealed by a regression analysis that between the three explanatory variables 'knowledge', 'risk-perception' and 'confidence', the latter has the greatest predictive power regarding the assessment of attitudes towards biotechnology. This means that attitudes are not solely constituted by an objective or calculated identification with the research field in question, but also - and strongly so - by a personal or emotional identification with the people engaged in scientific research within biotechnology. Biotechnology is an example of a field of research that has an enormous potential impact on society and will affect our social life in terms of developments within areas such as health, foods, environment and so forth, and the survey results suggest that Danish citizens need to have an extended trust in scientist in order to be in favour of modern biotechnology.

Box 3

Conclusion

- Increasing interest in research.
- Increasing awareness of biotechnology.
- Ability to differentiate between different applications or techniques.
- Increasing level of factuel knowledge.
- Decrease in supportive attitudes towards biotechnology.
- Sensivity towards research design: the contingency of respondent answers upon the exact phrasing of the questions posed.

In Denmark, the combination of a high level of interest in science and research and relatively well-functioning channels of information at the institutional level is reflected in a high level of knowledge of biotechnology within the Danish public, as well as a high level of awareness of biotechnology in comparison with other fields of research.

Associations towards biotechnology are quite homogeneously distributed on the categories 'cloning', 'medical research - technological development', 'GM food', 'the environment', and 'ethical/ philosophical questions'. Associations are influenced by social determinants such as gender, age, and school education.

When measuring public perceptions of biotechnology in surveys, it is of great importance that the operationalisation is done carefully, with attention to the contingency of respondent answers upon the exact phrasing of the questions posed. Comparing the 2000 survey with results from the 1999 Eurobarometer survey suggests that using the words 'genetic engineering' when measuring perceptions of modern biotechnology sets in motion a specific line of associations in the direction of 'human and animal cloning', thereby creating an invalid measurement of perceptions of modern biotechnology as a broader area. Excluding the words 'genetic engineering' from the question results in a significantly different distribution of associations, which indicates that methodological considerations are of critical importance in designing questionnaires.

The Danish population has generally higher expectations to biotech R&D within the area of medical research than within the area of food production. This result is in accordance with previous results on a European level. The 2000 survey also indicates that perceptions of biotechnology influence the general attitudes towards this field of research. Respondents who perceive of biotechnology in terms of 'medical research' or 'the environment' are generally more supportive towards biotechnology than respondents who associate modern biotechnology to 'ethical / philosophical questions' or 'human and animal cloning'.

In Denmark, there has been a moderate decrease in positive attitudes towards biotechnology over the last decade. Considering the increasing public awareness of biotechnology and general interest in science, it seems reasonable to say that the more negative attitude is not a symptom of neglect or fear of new technologies, but rather a sign of an increasingly subtle and reflexive public understanding of biotechnology. The impact of factors such as risk-perception and trust on attitudes - as compared to the minor impact of basic knowledge - implies that communicating research results is not a sufficient strategy with regard to increasing public support of biotechnology. In order to increase the public support of biotechnology, it is vital to embrace the citizens' opinions in a constructive dialogue that respects the need to discuss the risks connected to biotechnology and the need to create bonds of reliance between scientists and citizens.

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Public debate about genetically modified food

Jesper Lassen - The Royal Veterinary and Agricultural University

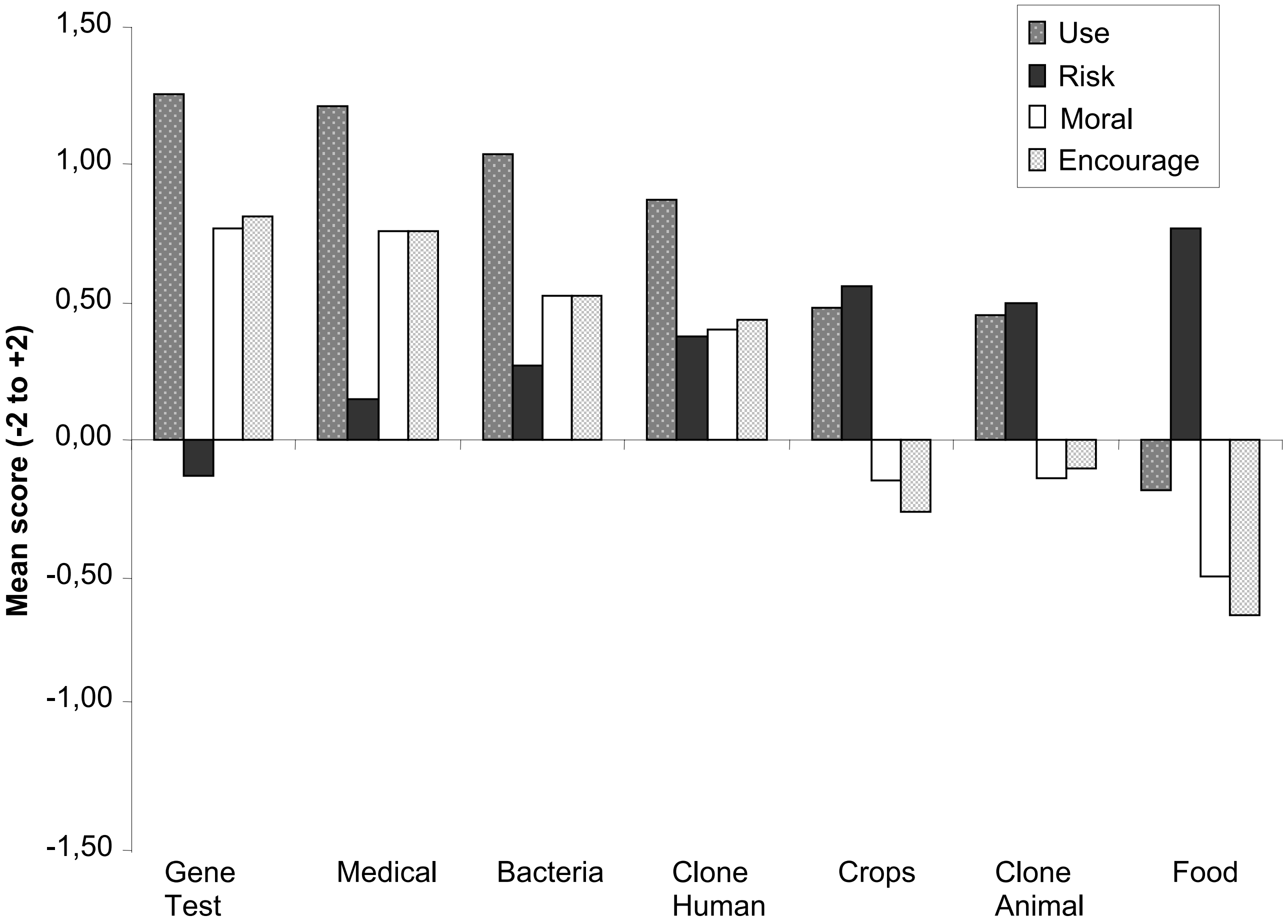

Figure 1 Public attitudes to biotechnology in Denmark (Eurobarometer 52.1)

Box 1

A qualitative analysis of the public perception of gene technology in Denmark

- 7 focus group interviews, spring 2000
- 5-7 participants in each group
- Criteria:
  - –Sex, age, occupation, income etc
  - –Expected attitude
- Copenhagen (2), Albertslund, Maribo, Ørum (Tjele), Vodskov, Aalborg
- 2-2½ hrs
- Three themes: food; non food involved actors

Box 2

Observations across the interviews

- Medical applications are perceived as more acceptable than food related applications
- Negative arguments are dominant when discussion GM food
- Medical gene technology is not totally rejected by anybody
- GM food is totally rejected by some – nobody accepts GM foods without reservations
- The only arguments having general appeal in favour of GM foods are related to possible benefits for the third world
- Three typical types of arguments: Those who reject; those who are critical and those who are sceptical

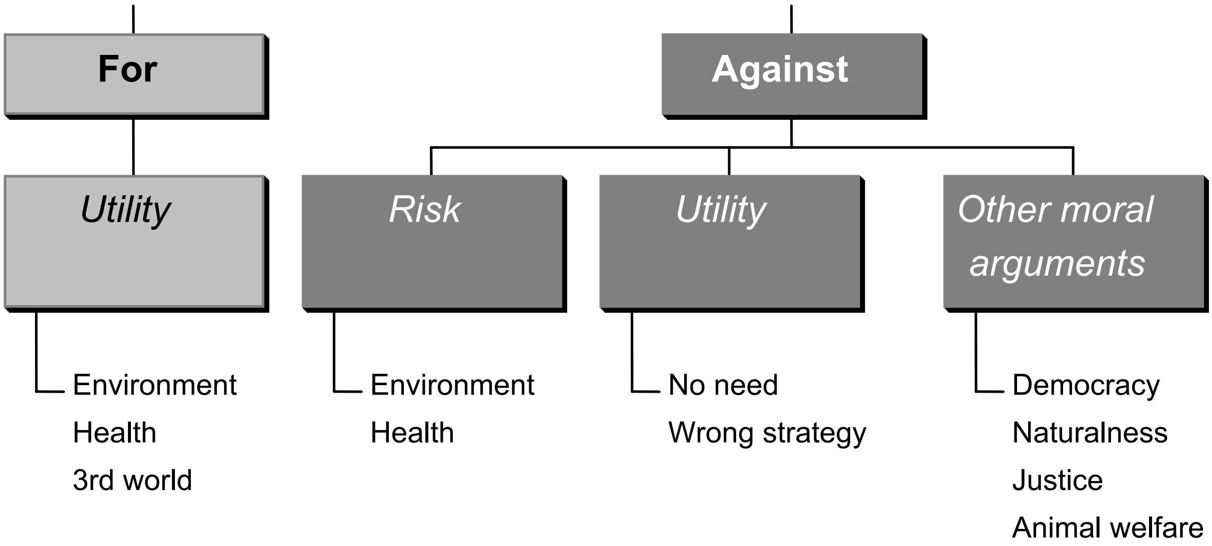

Figure 2 Arguments for and against food gene technology

Box 3

Environmental arguments

- Argumentations within the 'old' environmental discourse.
  –Arguments pro and con
  –Arguments about the level of harmful substances

- Argumentations within the 'new' environmental discourse about the release of manipulated organisms
  –Only arguments against the use of gene technology
  –Arguments often based on ecology

Box 4

Environmental arguments 1

- **Benefits are recognised, but often overruled by threatening perspectives:**Holger: *"… you don't have to use as much artificial fertiliser on the fields. And perhaps … if the plants are harmed by a parasite, you could put in or remove a gene, making the plant resistant to that parasite. Then you wouldn't need to spread so many pesticides on the fields. I think that is a good perspective, but I fear that the use of gene-technology will primarily be used to make profits - and that is more likely to result in an increase in the use of pesticides, than the opposite"*

Box 5

Environmental arguments 2

- **Worries over the unpredictable consequences:**

Benny: *"… if you take a cornfield and 'twist a gene' and you influence something next to the cornfield. [About manipulated animals] The problem is that you can't kill it. Take the BSE, it's all about a 'twisted protein'. Nobody knows, where it comes from (…) and even if you killed all the animals and burned them, even if you warmed it up, it would still be there. That's why I think it's incredibly difficult to get at, if you make a mistake"*

Box 6

Environmental arguments 3

- **Worries over impacts on the ecosystem and the long-term consequences**

Bodil*: "That is what makes you critical: Not that you don't know anything about it, but the researchers don't either. They don't know the consequences in ten years 'if you do it to a bee'. What is the consequence if they die? If they behave strangely or ...? Really, right now you can say "it's just a bee" but it is something ecological - it is part of a cycle"*

Box 7

Health and safety 1

- **Worries over the negative impacts on health now or in the future:**

Thomas*: "… I don't think [it is harmful] if you manipulate a potato, making it round and firm. But the problem comes, when you manipulate potatoes with corn - how will it react? (…) It is not possible to say, what happens to the potatoes in relation to all the other products eaten by the many different animals, until it reaches us."*

Box 8

Health and safety 2

- **GM-foods is not considered dangerous to eat - but rejected because of democratic draw backs, lack of usefulness, wrong motives etc.**

Helle*: "I must say, eating GM foods does not scare me for health reasons, not at all! But despite that, GM foods make me nervous because of the motive behind the manipulation. And I often disagree a lot with that motive - because it's all about getting cheaper products, making pesticide resistant plants and such things - and I don't want that! (…) [it could, however, be useful] but we haven't seen one single food product, where it has been applied in a useful manner - not one single!"*

Box 9

Health and safety 3

- **GM-foods are useful because we get healthier food products**

Alice*: "[There are some applications] where I can see the advantage - I don't know if I like them - but I can see the point in changing the nutritional composition of different food products - some people definitely need more vitamin A, and many Danes could do with less fat…I can easily see that such applications are useful."*

Box 10

The 3rd world argument

- **Application of GM foods in a third world context is useful, because they suffer and are poor**

Tom*: "Using genetic manipulation to fight hunger and poverty - it's probably a very cheap solution, I'm sure it is. (…) Making cows that produce more milk; rice with more vitamins and drought resistant cereals – these are cheap solutions (…) it's expensive to feed the third world, but today the West has got a good and cheap solution, and we should go for it…"*

Box 11

There are alternatives

- **Gene technology is a wrong strategy to solve the problems in the third world because there are less risky alternatives and strategies**

Ejvind: *"Most of the applications of gene technology are utterly useless. Take the vitamin A enriched rice – couldn't the aeroplane bringing us the rice take some vitamin A pills back home to those who need it!?*

Box 12

The dynamics of the market economy contradicts possible advantages

- **The use of gene technology will not benefit people in the 3rd world because the development of GM foods is motivated by profits and continued exploitation**

•Mads: *"The problem is that those developing gene technology don't do it for the sake of the brown eyes of the people in the 3rd world. The purpose is to sell something and make people dependent on the companies that have developed the products! These technologies are not developed to help anybody but to make money – that's the purpose!!"*

Box 13

It's a sliding slope

- **Even if the use of gene technologies in the 3rd world are useful, they are not acceptable because we can't delimit the development to the useful applications**

Tove: *"Basically you don't want gene technology – but then again there is this drought resistant plant for the deserts, that sounds brilliant, doesn't it?? But if you accept just one single application, you'll have to eat all of it!! What I mean is: You can't pick one and leave the other – that's impossible because I don't trust the scientists."*

Table 1 Different framings

	Risk (Health and environment)	Usefulness	Other moral concerns
Regulation	*Narrow*: Risk defined in technical / scientific terms. Measurable.	*None*	*None*
Citizens	*Broad*: Includes also long-term consequences and stress scientific uncertainty	*Broad*: Societal usefulness	*Many*: (Un)naturalness, justice, democracy, animal welfare …

Box 14

Lessons to be learned

- The conflict is about values not (only) risks!

- Dialogue requires respect for the values of ones opponents
  ”… it is only relevant to make risk assessments of (genetically modified) plants …”
  (Landbrugsraadet, 2000)

- Dialogue is important but not enough
  –Hear and listen!

- From citizen to consumer
  –The market is reactive - 10-20 years after R&D
  –The consumer is not necessarily in accordance with the citizen

Scientists' Understanding of the Public

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Binding to vested interests and blindness to ethical values at stake in the research are the two main barriers to scientific researchers' participation in public debate on genetically modified crops and food. This was the overall conclusion from a research project on communication between scientists and the public in Denmark about modern plant biotechnology. The project took place from August 2000 to June 2001. The research concentrated on the dialogue and the barriers to dialogue, rather than on the conclusions and results from the dialogue. The focus was on the scientific "camp", on working conditions and attitudes.

Comparing the findings from a series of qualitative interviews and a questionnaire with findings from earlier research about public opinion on biotechnology it was concluded that citizens and scientists tend to talk about biotechnology in different contexts. They are supposed to take part in one and the same debate, but in fact they don't. Citizens tend to talk about applied science in a social, economical, and political context, stressing ethical aspects of the application of science, and using a narrow, moral concept of usefulness but a broad concept of risk. Scientists tend to talk about science in the laboratory, stressing technical and strictly scientific aspects of the application of science, and using a broad, commercial concept of usefulness but a narrow concept of risk.

Scientists with little knowledge of - and little interest in - the values at stake in their research are at high risk of being excluded from the public debate about how to interpret, use or reject the use of their research results. The public debate about genetically modified plants and food may be seen as an example of this mechanism of exclusion from public dialogue. The very mechanism of inclusion in the scientific community - successful specialisation, with no requirement to understand wider perspectives of the research - thus works as exclusion from the public debate.

Life is not made easier for such highly specialised scientists when they are obliged - which is very often the case in plant biotechnology - by politicians and public authorities to collaborate closely with industry in order to be granted public money for research. A strong corporate link may be seen as an advantage to science and society and even as a precondition for furthering economic growth, but it does carry a dilemma: the link can be a disadvantage to scientists trying to enter public debate. Scientists so linked are at high risk of being excluded. The Big Money Link may easily become a Big Money Trap. Considerable parts of the population tend to identify scientists with huge commercial interests. Thereby the scientists are embraced by a suspicion directed against these commercial interests: a suspicion about only being "in it for money" and not caring about the common good.

Recommendations from the project aim at stimulating scientists to reflect on the social context of their research, including reflection on potential consequences of the research results to other groups in society, locally as well as globally. Other recommendations aim at turning the corporate link into a wider, societal link, thereby removing another obstacle to the participation of scientists in public debate.

The authors presume that the main findings and conclusions from the project are relevant in an European context rather than being specific to Denmark. Scientific culture is highly international. There is no reason to believe that working conditions in public biotech-research or attitudes among researchers in the field in Denmark represent a very special case, although the rather strong Nordic, egalitarian traditions point to a likelihood of Danish researchers being better prepared than most scientific researchers to take part in an open public dialogue.

The European relevance is, however, only presumed and not documented. Attitudes among scientific researchers are rarely looked into. Consequently almost nothing is known about the conditions and the ability of scientific researchers in Europe to take part in public dialogue on the interpretation and application of their own research results outside the laboratory. Are there economic and time constraints? Are there knowledge constraints? Are there attitude constraints to a dialogue on equal footing? So far these questions are open questions.

A dialogue project

Whether public dialogue about plant biotechnology leads to public acceptance or rejection of high (bio)tech plants and food has not been considered by this project, which has been supported by the Danish Ministry of Trade and Industry. There has been no intention to find ways or communication techniques to persuade the public to accept or reject plant biotechnology. An open public dialogue on biotechnology has been regarded primarily as a goal in its own right. In contrast to many projects and discussions on public debate about biotechnology, it has not been taken for granted that lack of scientific knowledge among the citizens is the main barrier to a dialogue between scientists and the public. Such lack of knowledge has often been looked for and found. Consequently, in the present project the binoculars have been directed towards the other side of the public/scientific gap, looking for barriers within the scientific community.

For practical reasons the research concentrated on scientists working with modern plant biotechnology at six public research institutions in Denmark. A group of approximately 200 scientists at those institutions was presented to the authors as a relevant group. When drawing on conclusions from the project, it should be remembered that no clear demarcation lines exist either between research on plant biotechnology and research on basic biotechnology, or between research on plant biotechnology and other varieties of modern research on plants. It has been outside the scope of the project to question the representativity of the chosen group.

A series of nine qualitative interviews with prominent representatives of the relevant research units was followed by a questionnaire to the whole group. In the questionnaire the scientists were asked to judge whether they actually were practising modern plant biotechnology or had done so during the last couple of years. Only a handful used this question to exclude themselves from the group. The questionnaire was e-mailed to the scientists. 15-20 percent of the scientists were found to be unable to answer the questionnaire, being non Danish speaking. Almost one half, 80 researchers, of the remaining 165 returned the questionnaire. Besides asking for basic information on age, gender, education, etc. the questionnaire included questions about research topics; purpose of research; financing of research; contacts with industry, agriculture and other groups in society; participation in public debate on biotechnology; and about reflection and debate within their research institutions on political and ethical aspects of biotechnology. This was combined with questions regarding attitudes to matters such as: patents on genes, plants and animals; the use of antibiotic resistance markers in genetically modified plants; and causes of public resistance to such plants. A project report in Danish was disseminated to scientific institutions, NGOs, politicians and public authorities in Denmark, and has recently been made available in English. (Meyer et al.)

Isolationism and isolation

One of the most distinct findings from the questionnaire is about how biological scientists explain the plant biotechnology controversies. The scientists were asked to agree or disagree, totally or predominantly, to a statement that lack of biological knowledge is the main reason for public resistance to genetically modified food and plants. Three out of four scientists agreed to the statement. Among the youngest scientists, under the age of 41, the tendency to agree was even more striking, encompassing almost nine out of ten. Their reasoning seems to be that supplied with more biological knowledge the public would accept modern plant biotechnology. This assertion by the scientists does not correspond well with findings from international research regarding the relationship between biological knowledge and resistance to/acceptance of modern plant biotechnology. Conclusions from such research has been that more knowledge seems to go hand in hand with taking a stand - whether for or against these new technologies - but a link between biological knowledge and social acceptance has not been established. Neither does the scientists' assertion correspond with recent research into the arguments behind Danish public attitudes to genetically modified food and plants. Conclusions from focus group interviews on this topic point to social and other ethical concerns playing a major role in public opposition to modern plant biotechnology. (Lassen) Concerns regarding the risk that society could become dependent on a small group of large biotech business corporations is one example.

To the Danish public biology is only a part of the picture and not the most important part. Viewed from inside the biotechnological research milieu, however, the biotechnology discussions are primarily about biology. The scientists themselves know a lot about biology, while other citizens know less about biology. It's a short step to the conclusion that the public is a deficient body in biotechnology debate and decision-making. The scientists tend to be less knowledgeable and rather uninterested in non-biological aspects of biotechnology, and they seem not to be aware of how much there is to know about social and economical implications of their own field of research. So, what seems to be the obvious conclusion seen from inside scientific research institutions is less obvious seen from the surrounding society, by other citizens. An example of the different perspectives is provided by the answers to a question about political and ethical aspects of patenting of genes, plants and animals, for more than a decade one of the most burning issues in international biotech-debate. Less than four out of ten scientists stated that they had taken part in such discussions at work, and only just fifty percent had taken part in such discussions at all. To informed citizens such lack of perspective may easily lead to defining the scientists as a deficient body in biotechnology debate and decision-making.

Danish plant biotechnology scientists complain about not gaining access to the public biotechnology debate. Ignorance regarding the social context of their research is a likely barrier to these scientists. Where does this ignorance come from, and where will it take the scientists? One possible answer is that it comes from scientific isolationism, and will take scientists into undesirable isolation from the public debate. This is not a scientific victory, and it is a problem for society at large: biotechnology is not pure science and it is heavily dependent on society. And society cannot do without scientific knowledge in informed decision-making on biotechnology. Thus, tracing and weakening the roots of scientific isolationism is important, to science and to society.

More science - or more than science

For centuries it has been regarded as a scientific virtue to concentrate on scientific facts, produced by means of scientific methods, and to keep out of touch with other spheres of human reality - politics, religion, ethics etc. These other spheres have, so to say, been kept in a black box - labelled "feelings" or "irrationality" - in the scientific mind. At the same time accelerating specialisation has been a driving force in science, and more and more scientists with highly specialised, scientific knowledge, but only little understanding of the context of the same knowledge, are being produced. Biotechnology is not suited for this way of thinking. It is not pure science. It is very much in touch with other spheres of human reality. Biotechnology is not an option for scientists looking for a hideaway from aspects of reality beyond the reach of scientific rationality. Nevertheless, scientists in plant biotechnology seem to work on the basis of a concept of "pure, biotechnological science", trying to turn biotechnology into a nice clean cave where they can concentrate on what they have been trained to do: the production of scientific facts. Consequences of this attitude can be observed in the public debate about biotechnology. There is little dialogue between scientists and the public for the good reason that the two parties do not talk about the same things. Both parties talk about risk and usefulness, but they understand these concepts in different ways.

In science risk is predominantly understood as risk factors suited for analyses by means of scientific methods. In the public a wider notion of risk prevails. People tend to worry about risks which are too wide and complex to be unveiled by scientific methods alone or at all. In short: it is a scientific credo that scientific methods can produce the best possible solutions and safety, but a large part of the population is worried exactly because of the narrowness of this scientific credo. So, there is a vicious circle: Scientists want to supply the public with more science - scientific risk assessment is an example - to lessen the public concerns, but the implicit, public demand is not about more science. It is about more than science.

Regarding usefulness the contradiction is the other way round. Scientists tend to operate with a broad, commercial notion. Anything marketable is regarded as useful. In the public a narrow, moral notion of usefulness is common. To be justified biotechnology should be genuinely beneficial. For years scientists has told the public that gene technology is about the use of knowledge of a higher order, being about nothing less than "the Book of Life." Consequently, high usefulness is demanded by the public, matching potential adverse effects of a higher order. But to the scientific mind more science is the remedy to potential negative consequences, and strong ethical demands on biotechnological research by the society seem not to be justified.

These contradictions and this lack of mutual understanding point to the need to inspire scientists to explore the darker corners of the scientific mind, and to persuade them that there may be more to reality and rationality than science is able to manage on its own. However, for the time being the barriers in the scientific world are high. International scientific competition is based strictly on conventional scientific criteria. Specialisation counts. No merit is gained from recognition of or reflection on the context of the specialised scientific knowledge, and there is a tendency to regard public demand for ethical considerations as nothing but a greedy time-consumer, robbing time which might have been used to gain scientific merit in a highly competitive, bio-scientific world. There is a long way to go before the vicious circle can be broken. One recommendation from the project is about widening the perspectives in science education at all levels. Another is about stimulating scientific institutions to break out of the present social isolation and develop contacts with other groups of society - non-commercial arrangements where all parties have something to give and something to learn. At present there are no such incentives in the Danish research system, but a window has been opened to science education at universities. The secretary of state for education and the heads of universities recently agreed that university curricula should be widened to include general, interdisciplinary aspects.

Minding the gap

Research in plant biotechnology at Danish public research institutions is heavily dependent on external funding. 85 percent of the respondents to the questionnaire stated that more than half of their research money came from external sources, and as a group the 80 respondents use five to six times as many working hours for fundraising as for others sorts of contacts outside the research institutions. To be granted funding from public research programmes, scientists in Denmark and in the EU are commonly expected to present a commercial partner. The series of qualitative interviews gave a clear message on this practice as being harmful to the public's trust in science and unfair to scientists. The close cooperation with commercial interests makes the public suspicious, and the scientists themselves can do nothing about it. Abstaining from commercial purposes and partners means no money. Cooperation means suspicion that scientists are the poodles of multinational corporations. The Big Money Link has become a Big Money Trap, and inside the trap the scientists are dependent on the whims of market forces, which at present in Denmark are turning their back on plant biotechnology because of public resistance. Opening the trap is one way of minding the gap between science and society. The authors recommend the introduction of a wider spectrum of criteria for granting money from public research programmes. Collaboration with other partners than industry and for other purposes than commercial should qualify. Other recommendations point at a need for regulation and new routines to ensure public access to research results from public institutions and explicit openness about how research projects are financed. Changes of that kind may not only serve to alleviate public suspicion towards scientists and science - they may also stimulate scientists to feel more at home in society at large, to take an interest in society, and perhaps even to look for a house in the agora, as the isolated ivory tower has become inhabitable and the conditions in the marketplace have been tried out and found rather harsh.

The commercial trapping of science is not a specific Danish phenomenon. Recently it was mentioned in the conclusions from the consultative cross-disciplinary EU/USA working group, the Consultative Forum on Biotechnology: "The Forum expressed concern that scientists in academic research institutions are increasingly seen to be serving the goals of industry rather than the public at large. Public policies that oblige academic scientists to collaborate with industry in order to secure public funding for research may mean that the independence of scientists who are employed by academic institutions comes into question."

The less than perfect dialogue between scientists and the public on biotechnology is also an international phenomenon with national variations, and recognition of a need to improve the dialogue between science and society in general seems to be growing. In October 2000 this need was, for instance, highlighted at an EU-conference in Brussels, organised by the European Commissions' Joint Research Centre, and focusing on the topic science and governance. (The IPTS-Report) The existence of the EU research programme STAGE (Science, Technology and Governance in Europe) is another example.

To diagnose the dialogue problems more knowledge is, however, needed about the scientific communities, their financing and working conditions as well as about knowledge and attitudes among scientific researchers. The authors recommend questions like the following to be highlighted.

Regarding isolation: Do researchers have contact with other groups in academia, outside the natural sciences? Do they have contact with industry and agriculture? Do they have contact with other groups in society? How much time do they use for research applications?

Regarding public science and private interests: How dependant are the researchers on commercial partners to finance research? How many researchers have biotechnology patents? How many researchers have biotechnology shares? How often do researchers work as consultants for biotech-companies?

Regarding knowledge and attitudes among scientists: What do the scientists know about the application of the results of their own research in a social context? Do they care? Is it a widespread attitude among scientific researchers that the responsibility of the researcher is limited to the lab or the research plot? Is pure science a common ideal? Do scientific researchers worry about the integrity and independence of scientific research? How is public resistance to genetically modified crops and food explained? Is natural science regarded as the producer of a superior form of knowledge, meaning that scientific facts will outrule objections outside the scope of scientific methods? Is science understood as beneficial by definition? How do scientific researchers think that scientific uncertainty should be managed by society?

During the project the authors were criticized by one of the leading scientists in the field for asking scientific researchers a lot of questions about topics upon which they had never reflected at all. That was, in fact, the point of the project: to highlight the level of reflection on social and ethical aspects of scientific research among scientific researchers. The Danish study may be seen as a pilot study to explorations on an European scale.

Such explorations would be novel. As indicated above the study of attitudes and knowledge among scientific researchers is quite a rare exercise when communication between scientists and the public is on the agenda. In other areas of communication studies it would be expected that all partners in a dialogue were put to scrutinity. Why should it be different when one of the partners is science? It seems to be a mainstream assumption that science and the scientific communities should be taken for granted. Nevertheless, science itself may be part of the problem, and therefore there are new understandings to gain from turning the binoculars towards science and scientists. Such new understandings are vital to the understanding of the public debate on biotechnology and bioethics.

The authors are convinced that it is necessary to integrate bioethics and science studies. In general, a clear demarcation line is presumed to exist between science and ethics. Science comes first. Afterwards there may be some ethical challenges. They can be managed independent of the scientific aspects. But when public opinion is looked into by means of qualitative methods this basic assumption is undermined. There is not a neat separation of scientific and ethical aspects. On the contrary, the public concern goes directly into the heart of science, questioning the questions of science, debating the limitations of scientific methods, discussing scientific uncertainty, being sceptic to the financing of scientific projects, asking for the motives of scientists, and calling for social responsibility of scientists. From these observations it is argued that the inclusion of science and scientists in studies on the biotech-controversies is a precondition to the understanding of these controversies and to finding new ways of solving them.

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Health care related biotech in the media - What are the controversial stories?

Maja Horst - Copenhagen Business School, DK

Box 1

Controversial stories

- Preliminary results from Ph.D. project
- 1600 newspaper articles 1997-2001
- 4 major newspapers (Politiken, Jyllandsposten, Information og Ekstra Bladet)
- Combination of quantitative and qualitative analyses
- Short introduction combined with example of cloning

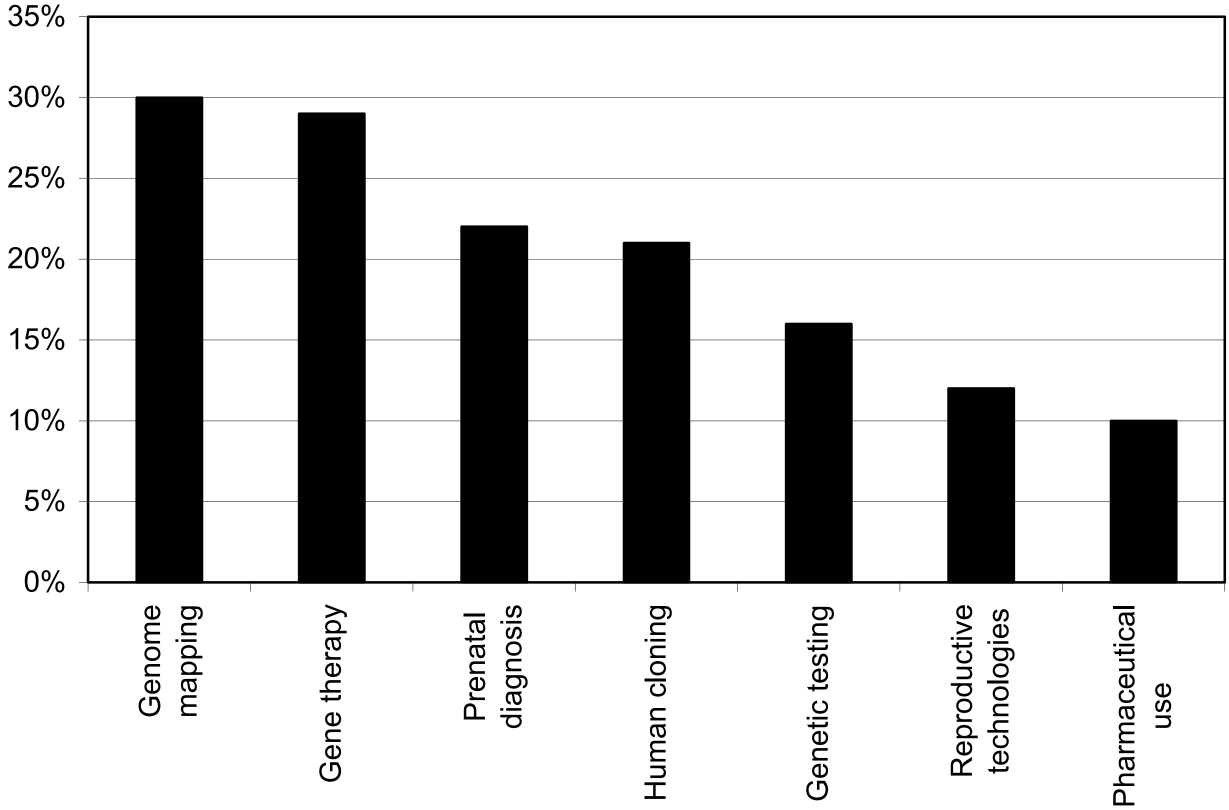

Figure 1 Technologies

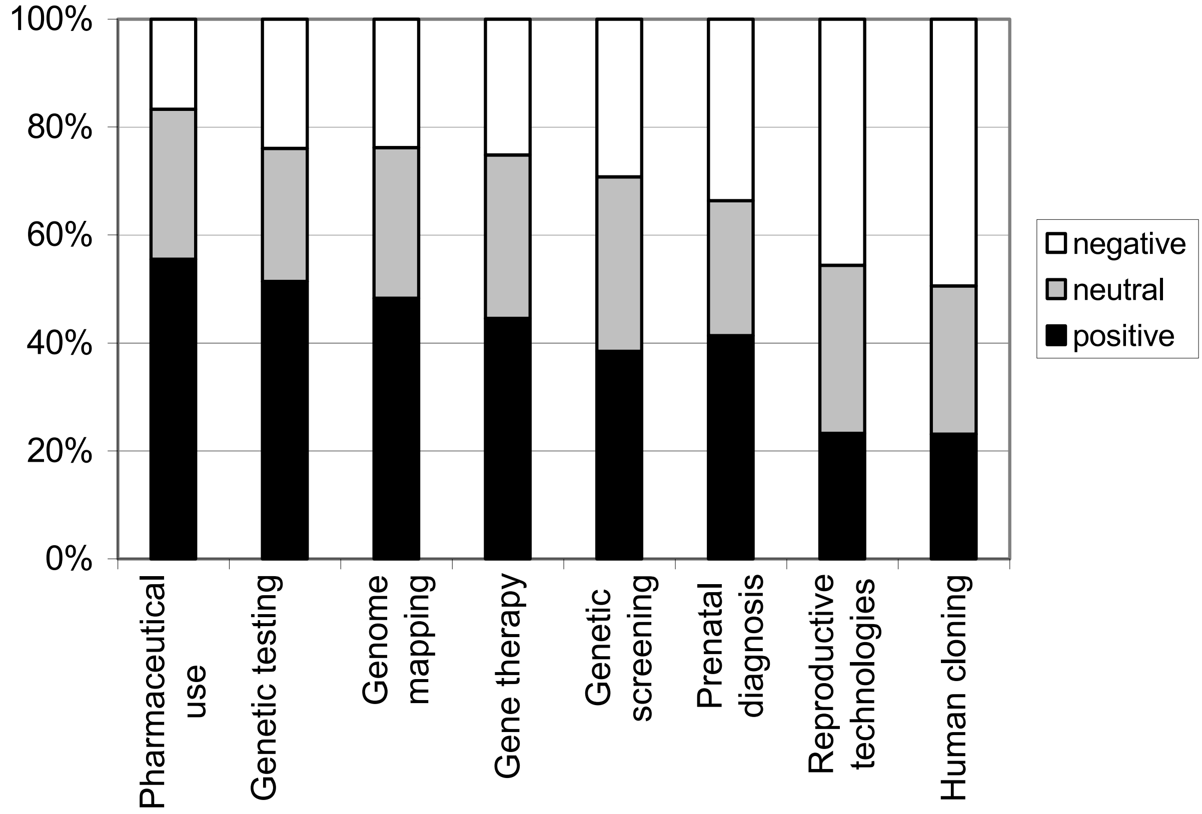

Figure 2 Valorising technologies

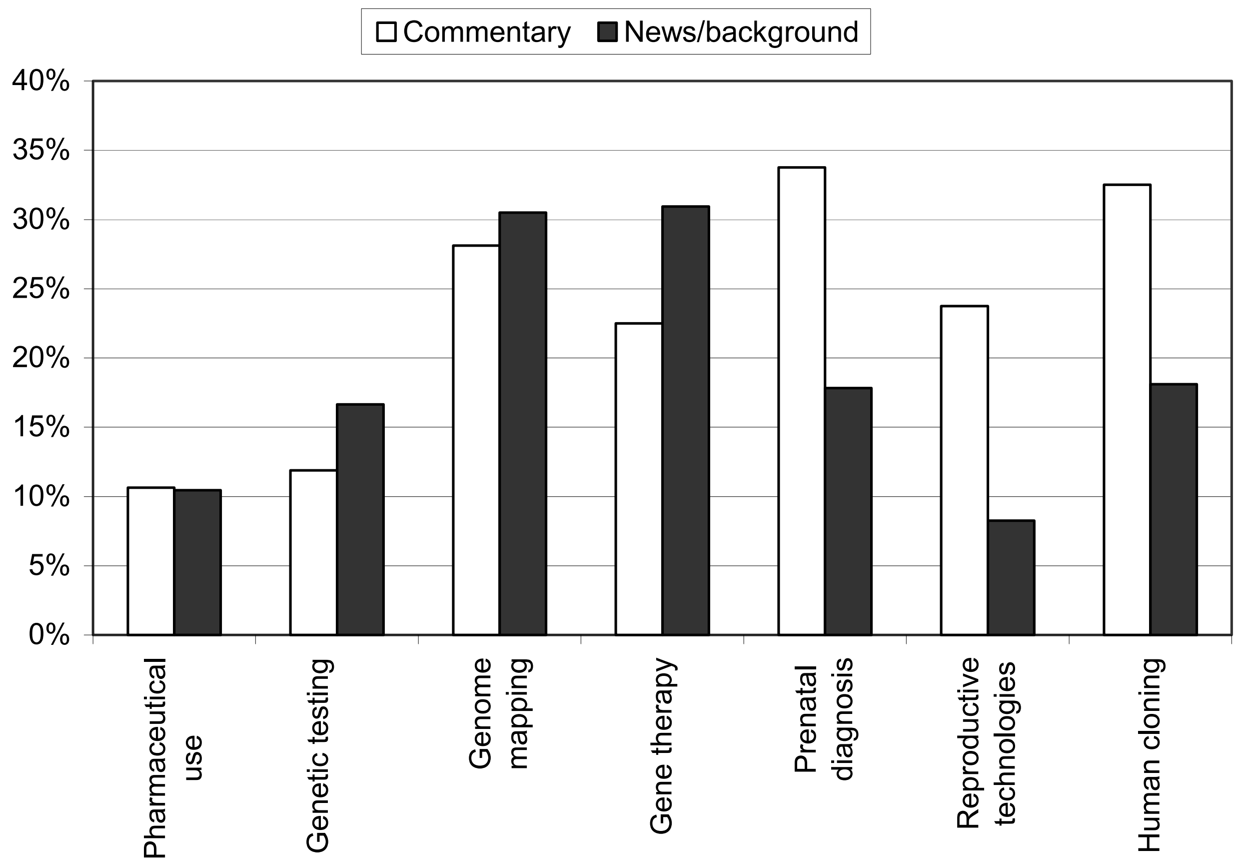

Figure 3 Technologies and different genres

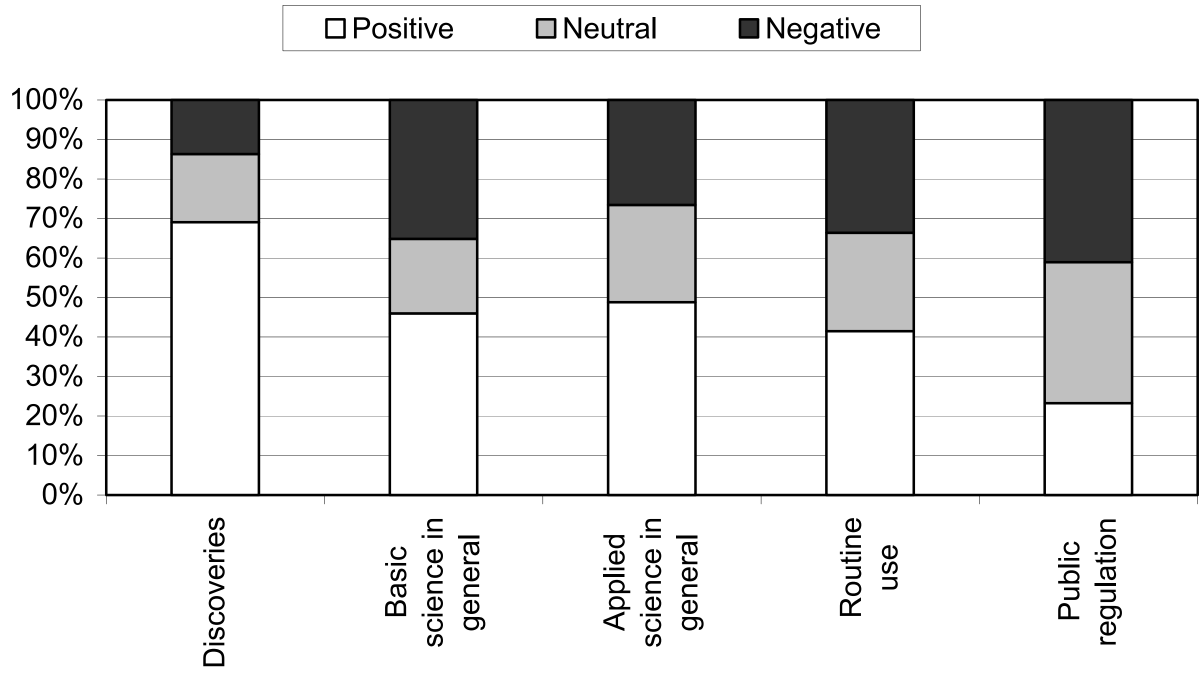

Figure 4 Valorising stages in technology

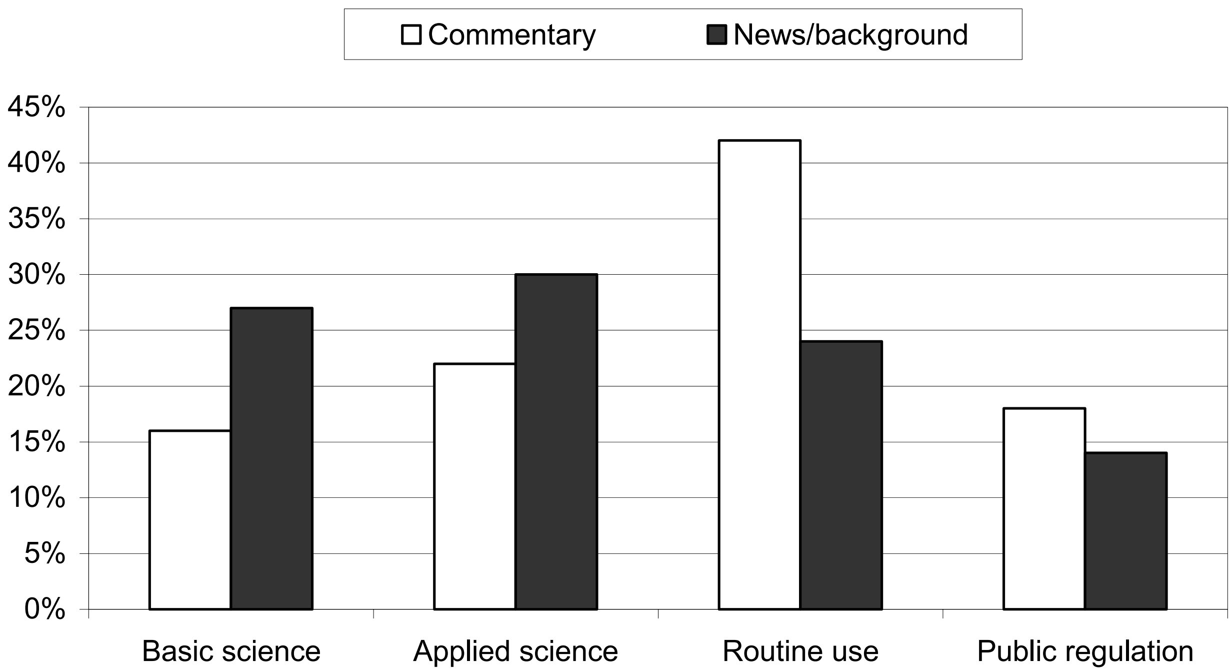

Figure 5 Genres and stages in technology

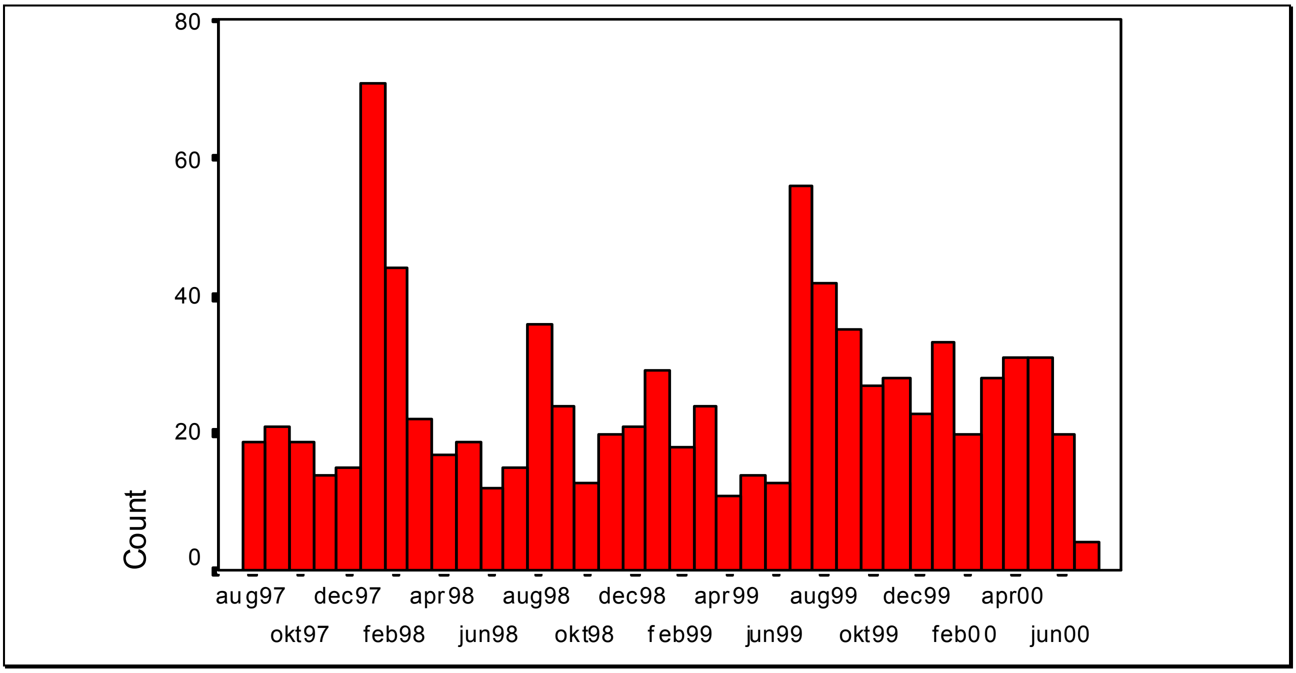

Figure 6 No. of articles about gene technology/month

Box 3

The study of media sensations

- Powerful images opening for a multitude of interpretations
- Occasions for sense-making about general problems and possibilities of research
- Sensations as extreme cases in a study of paradigms of interpretation and sense-making

Table 1 Paradigms of interpretation

Reproductive cloning as a risk	Reproductive cloning as a danger
Pragmatism • The order of nature is robust • Instrumental evaluation • *Jyllandsposten* as example	**Fatalism** • Darwinistic look on society • Experts' rationality is absurd • *Ekstra Bladet* as example
Rationalism • The rational order of society is fragile • Science communication as enlightenment • *Politiken* as example	**Idealism** • The Good Life is threathened by system-colonisation • Resistance against science • *Information* as example

An organizational view on strategy development in the biotechnology industry

Jesper Norus - Copenhagen Business School, DK

Abstract

This paper highlights the results of a study based on qualitative data on the evolution of the biotechnological industry in US and Denmark[1]. The study has identified three different types of strategies undertaken by the entrepreneurs in the biotechnological industry: the project strategy, the incremental strategy and the vertical integration strategy. The paper departs from a discussion on the concept of the firm. The paper suggests that the small biotechnology firms (SBF's) best can be perceived as a loose entity, a temporary meeting place, solely defined by its portfolio of R&D projects rather than a well-defined unit with clear jurisdictional boundaries.

Introduction

The biotechnological industry has been formed and developed predominantly by small biotechnological firms with very strong roots and antecedents in the scientific environments (Norus, 2002; McKelvey, 1996; Kenney, 1986, Powell, 1994; 1996; 1998). Although they have been able to develop quite sophisticated technological projects and products, the small biotechnological firms (SBFs) only have a few employees. These technological projects are developed through a wide range of collaborative arrangements, such as informal networks and formalized networks (joint ventures, licensing agreements and strategic alliances) with a variety of partners (venture capital firms, pharmaceutical and chemical firms, public and regulatory bodies, other small biotechnology firms, universities and research parks).

This means that a variety of different networks arrangements are to be regarded as means of survival in a new technological field where we would expect that only large multinational companies with large financial and human resources have the competencies and capabilities to direct and control the evolution of the biotechnology.

Due to the different character and combination of the collaborative arrangements undertaken by the SBFs it would be a flaw to search for an ideal strategy obtained by small biotechnological firms. A single best strategy in this area does not exist. Instead the search for best strategy has to be determined by the technological approach of the company, the aspirations of the entrepreneurs, and their modes of developing their business through the organization and establishment of external networks. Three types of strategies undertaken by the SBFs will be outlined: the project strategy; the incremental strategy; and the vertical integration strategy. These three strategies have been identified through a qualitative study of the biotechnological industry in US and Denmark (see appendix 1).

In relation to the "project strategy" the SBF tries to develop a market for a portfolio of related R&D projects, which the SBFs have carried out. This strategy can best characterize the SBF as a "science boutique" where the distinct aim is to sell or license projects to large pharmaceutical or chemical companies in a continuous stream. By this the science in itself are the product.

The "incremental strategy" has a slightly different strategic aspect where the SBF gradually learns and experience about the nature of the different task. The aim is stepwise to take command over more and more activities and by doing so fulfill the long-term goals of the company. The backbone of this strategy is to generate resources by selling projects, do consultancy services and by

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[1] The paper is based on my book: Biotechnology Organizations in Action – Turning Knowledge into Business (Norus, 2002). For the Danish audience a Danish version of the book exists (Norus, 1999). The major difference between the two books is that the five case studies have been updated and a new concluding chapter has been written.

establishing joint ventures with larger firms. Through these partnerships the SBF gradually builds up more and more competencies in house deliberately protecting what are considered the long-term assets of the company.

The SBFs that follow the "vertical integration strategy" have a much more comprehensible strategy in the sense that the idea is to become a vertical integrated company that takes care of all functions from the development of new products, to the production, sales, marketing and distribution. Only few SBFs follow the vertical integration strategy due to the complexity of the technology, the regulatory aspects of getting a product approved, and of course the lack of resources to achieve the long term goal. Another important reason is that small firms often faces competence traps implying that they cannot build up an organization fast enough that can handle all aspects from research, production, marketing, regulatory aspects and distribution to capitalize on patents with a limited duration. This strategy means that the firm has to become a public traded company through an initial public offering (IPO) that challenges the routines for strategy formation, management and establishment of external networks.

Entrepreneurial strategies in biotechnology

Some studies of the biotechnological firms have applied a population ecology approach. However these studies often fail to come to grips with central aspects of the industry in focusing narrowly on the survival rate as the overall criterion of success (Barley et.al.; 1987; Orsinigo,1989). The strategic decision making process in the small biotechnological firms has not been studied much. Therefore, it is a common characteristic of both the study of Barley et.al. (1992) and Orsinigo (1989) that they are incapable of capturing important characteristics about individual aspirations and strategic decisions.

As will be clear from this section, some biotechnological firms have much more diverse and ambiguous criteria of success, e.g. some firms have developed a strategy with the distinct aim to sell off projects, and even whole companies in order to start all over again. This type of deliberate strategic management will be seen as failure from a population ecology perspective. Many SBFs simply have neither aspiration nor the necessary resources to become a fully integrated manufacturing company. Therefore they enter into strategic alliances, licensing their technology or products to large corporations. Such strategies allow for autonomy and flexibility, enabling the SBFs to respond rapidly to the ongoing changes that occur in the biotechnological industry, and instead concentrate their efforts on fulfilling the aspirations of their scientific work. Hence I find it fruitful to think of the small biotechnology firms as a project, or a portfolio of interrelated projects due to the nature of the strategies pursued by the SBFs in my data population. Therefore we also often see that biotechnology firms capitalize on their intellectual property rights, such as projects and patents before they have never shown profitable.

This project-oriented view of the business firm is in opposition to standard economic approach to the nature of the firm where the firm is seen as a more or less autonomous actor in a market with a stable number of employees working toward a shared vision or strategy. In the biotechnology industry it seems like there is market for interesting projects. Projects that are bounded to individual careers and professional identities in very different organizational settings and also over time shifting organizations, such as universities, small biotechnology firms, venture capital firms and large chemical and pharmaceutical firms.

The project strategy

> *"There are many research boutiques out there and many of them have been very successful within the biotechnology field. They apply a specific area of expertise to drug discovery and drug development to a certain stage before they license it to a pharmaceutical company or a very large biotechnology company"*
>
> Lisa Peterson, Incyte Pharmaceuticals

The project strategy has two different configurations; “the science boutique or research boutique” and “the one timer”. The destination of the company very much depends on the goals/aspirations of the company and the choice of “exit strategy”. The choice of exit has two aspects. It is a matter of how far the SBF are interested or capable to develop a certain project before selling or licensing the technology to a large pharmaceutical or chemical company. Secondly it is a matter of the portfolio of projects connected to the SBF. From point of the SBF, the project strategy implies two types of exits. The first form, the science boutique that is based on a strategy with multiple exits. The idea is that the company function as a science boutique, which contains of a continuous stream of interrelated projects, all for sale.

The second form, the one timer” is a strategy based on a single exit whereupon the founder(s) returns to academia, gets a new job as a consultant for the venture capital community or does whatever he or she wants. A precondition for the project strategy is therefore that the SBF over time build up networks and external partnerships to search for business partners that are interested in building up biotechnological competencies into their organization. The acquiring organization afterwards takes responsibility of the resource demanding activities concerning the product approval, the sales organization, marketing activities and the distribution of new products and processes.

Since the knowledge of the technology almost solely belongs to the developers in the organization. The most interesting managerial problem concerning the project strategy is how to keep the key personal and how to manage and prioritize the human resources in between projects. If the SBF follow the “one timer” sub strategy it is important how the SBF are implemented into the acquiring organization. Otherwise the risk is that the developers/the scientific people leave the company, which imply that the acquirer will gain nothing from buying the SBF. This particular problem has been solved by letting the small biotechnological firms stay at their location, and from that point serve the pharmaceutical company as a almost autonomous research unit with the distinct aim to develop and apply biotechnology that can be transformed into new products or new production processes at the large company.

From the point of the science boutique the important problem are even more complex due to the problem that they often have to sell key personnel as part of the project sales. Thereby the network activities prior to the formal project sales serves as transformation of knowledge in between the organizations allowing the acquiring organization to build up the necessary competencies before they acquire or license a new technology from the SBF. Thus allowing the SBF to keep their key personnel in house. For this reason it is impossible to discuss network activities, project sales, and licensing agreements in the biotechnology industry without having a discussion in general on the development of mutual trust relations in these network arrangements or pilot projects between the SBFs and the large pharmaceutical companies. The second managerial aspect of the science boutique has to do with the confusion related to the ongoing development of new projects that imply that the SBF constantly has to reorganize it activities leaving the firm with a the problem of finding new opportunities/projects for the people in the organization in order to satisfy their aspiration.

A successful Danish biotechnological company, Kem-En-Tec, has followed the project strategy as a science boutique since the firm was founded in 1983. In beginning of 1998 the company have created a consecutive number of successful exits leaving the firm with the problem not having new promising projects to replace the old projects. At the same time the company had to let some of their key personal to go to the acquiring company. Now one would imagine that the company were a about to close, but interesting things happen when you have been successful in the biotechnological industry because successful SBFs earn reputation and become role models for the next generation of biotechnological firms. Therefore the company now is getting offers from scientists all around the world asking the small Danish SBF to develop and finance their ideas. This means that the company recently have been transformed from being a traditional biotechnological company into a highly advanced research boutique combining the skills of a venture capital firm, selecting and financing promising technological projects, with the role of a science park, offering managerial knowledge and laboratory facilities in order to create new interesting exits.

The incremental strategy

The incremental strategy resembles the project strategy in the sense that it at a looks alike the science boutique. Nevertheless, this strategy diverges in that the long-term goal of the firm is to develop a basic research project into a finished product. SBFs pursuing the incremental strategy develop projects with the distinct aim to enter into strategic alliances with sectors such as manufacturing, clinical testing, and marketing and sales. This can be regarded as a pure learning strategy, where the firm gradually develops toward becoming a vertical integrated firm, incrementally assuming control over an increasing number of functions along with expanding its internal skill base. Thus, the long-term goal of the firms is to free itself from resource dependencies, especially from the venture capital community to achieve autonomy over its own destiny.

The major problem concerning the incremental strategy is that the SBF have to rely the established strategic alliances with the large pharmaceutical firms. Whereas it was the entire goal of the SBFs to sell off projects in the project strategy implying that if a company was not interested in buying the technology then it was a matter of finding other interested partners. This is not the case with the firms following the incremental strategy. Their goal is not to sell their assets, but instead to build up strategic alliances or licensing agreements where the partner should be willing to take care of certain functions that the SBF does not have, the resources, the skills, or the short term interest in taking care of themselves. These kinds of networks are by nature much more formal that means that the SBF have are left with a major problem if a certain partner withdraw from the partnership.

Therefore the SBFs that are following the incremental strategy have to develop very flexible organizational forms in order to adjust to the changing conditions. Some firms adjust to the go-stop-go nature of the activities by hire and fire the personal. Other companies have developed some informal agreements where the companies in crisis can lent human resources for a period of time to SBFs that have much to do in order to reduce cost. Such an informal agreement was established with a whole range of SBFs located in the Chicago Technology Park. The great advantage is that the company can keep their key personnel. Whereas the lending company knows in advance that the people that they hire have both the knowledge about the firm and the skills needed because they almost live next door and thereby know of each others problems on a daily basis due to the collaborative nature of the environment.

The vertical integration strategy

Only a few of the SBFs that I visited were driven by a strategy of becoming vertical integrated firms which are in control of product development, procedures for clinical testing, manufacturing, marketing, and sales. Thus, a common trait of the SBFs that pursued this strategy was that they has established themselves from a R&D project, which they spoke about as “core technologies” (process technologies or process innovations). In most cases this involved the development of a specific process or technique from which a variety of products could be produced and developed. Therefore they establish themselves as a kind of consultancy service, selling knowledge. This consultancy service then has three functions: 1) to improve the financial situation of the SBF by securing a stable income and to avoid that the initial investment is the only financial source; 2) to demonstrate to future customers, that the company possesses the required skills and competencies, and therefore should be recognized as a legitimized partner in the biotechnology industry; 3) to broaden the technological scope of the company by getting access to work with large scale process technologies or product development activities in external organizations.

In relation to the two former strategies pursued by SBFs the vertical integration strategy can be seen as a successful last step in a developmental process. The SBFs ability to control all activities has two very important and primarily managerial implications. The SBF should be capable of going from being a very small and family like organization with very few employees concentrated on very few scientific skills to be a large multiple-project and multifunction organization with 300-500 employees with very diverse skills. Secondly, as the company takes over more functions the number of networks that the SBF has to serve and engage in multitudes. Implying that the management no longer can be involved or have the overview of the establishment of external networks. If therefore the idea that strategy and the individual networks established at the lower levels of the organization are two sides of the same coin in the biotechnological industry the management has to implement managerial tools in order to filter primary and secondary networks. Moreover the management has to find ways to motivate and legitimize network formation at all levels of the organization in order to keep up with customers, research, and the financial investors.

The strategies of the chemical and pharmaceutical firms

One must question the motive or the strategy of the large pharmaceutical and chemical firms when buying new technological projects from a small biotechnology company. The short answer is that the large companies through the acquisition of small biotechnological firms or biotechnology projects from SBFs does so either to get access to the state of the art technology to develop new products. Another reason is to be able to control the new technology in order to keep competitors away from the technology. A technology that the competitor also can get access to if they can enter into an alliance with the small biotechnological company.

The general feeling among biotechnological entrepreneurs is that until recently large pharmaceutical and chemical companies have been very conservative toward new biotechnologies. The pharmaceutical firms seem to have been pursuing the strategy of the late observer and now are willing to pay a high price in order to catch up. Large well-established companies have build up biotechnological competencies by buying SBFs or licensing their technologies and products. Hoffman Laroche bought Genentech, and Bayer has established a strategic alliance with Viagene. Companies in my population such as the North Carolina based firm, AndCare[2], was in the process of finding strategic partners to handle the manufacturing and marketing of their lead poison test kit. These examples show an interesting path. First of all, SBFs leave authority to others over activities in which they are neither interested nor possess the competencies to handle. Second, pharmaceutical firms' competencies in manufacturing technologies/process technologies, such as fermentation, and skills in marketing distribution give them a great advantage compared to SBFs. Third, the large pharmaceutical firms have difficulties in managing the exploitation of new technologies. Internal problems and resistance to change may be the primary reason for their late observer strategy.

In my view, the pharmaceutical companies suffer from the "divisionalized forms disease". Political conflicts between divisions make it very hard to make decisions and priorities between the corporate divisions. Moreover, it is very difficult to find "product champions" within the large corporation that are interested in taking the risk of internalizing uncertain new technologies into his or her corporate unit. The reason is that if implementation of the new technologies fails, which it most likely will, this endeavour will cost the responsible manager her job and career in the industry due to the nature of the reward and promotion systems in these organizations.

The pharmaceutical industry has responded by managing their technological change processes through joint ventures and acquisitions of small biotechnological firms. Isolating the innovative units in relatively autonomous divisions has done the incorporation of new ideas into the existing structure extremely difficult. Thereby, the companies deliberately have avoided taking decisions about how to explore and exploit these new technologies across the organization (March, 1999). If large firm do not integrate their acquisitions, there is little reason to believe that they will be able to utilize the innovative potential. Therefore, if large corporations are to benefit from their huge investments in SBFs, they will have to follow up internally and try to develop new forms of cross-

[2] AndCare changed their name to Alderon Biosciences by the end of 2001.

organizational learning. Otherwise, biotechnological units will live their own lives and only be perceived as components necessary for showing external stakeholders that the companies have taken steps to implement the new biotechnological disciplines. The question is how a rigid organization can manage and secure that scientific developers will stay with the company when their autonomy over research and development projects diminishes and simultaneously preserve the creativity necessary to develop an innovative climate?

Viable strategies in a volatile world

In the concluding part of this paper the role of the small entrepreneurs in the biotechnological industry has to be discussed because my results shows that small business plays an important role in the creation of the new technologies. The role of SBFs have been to define an technological area that large companies are too rigid to find or engage in. From that point the SBFs have made themselves attractive for the large companies to invest in through joint ventures, strategic alliances, licensing agreements and buy outs. Due to technological, lack of competencies and financial resources the SBFs cannot take care of all aspects of turning of research project into a finished product or process. Thanks to profound insight into the history of technology and trial and error learning the small firms have been able to overcome the critical mass problem through strategies that mobilize the necessary knowledge, skills and financial resources in external networks. This has led the small biotechnology firms to hand over ownership of the technology and management authorities to venture capital firms. The majority of entrepreneurs have also given up trying to become vertically integrated firms. Instead they have formed licensing agreements where a large company produces and markets their products and services. This is not only due to the lack of skills and competencies in these areas, but also a result of the investment and exit strategies of the venture capital firms that normally will stay no more than 3-5 years with a single investment. Sales are either done through public stock offering or the small biotechnology firm is sold to one of the large chemical or pharmaceutical firms that has entered into biotechnology over the last couple of years.

But what is left of the corporate independence? Has the small biotechnology firm given up the authority over the most important and interesting aspects of setting up a new business? From a classical economic point of view the answer is yes. There is nothing left. However, such an explanation cannot come to grips with the opinions of the entrepreneurs. From the perspective of the entrepreneurs, it is the basic idea of the company that has their interest. The basic idea is a term used without any relations to the profit or the managerial aspects. Instead the basic idea is a notion that relates to the development aspects of the basic knowledge behind the products and techniques that the firm is exploring and exploiting.

A theoretically based explanation of the nature of the biotechnology industry and the behavior of the small biotechnology firms will fit into a resource dependency approach (Pfeffer & Salanzick, 1978; Pfeffer, 1987). Biotechnology firms are responding to external problem through the development and formation of networks to other stakeholders in biotechnology. These formative arrangements are allowing the companies to remain in control over the development of the core technologies, but at the same time they are handing over authority of parts of the company in which the founders are not interested. This calls forth a system of stakeholders in the biotechnology industry that has both the interest in and the competency for taking over the functions that are left out.

Appendix 1: Data collection and research method

The empirical data consists of 54 interviews with people from the biotechnological community in the San Francisco Bay Area, San Diego, Boston, New York City, Chicago, Research Triangle Park, North Carolina and Copenhagen, Denmark.

Table 1:
Geographic Distribution of Interviews

Boston	7
Chicago	6
New York City	3
Research Triangle Park, NC	9
San Diego	4
San Francisco Bay Area	17
Copenhagen, Denmark	8

Table 2:
Institutional Background of Informants*

Small Biotechnological Firms	42
Research Parks	3
Universities (Licensing Offices)	7
Public and regulatory bodies	6
Venture capital firms	6

The interviews were conducted in three different periods. The first series of interviews were held over a period of 8 months in 1993-94. The second phase took place in late 1997 where only small biotechnological companies were visited. The third phase took place by the end of 2001 where updating of the companies strategies was done through phone interviews in five SBFs. Empirical data further consists of written material, such as company presentations, annual reports, corporate homepages, and corporate prospectuses. Moreover my data consists of Federal and State R&D Programs in biotechnology, and reviews of industrial related journals on biotechnology, such as all volumes of Genetic Engineering News from the 1970'ies to 1994.

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* The numbers of interviews exceeds the actual total numbers of interviews since some of the informants belong to more than one category.

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Financial and strategic aspects in knowledge-based entrepreneurial firms - Focus on the biotechnology industry

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This paper contributes to the discussion of how knowledge-based entrepreneurial firms can obtain funding for their business ideas and create a sustainable competitive advantage on their market. Venture capital firms have specialised in financing these new firms, but there are many ways in which a co-operation between the two can go wrong. An in-depth analysis of the two is therefore required to understand how a fruitful co-operation can be developed. Is this done successfully the foundation for value creation through a sustainable competitive advantage is created. My working thesis is therefore:

> "How is a fruitful co-operation secured between a knowledge-based entrepreneur and venture capital?, and what sub-questions has to be answered so that the newly created firm is able to sustain and secure value in an environment characterised by high uncertainty"

The method used to answer these questions is mainly found through relevant economic theory such as the principal-agent theory by Jensen & Meckling (1976) and the resource-based theory by Rumelt (1984) and later by Makadok (2000). Further different empirical research mainly around the biotechnology industry will be used to support my arguments. To set the theoretical findings in a practical light I have also conducted two interviews, one with the venture capital firm BankInvest Bio Venture and one with the founder and CEO of the entrepreneurial biotech firm CMC Biotech A/S. These interviews have disclosed helpful information in support of my general findings.

Box 1

New knowledge-based entrepreneurial firm

- Scientist with an idea that has possibilities
- Large R&D expenditure
- High uncertainty of R&D outcome
- No income due to no products on the market
- Years before break even

↓

Capital needed

Box 1 shows the characteristics of new knowledge-based entrepreneurial firms. Usually a scientist develops an idea and if the possibilities in this idea are good the new entrepreneurial firm is born. The foundation on which the idea is created typically demands further research and development. This is costly to the firm and because the firm is new and therefore has no income from already existing products, the need for capital is very high. Possible investors face a complex situation. The new knowledge-based entrepreneurial firm is based on research and development (R&D) and therefore a high level of uncertainty is associated with the outcome of this R&D. Added to that, the time horizon before the new knowledge-based entrepreneurial firm reaches a break-even point is very long (usually 3 to 10 years) so large capital infusions are needed.

This brings me on to the characteristics of the venture capital. This kind of capital is suited for investments in these uncertain environments. The supply of venture capital has increased significantly over the years as disclosed in box 2. Venture capital firms supply an equity financing solution to new knowledge-based entrepreneurial firms. This course is taken so the risk of investment is reflected in the ownership stake the venture capital firm demands. The higher the risk of investment in the new knowledge-based entrepreneurial firm, the larger ownership stake is demanded by the venture capitalist.

Box 2

Venture Capital – active capital

- Capital segment increases (US$ 177b in 2000 – US$ 41b in 1995)
- Early investment in firms
- Equity finance, large ownership stakes due to large riskVenture capital provide (besides money)
  - – Specific knowledge about an industry
  - – Knowledge about starting and managing a new firm
  - – Management
  - – Contacts and signal value

Venture capital firms differ compared to other financial institutions because they provide more than just money. They also provide specific knowledge about the industry and about starting and managing a (new) firm. Venture capital firms also tend to be involved in the management of the new firm, and they supply contacts in the market that are favourable for the new knowledge-based entrepreneurial firm. Lastly the involvement of a venture capital firm gives a positive signal value to the market hereby making it easier for the new knowledge-based entrepreneurial firm to obtain further funding.

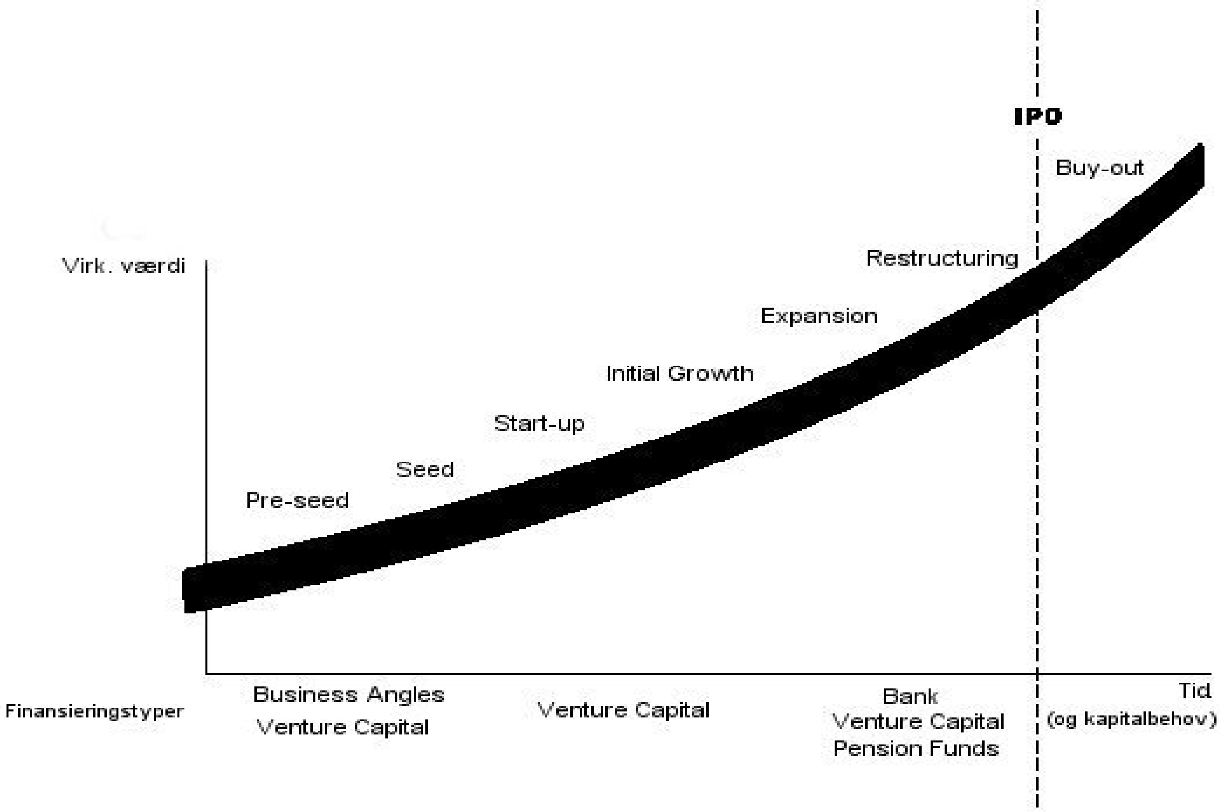

Figure 1 Types of financing in the growth cycle of the firm

Figure 1 gives an overview of the types of funding available to new knowledge-based entrepreneurial firms depending on their age (time on the market) and their capital needs. More traditional financing types such as banks will not get involved in these firms before the uncertainty of their product outcome is significantly reduced and the firm is in a relatively good and stable market position.

The relationship between the venture capitalist and a knowledge-based entrepreneur can be described through the principal-agent theory. In this framework, the venture capitalist is considered the principal and the entrepreneur is the agent. Due to the high uncertainty levels that exist in the co-operation between the knowledge-based entrepreneur and the venture capitalist the existence of agency costs is significant. These agency costs are described in Box 3.

Box 3

New knowledge-based entrepreneurial firms have large agency costs due to:

- Entrepreneurial actions
  - – Adverse selection (hidden information - before)
  - – Moral hazard (hidden action – after)

- Asset characteristic
  - – Intangibility
  - – Specificity
  - – Future growth options

The agency costs can be divided into the actions undertaken by the entrepreneur (the agent) and the asset characteristic of the firm. The actions undertaken by the entrepreneur can be divided into adverse selection and moral hazard problems, both related to the asymmetric information problem. Adverse selection is the situation where the entrepreneur does not disclose all relevant information before a contract is signed and therefore benefits personally afterwards. Moral hazard is the situation where the entrepreneur does not act on relevant information after a contract is signed also due to personal benefits, such as personal recognition in the scientific environment.

The asset characteristic of new knowledge-based entrepreneurial firms is also a large contributor to the agency costs involved in a co-operation between a knowledge-based entrepreneur and a venture capitalist. As discussed by Gompers & Lerner (2000) the assets in knowledge-based firms are usually specific and intangible. Further more the foundation of the knowledge-based entrepreneurial firm is built on future growth options that may or may not be valuable to exercise. These asset characteristics lead to larger agency costs.

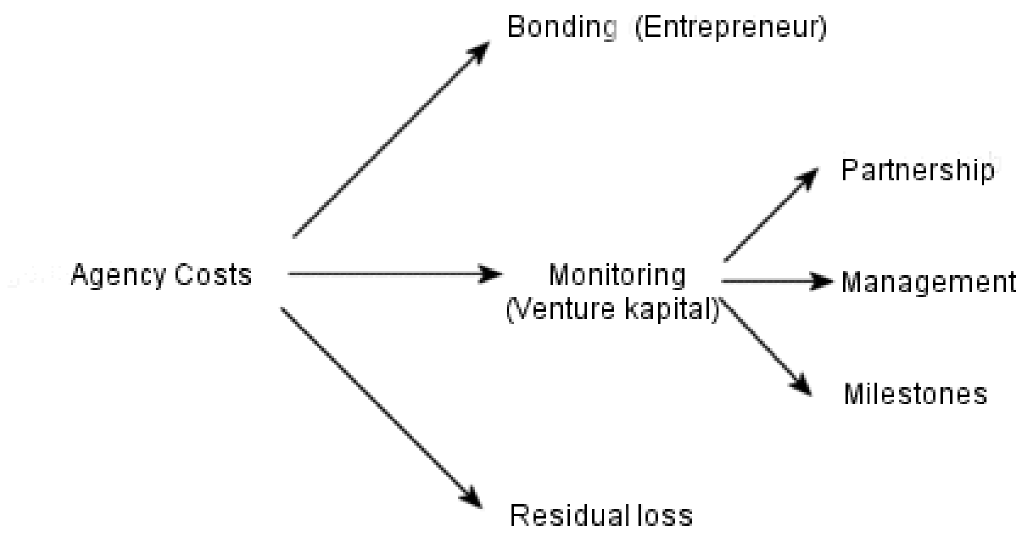

Figure 2 How to minimize agency costs

It is naturally in the interest of the venture capitalist to minimize these agency costs. This is shown in figure 2. The venture capitalist actually profit form the asymmetrical information and uncertainty because they have means of controlling new knowledge-based entrepreneurial firms that other financing types does not have. It is of course in the interest of the venture capitalist that the actions of the entrepreneur are in the overall benefit of the firm, hereby minimizing the agency costs. Agency costs are associated to three different areas.

Bonding costs are actions taken by the entrepreneur in order to align own motives to those of the firm. These are not very reliable due to lack of sanctions if they are violated.

Monitoring actions taken by the venture capitalist are the best method for minimizing agency costs, and this is where venture capitalists have an advantage over other financing types. Firstly they can make a partnership with other venture capitalist hereby getting a second and/or third opinion about the project of the new knowledge-based entrepreneurial firm. Secondly, venture capitalist involvement in management of the new knowledge-based entrepreneurial firm are of great value, since they can monitor the firm "from the inside" and also be an influential factor when important decisions are taken. Thirdly, contracts incorporating milestones is an important way for the venture capitalist to secure that the actions of the entrepreneur are in coherence with those of the firm. In milestone-contracts there are built-in motivation factors for the entrepreneur to act in the overall benefit of the firm. The entrepreneur will obtain a relative larger ownership stake through warrant-options if certain goals/milestones are achieved. Economic literature also emphasizes that the best way to achieve commitment to a project is through motivating contracts and ownership and this is precisely what milestone-contracts do.

The last area that describes agency costs is the residual loss. This loss is the difference between the situation where the agent acts as the principal desires and the situation where optimal bonding and monitoring actions are taken.

Box 4

The strategy aspect

- The human aspect sets the foundation for value creation in knowledge-based entrepreneurial firms
- The venture capital makes it possible to create value in knowledge-based entrepreneurial firms
- The strategic aspect secures value to the knowledge-based entrepreneurial firms through reation and protection of the firms competitive advantage

Box 4 shows the three aspects on which the paper is made. The human aspect sets the foundation for value creation; the financial aspect secured by venture capital firms makes it possible for the new knowledge-based entrepreneurial firm to create value. The strategy aspect of new knowledge-based entrepreneurial firms is the cornerstone of this paper, since it is through the strategy of the new knowledge-based entrepreneurial firm that value is created and secured through the creation and protection of the firms competitive advantage. Strategic decisions are taken both in the decision process of the venture capitalist and in the new knowledge-based entrepreneurial firm. They are equally important since they are dependent of each other. Box 5 describes the strategy aspect in the venture capital firm.

Box 5

The venture capital strategy

The decision process:

- Screening the business ideas, focus areas:
  - – Management
  - – Attractiveness of industry
  - – Market size
  - – Returns on investment
- Exit strategies
  - – IPO
  - – Buy-out / spin off

When a venture capitalist is to make a decision of whether or not to get involved in a new project, it has to rely on a strategy for choosing between different investment opportunities. In screening between different business ideas four factors are of importance to the venture capital firm. Firstly the management has to be reliable – this can be shown through their previous jobs, education and initiatives. Secondly the attractiveness of the industry is important, and thirdly the market size has to be significant large so the scale and scope advantages can be applied. Fourthly return on investment is important for the venture capitalist when deciding on involvement in an investment opportunity. All factors are more or less interlinked, but it is emphasized that the venture capitalist will rather support a B business idea with an A management team than an A business idea with a B management team. Management of the business idea is seen as the single most important factor if two investment opportunities are similar.

The venture capital firm also has to decide on an exit strategy for the investment. The most favourable way for a venture capital firm to exit an investment is through an initial public offering

(IPO). This is not the most likely outcome, so usually the venture capital firm exits through a buy-out from more traditional investors or different parts of the firm is split up and sold of in pieces.

This leads me to box 6 that describe the strategy aspect in the new knowledge-based entrepreneurial firm.

Box 6

Strategy in the new knowledge-based entrepreneurial firm

- building a sustainable competitive advantage

– No check list
– The resource based theory
– Economic rent (profit)

– First move advantage
– Lead time

When a venture capitalist has made a commitment in a knowledge-based entrepreneurial firm, the formation of the strategy in the firm is very important for it's value creation. It is not my plan to make a checklist for what is good or bad for new knowledge-based entrepreneurial firm because of the fact that many individual aspects have influence on this. But it is possible to create a framework for the strategy of new knowledge-based entrepreneurial firms. As box 6 shows this framework is developed through the resource-based theory and an economic rent argumentation. The economic rent concept is used to measure the success of new knowledge-based entrepreneurial firms since this concept is not influenced by different types of calculation features and various measures such as the profit amount in the financial statement is.

Through a discussion of the economic rent concept (rent seeking) it is shown how a new knowledge-based entrepreneurial firm can enter a market and build up a sustainable competitive advantage. There are some general decisions that can be taken to improve the stakes of success of the firm. These include a first mover advantage and the amount of lead-time the new knowledge-based entrepreneurial firm is able to have on the market. From a resource-based theory point of view my conclusions are added up in figure 1.

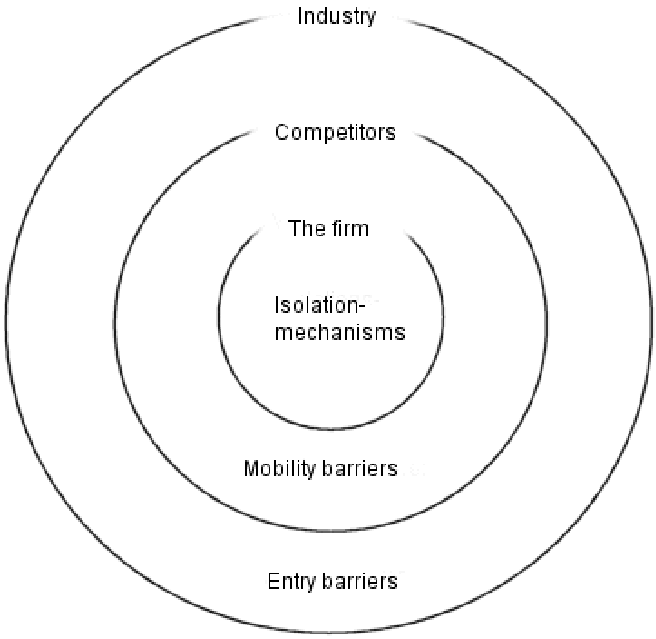

Figure 3 Strategy in the new knowledge-based entrepreneurial firm - building a sustainable competitive advantage

The new knowledge-based entrepreneurial firm has to use its isolation-mechanisms so a unique entity is created. Examples of isolation-mechanisms can be the skill-set in the firm, the capabilities and special resources in the firm, the education and learning of the workforce, patents and reputation of the firm. The isolation-mechanisms creates "casual ambiguity" and market power for the firm, that is, the isolation-mechanisms creates an entity that is hard to imitate for other competitors, hereby keeping the initial firm in a favourable market position where it will be able to build a sustainable competitive advantage through access to economic rent. These isolation-mechanisms create mobility-barriers within the industry, which makes it hard if not impossible for competitors to acquire or imitate the internal resources and capabilities of the firm.

This also leads to the creation of entry-barriers. If a firm is capable of creating "casual ambiguity" and develop mobility-barriers as it grows, it will also create entry-barriers. This means that a situation is created where other firms are deterred to enter a market because of the position and market power the initial firm has created. They are scared of making the high specific investments required to be a player in the market. This again leads to the firm being able to sustain and further develop its competitive advantage on the market through access to economic rent. The firm has through its capabilities and resources built a "winning team". As the firm develops and grows these entry-barriers are further extended.

Box 7

Strategy in the new knowledge-based entrepreneurial firm

- building a sustainable competitive advantage

- Isolation mechanisms (internal organisation)
- Casual ambiguity and market power
  - – creates mobility-barriers between competitors
  - – Deter other firms to enter the industry through entry-barriers
- Motivation through
  - – Ownership
  - – Incentive contracts

Box 7 adds up my results. The creation of mobility- and entry-barriers through isolation-mechanisms is not an easy task. But the task is made easier by motivating the workforce to act in line with the interest of the firm. This is best done by giving ownership to the entrepreneur and other leading people in the new knowledge-based entrepreneurial firm and extending this as the firm grows. Creating incentive contracts to the workforce in the firm is also a way to motivate the workforce to act in line of interest with the firm. Together ownership and incentive contracts can be an effective way for management in a new knowledge-based entrepreneurial firm to build and develop isolation-mechanisms. Hereby mobility- and entry-barriers are created making it possible for the firm to sustain and develop a competitive advantage through continuing access to economic rent.

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Strategic behavior in Medicon Valley

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Introduction

This paper is about the biotechnology field – Medicon Valley[3] – and the strategic behaviour of its research firms. The relation between a firm's external context and its strategy is the focus in many theories. I am particularly seeking an understanding of the relationship between the surrounding context and the strategy of the firm. Thereby my analysis is focused on a analytical level with the actor >< structure correlation in the centre for my view. It has the effect that I analyse the external context in structures and not process and the actor as one organisation and not persons.

My theoretical point of departure is the meta-theoretical perspective – Industrial Sociology, which I use to simplify my way in the "safari" of strategy theories. In my study, I use the Business System (Whitley 1992A, 1992B, 1994, 1996) approach as my conceptualising theoretic tool that is providing categories for my regard to on the external context. This theory is explaining the relation between the organisation and the external context as the "*institutionalisation of successful principles of organising"* (Whitley 1992A:6), which means that the strategic behaviour of the firm is shaped as a negotiation with forces from inside and outside the firm. The actors and their external boundaries are formed with the help of Resource Dependency (Pfeffer & Salancik 1978) and I use the Networking approach of Norus (2002) to understand the communication and coordination in the biotechnology field.

A common point for the theories is the ability not to predict my empirical meeting, thereby making the analytical process a co-operation between my theories and my empirical observations. That's the reason why I use the biotechnology field of Rhône-Alpes as an empirical perspective making my understanding of strategic behaviour in Medicon Valley more profound.

The construction of the article
A short empirical introduction to both biotechnology fields is necessary to create an empirical framework that is providing understanding for the different ways of organising. The organising of the Medicon Valley is the primary analysis, but as mentioned its conclusion is confronted with the conclusions from a similar study conducted in Rhône-Alpes. This empirical challenge makes it possible to draw individual conclusions for Medicon Valley.

The biotechnology fields

Medicon Valley
The historical background is important in comprehending the case of Medicon Valley and three similar stories make a good fundament for understanding the evolution of Medicon Valley. The first is about the infrastructural regional development and how the fixed connection between Denmark and Sweden became a reality. The fixed connection between Denmark and Sweden has always been of international concern and one of the first propositions concerning a bridge, came from a French consortium in 1886. The bridge was seen as a part of a European railway-system, managed by the French consortium, but the Danish and Swedish government didn't agree and wanted to build the bridge by them self. (Wendt 1979) This decision didn't stop the propositions of different ways of fixed connection through out the 20th century and in 1993 the Øresundsbroen[4] was decided. (Tangkjær 2000)

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[3] Medicon Valley is the biotechnology field situated in the Øresund Region. That is the southern part of Sweden: Skåne County and the eastern part of Denmark: Zealand and Bornholm. In the region there is approximately 100 biotechnology companies and a couple of producing and marketing pharmaceutical companies, like Novo Nordisk, Novozymes and AstraZeneca. (www.mva.org).
[4] A combined bridge and tunnel from Malmö to Copenhagen.

The second story concerns the existing pharmaceutical competencies, which made it possible to pinpoint biotechnology as a regional speciality in the search for an industrial identity for the Øresund Region. In the latter part of the 19th centuries the pharmaceutical starts with the founding of LEO on the basis of a Copenhagen drugstore. In 1908 they began the production of Paraghurt – still for sale – and today it's the third largest Danish pharmaceutical company. (leo.com) On the other side of Øresund the Swedish part of the 1998 merger AstraZeneca – Astra – is founded in 1913 and during the 20th century Astra's research, development and marketing efforts were focused primarily on pharmaceutical products in four main product groups: gastrointestinal, cardiovascular, respiratory and pain control. (astrazeneca.com)

The presence of the private pharmaceutical competencies already showed its effectiveness in 1923, where H.C. Hagedorn and August Krogh decided to use the expertise of LEO to start their production of insulin. They had the choice of doing it with governmental support or creating their own company, but chose to benefit from the know-how of LEO. This was the start of Novo Nordisk and Denmark's position as one of the worlds leading insulin-producing and -researching countries. (Deckert 1998)

The third is an international perception of biotechnology as a socio-economic tool, making it possible for politicians to create societal development through the promotion of biotechnology. It started in USA in the beginning of the 8o and came to Europe some years later and created a series of governmental programmes. (Norus 2002)

When the two stories meet with the socio-economic story in 1993 talks about Medicon Valley went into a debate with a realistic focus. Today there are approximately 100 biotechnology firms in the region and the networking organisation of the region – Medicon Valley Academy – has the vision of creating the leading knowledge region in Europe 2005. (mva.org) During the last three years the venture capital environment has evolved into a large and hungry capital supplier and the region has been apple of attracting large foreign Venture Capital companies like 3i. (Pedersen 2001) Both producing pharmaceutical companies like Biogen and researching start-ups like Genmab has chosen Medicon Valley as the environment for their further expansion.

That gives a indication of the context of Medicon Valley: strong governmental support through programmes involving the universities and strong existing industrial competencies has made it possible to attract venture capital companies.

Rhône-Alpes

Strong industrial competencies are also characteristic for this region and they are going back to the seventeenths century, where Lyon was a European centre of trade because of geographical position and its two joining rivers – The Saone and The Rhône. This position made Lyon a centre for the European silk-industry and as a consequence a supporting textile-industry grew. (Museé des beaux arts 2001) Later on, the chemical industry of colouring the silk turned in to both a chemical and a petro-chemical industry, which was the foundation for the creation of Rhône-Poulenc.

Lyon is the second largest city in France and has a large educational system, which has evolved together with the expansion of the industrial competencies. Similar the local chamber of commerce has made the same evolution. The local chamber of commerce is administrating the local airport, the railway station and has a long tradition of supporting new companies. (Jolly 1995) This is example of the influence of the chamber of commerce, which is making and governing the local industrial policy.

France had, during the late eighties like Denmark, governmental programmes supporting the development of biotechnological industry whether as dedicated start-up or as a supplementing process technology for traditional industry. (Jolly 1995) In that respect the two region has similar point of reference. The region has a networking organisation, as a direct consequence of the governmental efforts in the eighties. Arteb is financed by the local department and the city of Lyon and has approximately 175 members including universities, hospitals and the supporting service industry. (Arteb 2001) It's important to notice the difference in the networking organisations vision. Arteb wants to promote and further advance the synergy between knowledge, capital and business – a vision without a clear goal but an acceptance of the difficulties in deciding when a biotechnology field is successful.

Now I have introduced the two regions historical and present context and will go further into detail with the characteristics of the strategic behaviour in Medicon Valley. It will be an analysing description of the common strategic behaviour in the three firms, where I conducted my interviews.

Medicon Valley

The pharmaceutical inspiration
I am going to divide this section of the article into four smaller parts as a part of my use of Business System. In this theoretical approach the first analytical point is the actor in an economical perspective raising the question of ownership, financing of daily activities – the research. This point is concerning the economical control with the company and linking the way of ownership together with the principles of organising. The next analytical focus is exclusively external and is concerning the actors relation with the market and which kind of mechanism that regulate the behaviour of the firms. Third and final is the internal co-ordination and control mechanism important since the main point is to create a connection between the external and internal context. (Whitley 1994, 1996) I will at the end conclude my findings by a summery of my meeting with the Danish biotechnology field.

The Danish biotechnology firm specialising in research is a small, young company, which is very specialised in its main activity: scientific research. The age, size and main activity of the company are no surprise since it was criteria of selection. But the impressive specialisation is considerable symptoms of the field together with the large initial need for capital and the small, external context with few important players.

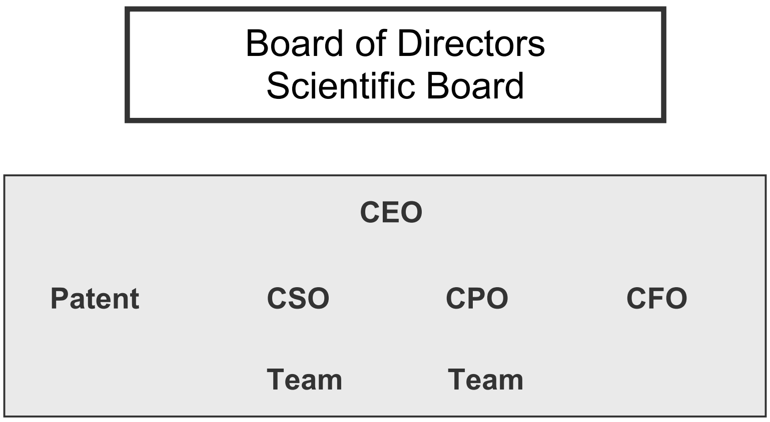

Figure 1: The formalised organisational structure in Medicon Valley

The organising of the activities is closely related to the way of organising research in the pharmaceutical companies. The small companies' board of directors and Scientific Board are one exception in structural way of organising because the pharmaceutical companies don't use a Scientific board to legitimatise their scientific capabilities. The managers have English titles and the areas of management are classical CEO, CFO, CSO and sometimes a patent-manager. The company is characterised by distance between the managers and the research, which is planned in formalised routines. There are no double positions among the managers, leaving the relation with the market limited, well considered and planned. That is a description, which summarise the whole biotechnology field.

A Novo way of organising
I will start with the company's role as economic actor in my description of the characteristics. The question of economic actor concentrates on the common way of ownership in Medicon Valley and the ownership is treated as both financing of daily activities and the direct ownership. In Medicon Valley the owner of the majority of the shares and the financier of the research is the same player: a venture capital company. Even though the company isn't listed on the stock exchange, the ownership is counted in shares. This double role as owner and financier gives the venture capital company a lot of influence in the way of organising the research and the management in the biotechnology field. That's a point, which is treated more closely when looking at the relation between the actors in Medicon Valley.

The main relation with the market concerns the main activity in the company – the research. With the separation between the managers and the research, then the researchers carry out the network of knowledge. This communication is characterised by a contractual terms, where the company bye a specific amount of consulting hours. The network of knowledge consists of experts from the universities and the hospitals, with each sorts of practical knowledge. The venture capital companies use their network of knowledge to validate the business plans and because the managers mostly are hired from the pharmaceutical companies, then they use the same network of knowledge. Being a scientific manager in a large pharmaceutical company, then you are surrounded by experts and you are not forced to build your own personal network of knowledge. Then you have a problem when you are starting up a company and the venture capital company use this position. When the company is using their experts then they have complex scientific control with the company.

The financial relations are few and limited to players with influence and this knowledge are the companies conscious about in their communication with their venture capital company. One example was the distribution of scientific results 14 days before a meeting in the board of directors. The combination of the double role of the venture capital company have serious consequence for the companies relation with the market because they're usually aren't created a traditional market yet. The relations are tied up to the company instead of a personal network and the content is capital and knowledge and I see this as the primary reason why the biotechnology field is relatively closed.

The venture capital company indirectly have influence on the control and co-ordination system inside the company. They want to minimise their risk when investing in biotech. A biotechnology investment is an investment in dreams of future profit because when investing in a future medicament, the calculation is based on a future need for a non-existing product. When minimising their risk the venture capitalist use the selection of managers as their primary tool. They seek managers, who have a record of experience in science management from a pharmaceutical company. The companies are designed to make specific research progress according to the goal mentioned in the business plan. And the companies' reliability is closely linked to the fulfilment of these plans, since it's one of the only measurable indicators.

The company is specialised in a very specific scientific area and the vision is to create a pipeline of medical product. The managers' co-ordinate and control that the "milestones" of the business plans are reached in proper time.

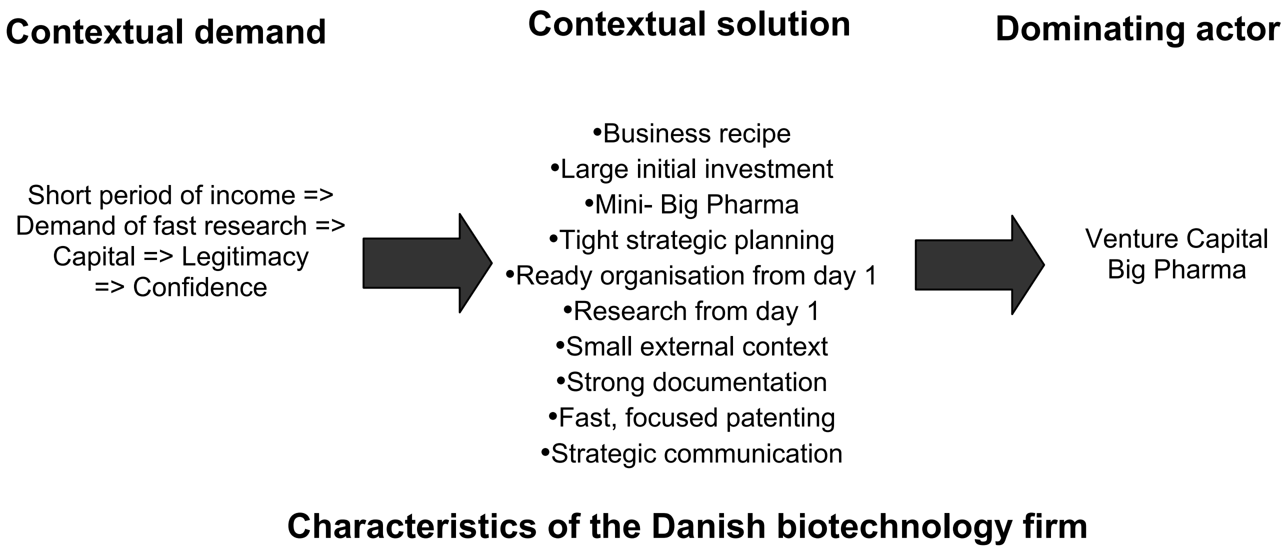

Figure 2: Characteristics of The Medicon Valley context, its solution and dominating actors

The figure is summarising how the Danish firm is responding in the negotiation with the external context. It's also showing how the analytical way through the context to the internal company is made and how this is used to pinpoint the dominating actors in the context. As a result of the relation between the context and the organisation, the management role in Medicon Valley has turned into being an experienced pharmaceutical manager with a scientific graduate degree. The managerial type is educated in the field by the field and not on a Business School.

This analysis of three dedicated biotechnology firms in Medicon Valley crystallise the direct dominating role of the venture capital companies and the indirect role of the pharmaceutical companies. When the pharmaceutical managers bring their organising principle with them, they are not creating "carpon-copy" companies but they are affecting the biotechnology field. The Medicon Valley is thereby very influenced by the pharmaceutical way of managing a biotechnology firm, making the region a Novo Region.

Rhône-Alpes

The university company
In the beginning of my French study my background knowledge wasn't satisfying and therefore I conducted additional interviews with the local chamber of commerce, the local networking organisation (Arteb) and two affiliates of Aventis. My French analyse is based on the study of two Rhône-Alpes biotech companies, which was selected under the same premises as the Danish ones.

The French biotechnology firm is also a small, young company specialised in research, but not as dedicated as the Danish one. And the organisation of the activities is influenced by the double role as CEO and CSO by the entrepreneur. The organising reminds of the way universities organise their research activities. The company doesn't have a Scientific Board, but keep the board of director as demanded by the French Law.

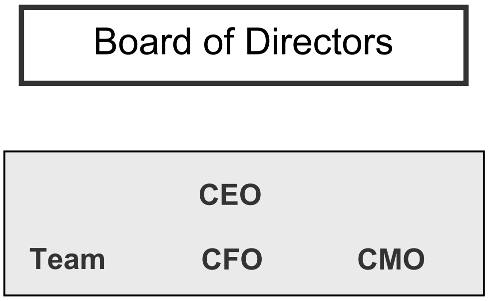

Figure 3: The formalised organisational structure in Rhône-Alpes

The company is partly owned by the entrepreneur and the venture capital Company with the entrepreneur as the majority owner. The entrepreneur isn't as dependant upon the venture capital companies advisor in the start-up phase, because of the chamber of commerce. They have traditionally taken this role in the important founding period, where many of the companies' routines are established. The French manager is educated on a Business School by the Business School, because the chamber of commerce own the business schools and thereby they are a part of the fields educating system. In this period the universities also play an important role because they provide cheap laboratories and thereby they allow the company to rest independent.

The relations with the market are again affected by the ownership, but in an indirect manner. The French entrepreneur can select its network of knowledge more freely than the Danish entrepreneur and it 's common that the entrepreneur use his existing personal network to establish his company's network of knowledge. The financial relation isn't that dominating because the relation is limited to capital and not the core activities of the company.

The management has, through the contact with the daily activities, relation with the scientist' and the CEO/CSO has around him managers of finance and marketing. The centralising way of organising is stronger in France than in Denmark, which is related to the university way of organising research. This is a clear example of the relation between the constitution of the external context and the organising of activities inside the firm. The control with the research isn't tied up in planned schedule like in Denmark. With the CEO in the laboratory, it's more informal and personalised. The focus is on another technology because the market focus is so present, which means that the external context becomes complex and larger. This technological question can have important implications and it's a point that I will treat in my conclusion.

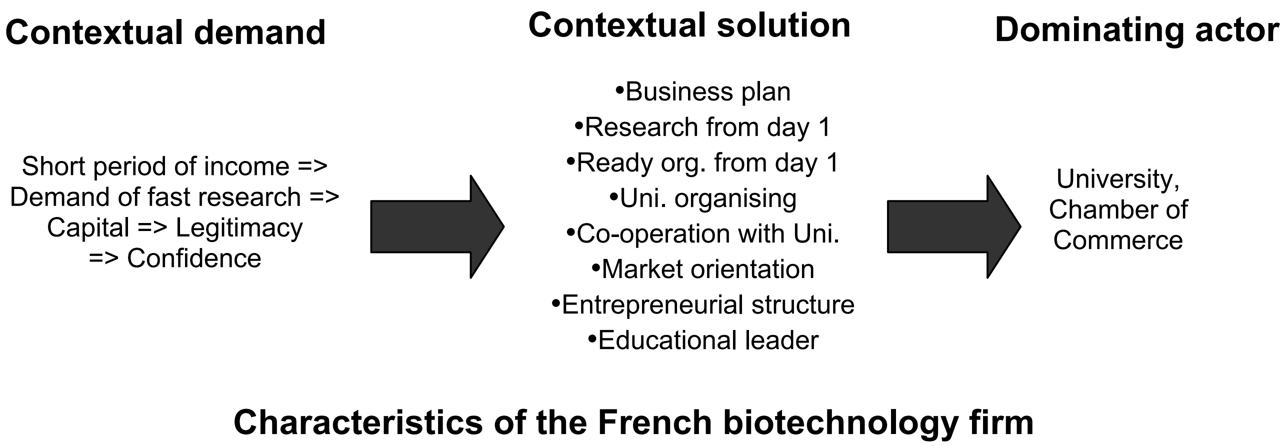

Figure 4: Characteristics of The Rhône-Alpes context, its solution and dominating actors

In Rhône-Alpes there is the same level of contextual expectations as in Medicon Valley but the contextual and individual organising solution are quiet different anyway. The French company is characterised by two dominant actors - the universities and the chamber of commerce. This design makes the context quiet different from the one in Medicon Valley and thereby the empirical perspective is going to be even better. I have used my theoretical tools to make the analysing description and now I will use my French empirical findings to understand the organising principle of Medicon Valley even better.

Conclusion

A Novo region

In figure 5 the differences are pinpointed and in comparison with Rhône-Alpes, Medicon Valley turns out to have a different entrepreneurial set-up. The real entrepreneur is the venture capital company and that has impact on the organising principle both inside the organisation and certainly also on the constitution of the biotechnology field. When I analyse the role of the universities in Rhône-Alpes, then one of the reasons why the venture capital companies have this dominating position is because of the missing possibilities of knowledge transfer from the university. Together with poor independent business support during the start-up phase, it explains the very influential position of the venture capital companies in Medicon Valley.

Differences

Medicon Valley	Rhône-Alpes
Professional	Entrepreneurial
VC = Entrepreneur	CEO = Entrepreneur
Only Research	Product and research
Pharma-research	Uni-research
Mgr. from Pharma	Mgr. from Business Sch.

Figure 5: Main differences between the biotechnology fields: Medicon Valley and Rhône-Alpes

As a consequence of the risk in biotechnology investment the venture capital companies seek to minimise risk through the selection of management. This is forming the managerial role as an organising principle in Medicon Valley and the traditional manager is graduated from the university with a scientific degree or even better a PhD. The experience as manager is achieved through on-the-job training in a pharmaceutical company making the manager educated by the biotechnology field in the field. When the manager is working at the pharmaceutical company, it isn't necessary to create an external network of knowledge and this is making the manager dependant of the venture capital companies existing knowledge network. The pharmaceutical manager introduce the pharmaceutical way of organising research – a formalised and planned way of research. Thereby the organising principles in Medicon Valley are on several areas similar to a pharmaceutical company.

I have used the Business System approach and therefore making the relation between the external context and the organisation a primary argument. But this form of analyse is weakened by the fact that the biotechnology concept is very difficult to define – for several different academic disciplines. Also for the Industrial sociology, it makes some analytical problems. In the comparison of the different ways of organising and strategic behaviour, another explanatory fact could be the technological aspect. Is the organising principle linked together with the specific technology? Are the patterns of development better for a specific technology, when using a specific organising principle ? That will give the different biotechnology field different organisational and strategic identity and would be a considerable area when comparing biotechnology field.

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Managing complex research on the boundary

Mette Mønsted - Copenhagen Business School, DK

The point of departure in the analysis of management and leadership in research as well as in R&D is the lack of certainty, transparency and the asymmetric knowledge of the technical aspects of the projects. The usual issues of planning and management in well defined projects are hard to apply directly, and have to be supplemented in some way to adapt to the fuzzy environment, highly complex, technical uncertainty and often a time pressure, where the usual linear project management has to be replaced by other simultaneous developments. This is valid for biotechnology as well.

Small and new firms do not have management in the normal sense. They have to establish a network and create a networking behaviour, generating "the meaning of management" in their network. They do not start by having specified roles, and this makes the networking as action very important. Networking is a self-organising type in which the new small high tech firms develop projects. It is impossible to understand these firms without their networks. Tight and loose relations and the combination of these create the organising set-up, the infrastructure in which confidence has to be generated in order to create a positive experience to develop more trust and more positive reference points via the primary network (Johannisson & Mønsted 1997, Mønsted 1998).

What is management in research?

The question is what is management and steering, 1) when the manager does not know, 2) when there is a high level of uncertainty and complexity, when 3) power is negotiated between persons or firms. Some of these issues are also valid in other industries, but so much more important in advanced research and development in both biotechnology and in IT, where a learning process and regular evaluations of findings and methods make decisions very important at times, where the knowledge is meagre.

Leaders may know the methods and try to hold the strings, but the problem is defining what you do not know to other people, to search for possible means or solutions, even if at an early stage the problem definition is vague. It's a nightmare of managing anarchy in a "*both hierarchy and not, and both strong accountability and loose accountability*" (Hastings 1993, p. 159). This has to lead to some kind of project manager role, to manage energy, creating and amplifying energy, unblocking and releasing energy as the animator (Hastings 1993, p. 161-162).

To get an empirical phrasing of some of the problems, a young biotechnology owner-manager stated the following:

"As my firm is a network firm, I lose control and how can I handle this uncertainty? I guess you just learn to live <u>with</u> it, as I live <u>from</u> it. This type of collaboration (in networks) is a delicate balance, as there are some things I have to try to keep secret. My basic knowledge, I have to keep for myself, as this is what I am surviving on. It is a dilemma. On the one side, I need information from people in my network and to get some of that I have to provide knowledge, and this is the balancing, which determines whether I survive."

Handling uncertainty does not have to imply thriving on chaos, but embracing uncertainty as an embedded feature (Poulfelt & Mønsted 1998, Van de Ven 1986, p. 605). The fluidity forms a kind of decision rationality in Kreiner's (1998) sense, which could be seen better as an action rationality and creation of meaning in context, straddling from one ridge to the next and creating the path while walking. The decision to keep a longer vision while having to work with many factors of uncertainty, forces one to make interpretations and to create meanings in actions and dialogues and press for an avoidance to closure, as a finished solution to a problem The balance between opening and closing of contextual meaning is fundamental for the understanding of acting and generation of credibility in these firms (This is not an "either-or"- situation, but definitely a combination or a straddling on both). The perspective leads to an emphasis of innovation management, or rather knowledge management as knowledge creation.

Innovation as knowledge management

An important part of knowledge management is the creation of knowledge, the inventions and innovations. In relation to the management, this is the effort to search for the boundary of knowledge, for the issues we do not yet know, and which constitute opportunities and risks. New ideas in advanced technology or research is in the form of formulated visions of possibilities, rather than documented knowledge. The openness of the questioning and the creation of ideas is the most important in the early stages, building on the existing research knowledge (Mønsted 1997).

The role of the manager in this process is to create new opportunities, and to stimulate the researchers involved. Later in the process the role of creating sense, and beginning the analysis in a Sherlock Holmes role has to be stimulated to argue scientifically for the technology to be recognized as knowledge. The two roles are very different, and may have to be taken up by different managers in the organisation. The one accepts the complexity and ambiguity, the other search for consistency and rationality in a scientific legitimacy.

The human relation aspect may come out as one of the most important, when research management as knowledge management is not about managing knowledge as a "thing".

"Knowledge management suffers from the same problem as several other management labels: it assumes that knowledge is a 'thing' (object), which is amenable to being 'managed' - by a 'subject' (a manager)." (Quintas, Lefrere & Jones 1997, p. 389). This may be tied to the consideration of learning and how individuals will be better to manage their own knowledge and that of their organisation (ibid.). If management is perceived as a "thing" and an "object" or even a "target" and result, factors leading to this kind of management are interesting. However, most often this is not the case. In most cases, management is the tool to reach growth or even innovation targets.

The management of researchers is tied to the issue of sticky knowledge in persons, to keep people who have the insights, and to preserve and develop intellectual capital. These are all concepts related to an economic value of knowledge, whereas the motivation and learning aspects are maybe much more important, as the brainpower and creativity of the researchers has to be stimulated to get really good research. A limitation and control at an early stage may hinder creativity (Amabile 1996).

Communication of uncertainty and complexity

It is very difficult to communicate about the not-yet-known, but it forms the basis for innovations. The sense-making of fragments of information is much easier with people of the same background who can continue the vaguely hinted suggestions. This may happen within Communities of practice, where people share experience (Wenger 1998). The whole idea at this stage is to create meaning of the fragments of hints and knowledge. One of the problems at this stage is to find methods to cope with these types of uncertainty, and managers may act and decide "as if" they have certainty (Stacey 1992). In one of the studies of biotech, the development projects are described more as a travel, where some events (results) happen during the travel (Rip & te Velde 1997). The description of travels is opening the idea of "serendipity" and of the basis for decisions. Managers have to decide to give more resources based on their own sense-making of these hints. The problem compared to other decisions, is that many of these problems are on the boundaries of what we know, and who is the expert on the not-yet-known?

R&D Management in small innovative firms is seen as closely tied to uncertainty as an embedded part of the development. The development of new technology is a project of creating a vision or a fiction as Latour formulates it:

> *"By definition, a technological project is a fiction, since at the outset it does not exist, and there is no way it can exist yet because it is in the project phase...This tautology frees the analysis of technologies from the burden that weighs on analysis of the sciences. As accustomed as we have become to the idea of a science that "constructs", "fashions", or "produces" its objects, the fact still remains that, after all the controversies, the sciences seem to have discovered a world that came into being without men and without sciences."* (Latour 1996: 23).

For managers, the importance of handling the uncertain process of innovation is tied to some of the above perception of technology. Technology projects produces something other than science. R&D are developing opportunities and are based on knowledge. They create opportunities on the boundaries of what they know and generate a space of opportunities in uncertainty. The understanding of small firms in an uncertain environment is the basis for understanding the growth potential and processes in small high tech firms.

A high level of uncertainty and low inertia seems to change not only the qualitative conditions, but also the decision structures, communication and organisational forms. The main argument for the focus on uncertainty is the perception of uncertainty as a characteristic specificity of high tech and innovation.

The question could be how to handle complexity, by creating the whole in the parts (Van de Ven 1986, p. 598) is a different and more fruitful way of formulating the necessity to co-ordinate when specialising. The necessity to subdivide complex issues demands a division of labour, but at the same time the complex tasks cannot be divided in a strict Tayloristic manner. The vision and perception of the whole have to be included in the parts to create meaning in context.

Leaders may know the methods and try to hold the strings, but the catch 22 is the lack of focused planned research as formulated by Hastings: "The trouble is I don't know who I don't know and I don't know what I need to know that I don't already know" (Hastings 1993, p. 130). In a management context of creating meaning, the ex-post rationalization tends to replace rationality, as rationality in action and while acting is sometimes closer to intuition than to formulated rationality, whereas the ex-post evaluation has to be tied to specific rationalization models, which have legitimacy, whether relevant or not (ex. Staudt 1997).

Network management

Instead of focusing on the weaknesses of being small, which are definitely important, the study has focused on how to develop and create a platform for management beyond the firm. The perception of networking strategies is very different in a strong international corporation and a small firm. If the process of building up networking strategies under high level of uncertainty is the focus, small firms who can not lean on existing power structures form a very interesting base, seeing power and management as a social construction in a space between firms. The formation of credibility and legitimacy of high tech in this space is against many economic and social odds (Mønsted 1998). Because of this the managers and small firms who thrive in this space are to be viewed as "best practices" and interesting for building an experience of how to survive in the jungle of the New Economy. The experience is seen also as a good case of knowledge management on the boundaries of knowledge. The creation of meaning in the not-yet-known may be easier within a close project team of a firm, but may create other qualities if some of the external resource persons are also included in the process. This is very difficult in large firms, and hard also in the small firms. But only in the small innovative firms, there is such a pressure to share not only knowledge but also visions on opportunities, that this has to be part of not only R&D, but also of the strategy to find partners and to sell products.

The idea to form networks as an organising logic, governing relations among the economic actors, and building a net of intermediaries, who put each other into circulation (Callon 1991) is a way of forming loose coupling to a larger platform of resources and skills. Also it is the principle of managing via the third, i.e. using other experts to function as brokers, to new information, to legitimising research findings or to get access to financing or customers.

The main issue in this is the constitution of management in this fluid social relationship. The management of knowledge and creation of rules for management without the organisational hierarchy of power and control change both the power base and the rules for project management. A social construction is built, and motivation is generated in the dialogue, leaders have to have competence beyond the administrative management. Most of the managers in the cases of small biotech firms are not “professional” managers, but are competent players in the high tech field they work in. They have no chance of keeping up the hands-on research, but they have the insight, the feeling, and the visions of the technical field as well. This is part of the management, as they have to communicate to other technical people in creating the legitimacy of the production and the product.

Management on the boundary then constitutes a process of self-management, a process of management, where you are only a manager while acting and while accepted as a manager, by the partners. This is a process of persuasion and selling ideas and creating meaning out of fragments, both internally and externally, both to collaborating partners and to customers.

Networks both function as access to resources, but also to form project groups around certain project development. A case from a small biotech firm, shows how the partners in project groups change.

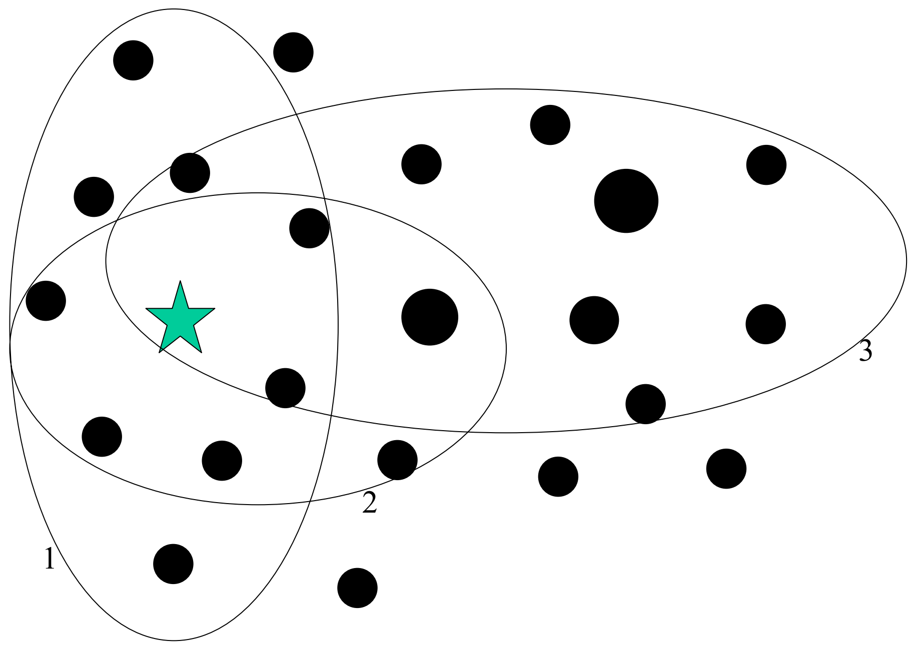

Figure: 3 different projects of a small firm

The perception of networking project groups, thus questions what is the boundary of the firm? The resources of the projects go much beyond the boundary of the firm itself, and cannot be understood from this small firm of 12 employees alone.

The management process in networking is based on a basic understanding of small firms, and the way small firms manoeuvre and develop new opportunities. It is tempting in a functionalistic way to assume, that small firms would not survive, if they did not have this entrepreneurial and flexible way of handling uncertainties. Instead of seeing small firms as dwarfs or handicapped large firms, this group of high tech entrepreneurs could be seen as representative of the New Economy, as some of the managers who have learned to deal with the uncertainty, turbulence and inter-organisational forms of organising, and be used as a learning case for other managers, who until now have not been much challenged by the new turbulent conditions. The New Economy changes conditions in many other types of firms as well.

The high level of technical uncertainty of many of the small and new firms creates a need for some kind of legitimacy or image of professionalisation. The management of small firms is tied to this self-organising. Networking may be perceived as a self-organised management as a social construction. Management of network ties do not provide a hierarchy or "given" management structures. The ego-centred networker constitutes him(her)self as the manager and manoeuvres in creating the setting, thus involving actors of management processes.

A biotech manager of a small firm: "I see myself as a spider that controls the web. The problem now is that many small, but potentially good projects are blocked by the time used on the large antioxidant project. I.e. in this early phase of the project, I need more time, and the possibilities are immense. I have to concentrate, but also need new network contacts to evaluate the choices and need to find measures to control some of the relationships."

The managing role is tied to this perception of action and negotiated management in networks. The need for managing skills to do this increases tremendously, when a few projects are including external partners at a time. Especially as the manager is in this case not only managing, but also one of the important inventors, and time pressures and –dilemmas develop a pressure on the resources and the central person of the firm.

Conclusion

The effort of management is to a high extend a management of the self-managed. It is to be seen as much more action than hierarchical structure. Management may be a strong position in a firm, but still it is perceived as the personal credibility and much more action than structure. The effort is to create legitimacy of new ideas as knowledge. The importance for small biotech firms is then to try to use the network to create reputation among recognized experts. The knowledge itself is not yet knowledge, but the research management perspective is to get this legitimized as knowledge to customers.

The network is a means to create legitimacy, and to create power and influence via the third person or institution. Management is thus much more the creation of meaning and decisions based on intuition, and then the hard work to legitimize via other persons.

The deadlines and finance of the adventure is one of the roles of the manager. Bearing in mind what has been said on the uncertainty, asymmetric information and intuition, the decisions on the economic support, and search for finance has to be considered. This is where networks and the dialogue of negotiated management come in. Resources are not "a given" and easy to measure, but mobilized in the process of the project, thus increasing the pressures of leadership and time-management.

The role of the manager has to adapt to the many uncertainties and complexities. Also it is important that control of projects is not the power to control in the usual sense of the concept. It is much more a negotiation and dialogue, and openness to opportunities, at a time, where the documentation is very meager. Research management is not steering, but rather a "yo-yo" of opening and closing relations and project perspectives. The dilemmas of time and problems of division of labourare severe in this process, and management is looking more like the director of a jazz-band, than the "rational" models of management in bureaucratic organizations. It is hard to perceive as control and rationality, except when formulated ex-post the innovation.

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Developments in R&D in biotechnology

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In this presentation the state of art of statistics on R&D Biotechnology will be presented and discussed.

Box 1

Developments in R&D in Biotech

Statistics are needed

=>

- Definition of Biotechnology
- Units to include
- Descriptive measures

Box 2

Statistics on R&D in Biotech

Definition:

- In OECD: Just a provisional single definition and a list-based with 5 categories
- Patent offices: Seems to be well defined(EPO: 5 IPC codes; USPTO: class 435)
- In Danish questionnaires: no definition =>
- The respondents determine themselves what share of their R&D is Biotech R&D

Box 2 shows that an internationally accepted definition of Biotech is needed to ensure comparable and reliable statistics. This definition might include more areas of use of Biotech, re the 5 categories.

Box 3

Statistics on R&D in Biotech

Units to be included:

- Industries
  Using NACE-codes is not possible (DK: 25 NACE-codes with Biotech research)
  => on a company-by-company base
- Public institutions
  Type of institution: universities, hospitals, PNP's, others
  Field of science: all 6 fields are doing some biotech R&D

Box 3 shows that it is only possible to exclude few industries and even fewer public institutions from being potential performers of R&D Biotech.

Box 4

Statistics on R&D in Biotech

State of the art:

- Lack of systematic data collection in most countries (OECD, STI WP 2001/6)
- Lack of uniform methodology (definitions, units)
  => comparable data are extremely limited (OECD, STI Scoreboard 2001)
- International statstics
  Publications, Citations, Patents, Venture Capital

Box 4 shows that very little general international statistics on R&D Biotech exists. However, some countries have collected special statistics, not comparable with other countries.

Box 5

Statistics on R&D in Biotech

◆ **Intention**:	Government Budget
◆ **Input**:	Heads/FTE's and funding
◆ **Production**:	Facilities, Cooperation
◆ **Output**:	Publications, Patent applications
◆ **Impact**:	Citations, Granted patents
◆ **Innovation**:	Venture capital, Products new to the market

Box 5 shows the 6 elements of R&D statistics.

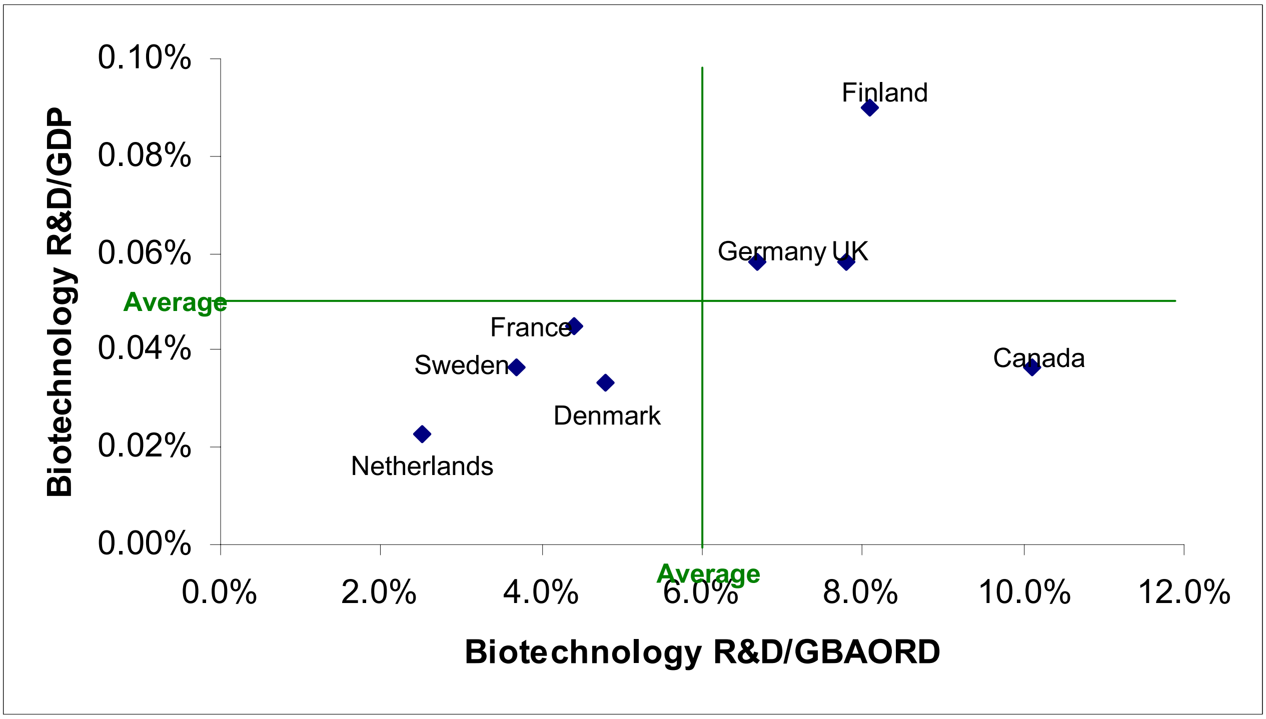


Figure 1 Intention: Government-funded R&D in biotech, 1997

Figure 1 shows that Finland, Germany and UK are above the average of OECD-countries concerning funding R&D Biotech compared to "Government Budget on R&D" and compared to GDP. Remark that only some of the OECD-countries are included in the figure.

Box 6

Statistics on R&D in Biotech

- R&D expenditures /according to OECD):
  Canada, Denmark, Germany and Japan (partly)
- Full R&D statistics:
  Canada

Box 6 shows that only Canada can provide a full statistics on the resources used on R&D Biotech, while a few other countries do collect the R&D expenditures.

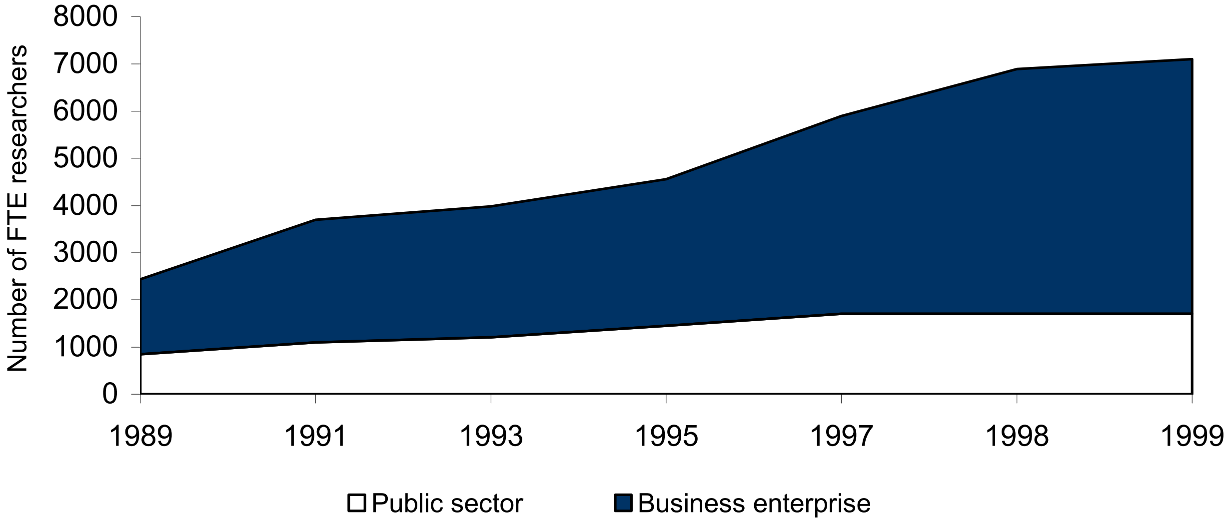


Figure 2 Input: Numbers of full time equivalent biotech researchers in Denmark, 1989-1999

Figure 2 shows the Danish numbers on FTE's in Biotech. In the public sector there has only been a slight increase during the 90's, while the BE-sector has increased very much.

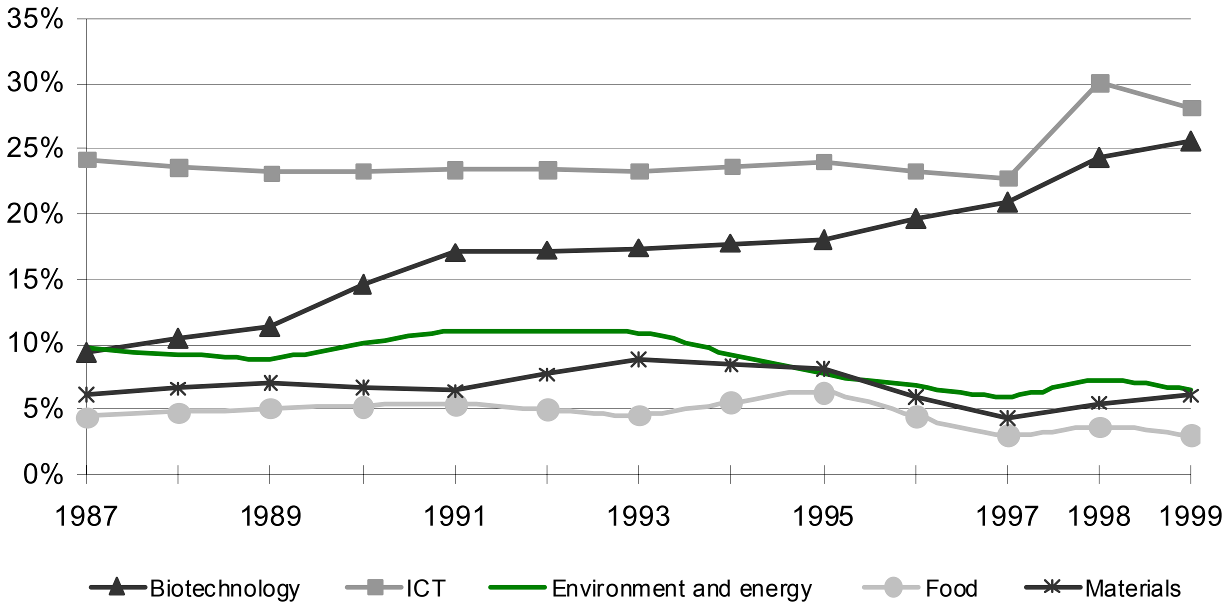


Figure 3 Input: Share of Danish companies R&D expenditure in selected areas, 1987-1999

Figure 3 shows that the R&D Biotech also has increased its share of the total R&D in Danish companies during the 90's, while the ICT-sector just lately has increased its share – and is expected to have declined in 2000-02.

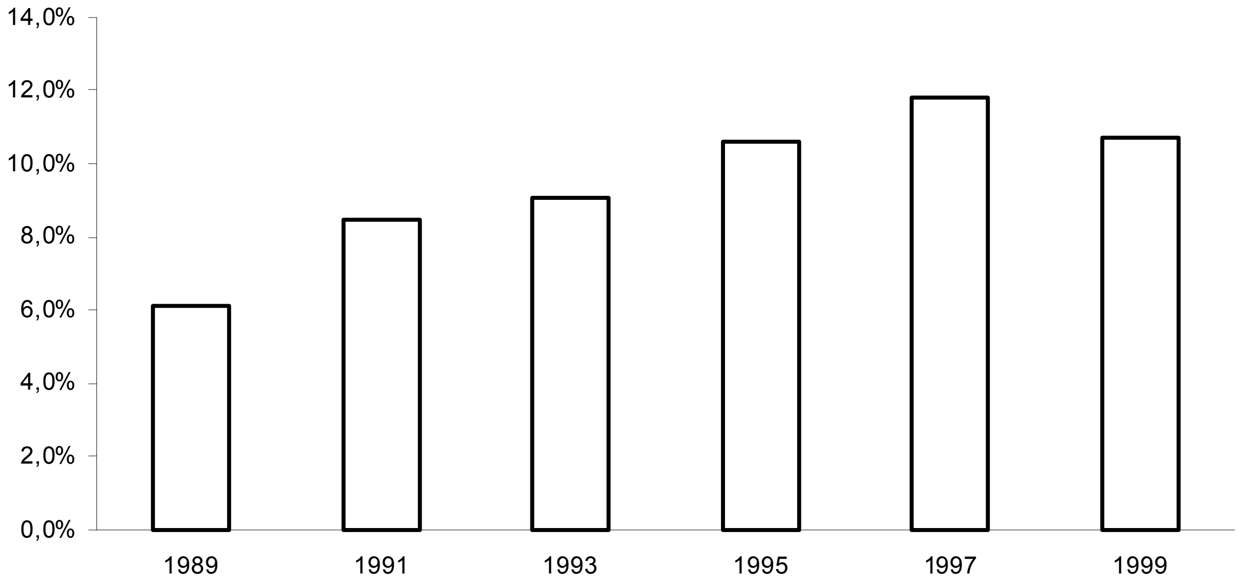


Figure 4 Input: Public expenditures on R&D in biotech (% of GERD), 1989-1999

Figure 4 shows for the public sector that the share of R&D performed in Biotech increased from 1989-1997, but then declined.

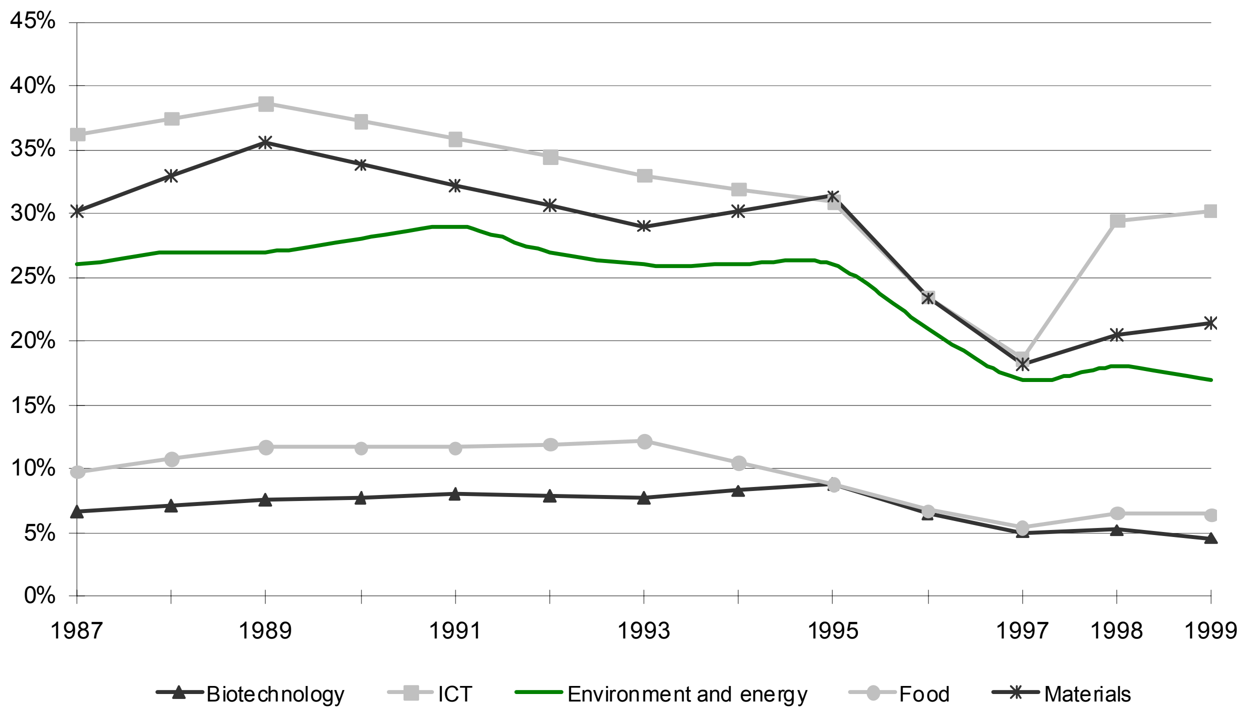


Figure 5 Input: Distribution of Danish R&D-active companies, selected areas, 1987-1999

Figure 5 shows that the share of companies performing R&D Biotech has been stable – or even declining, while the expenditures and manpower have been increasing (see figure 2-3). Remark that the shares for 1997 are not fully comparable with the other years.

Table 1 Cooperation – Danish companies, 1999

Kind of cooperation	Biotech companies	Other companies
Report of cooperation	62%	41%
Universities and R&D institutions	90%	79%
All over the world (DK, EU and the world)	66%	23%
Just Denmark	10%	33%

Table 1 shows that a higher share of companies performing R&D Biotech are cooperating with universities and cooperating worldwide.

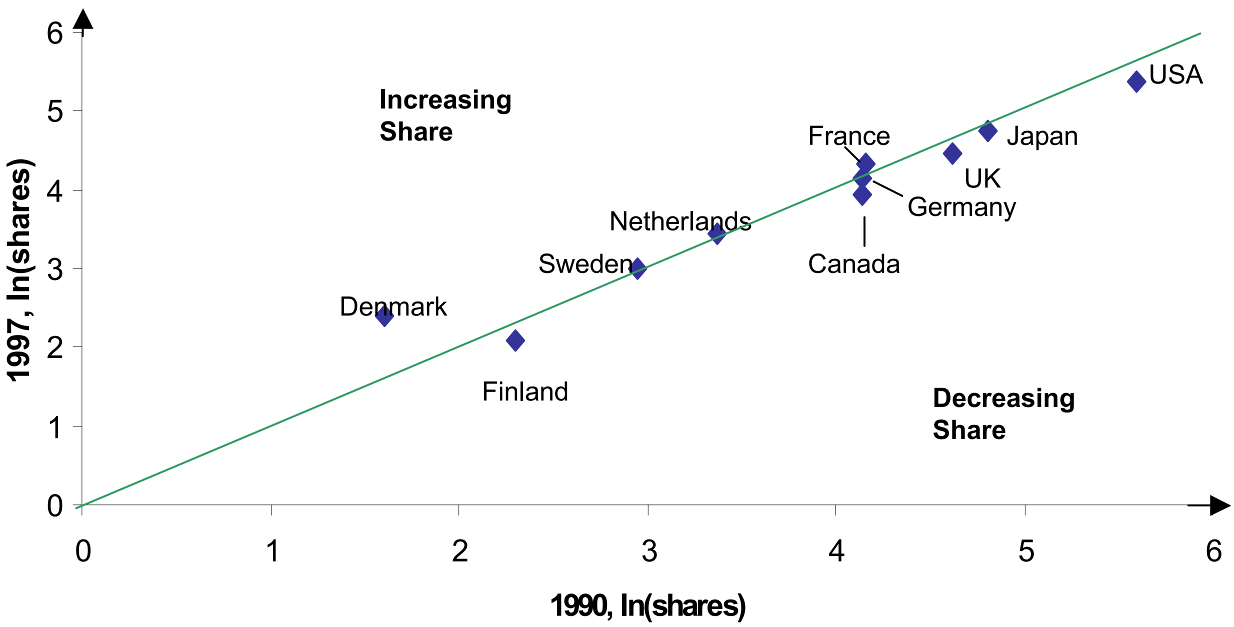


Figure 6 Output: National shares of the total number of biotech publications

Figure 6 compares the shares of biotech publications for 1990 and 1997. Danish researchers seem to be lacking behind comparable countries like Sweden and The Netherlands, but Denmark has passed Finland, caused by an increasing share.

Remark that only some of the OECD-countries are included in the figure.

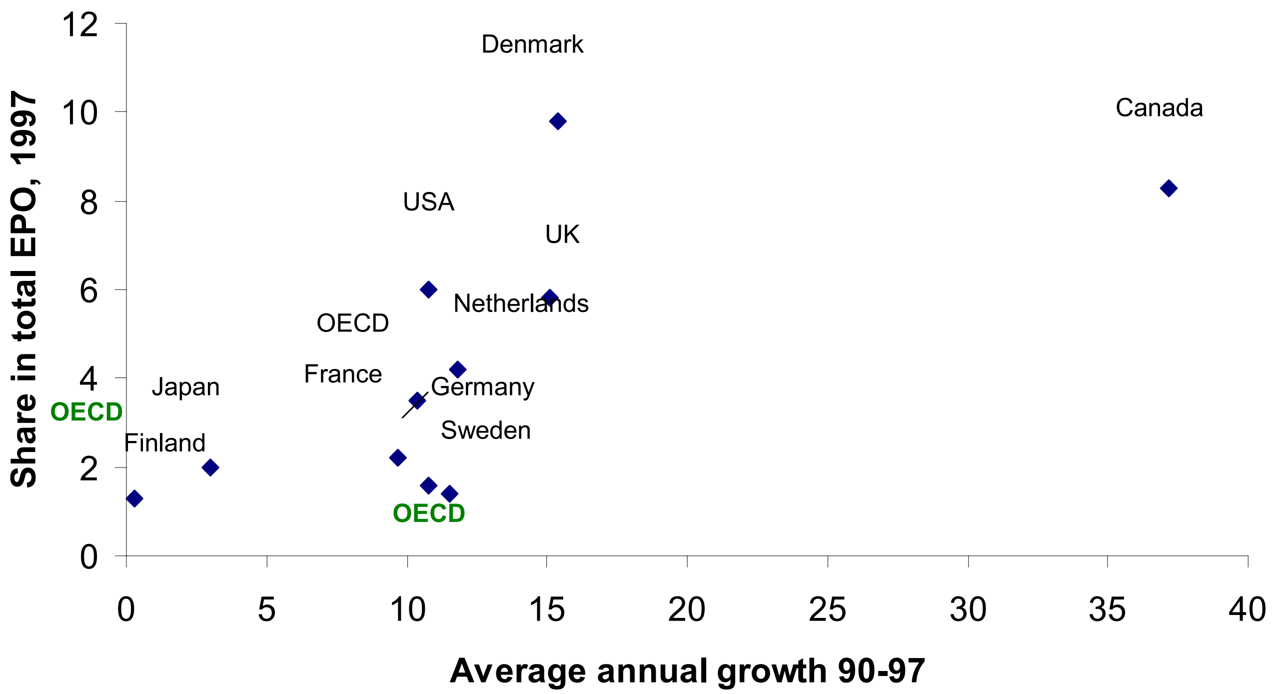


Figure 7 Output: Biotech patent applications to the EPO

Figure 7 shows the growth (1990-97) in Biotech patent application and the share of patents being in Biotech in 1997. Canada and Denmark do have the highest numbers on these two measures, while Finland and Japan are lacking behind.

Remark that only some of the OECD-countries are included in the figure.

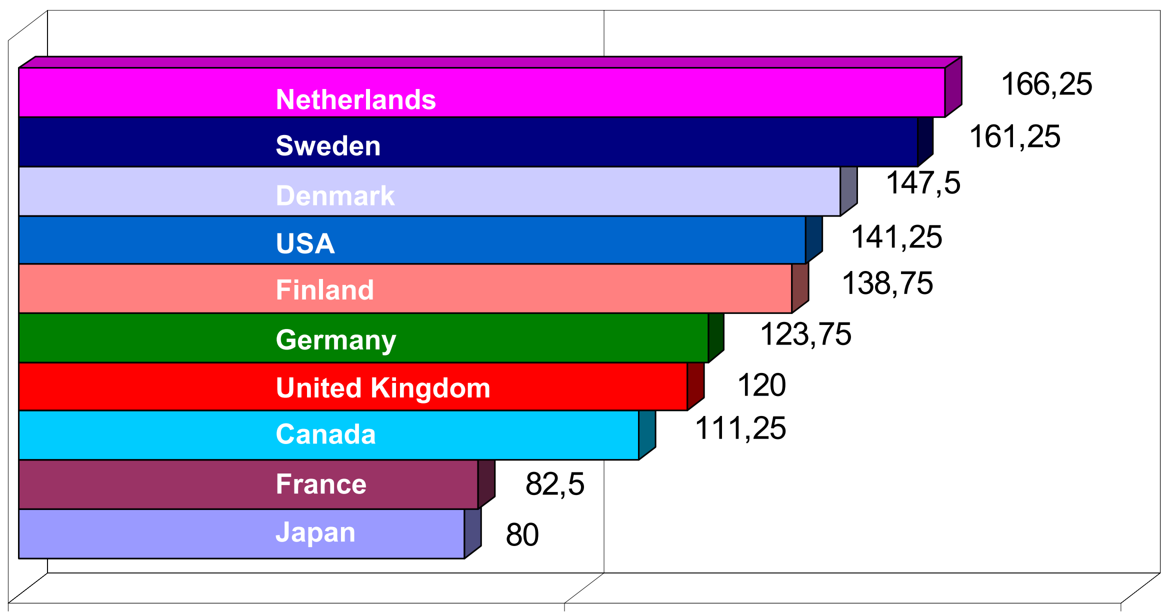


Figure 8 Impact: Citations of biotech publications*, average of indexes for 1990-1997

Figure 8 shows the impact of biotech publications. Researchers in The Netherlands and Sweden have the highest impact of their articles, while Japan and France are below the average.

Remark that only some of the OECD-countries are included in the figure.

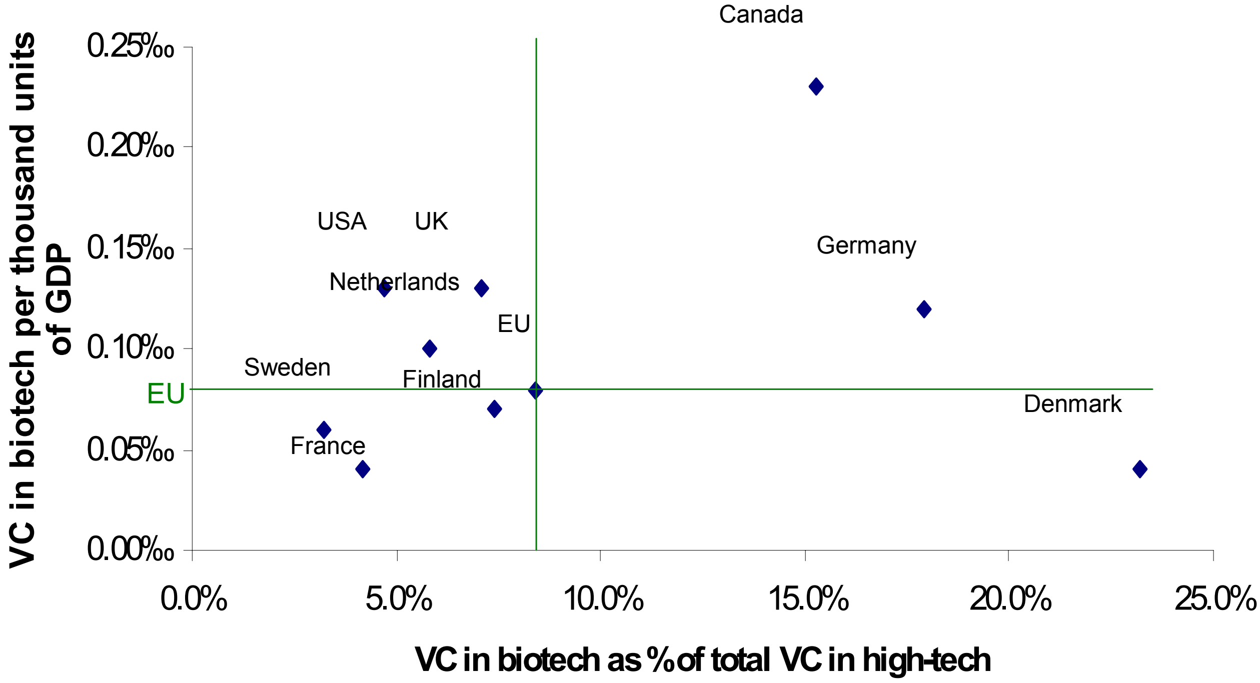


Figure 9 Innovation: Venture capital investment in biotech, 1999

Figure 9 shows that the indicator for innovation, venture capital, is very high for Canada and Germany, measured as a percentage of all venture capital in high-tech industries and as the share of GDP. Denmark does use the most of its high-tech venture capital on Biotech, but it is still below average concerning GDP.

Remark that only some of the OECD-countries are included in the figure.

The role of networks and skilled labour for regional innovation - Biotechnology locations in comparative perspective

Ulrich Hilpert & Dietmar Bastian - University of Jena, DE

Contents:

1. Introduction: Studying Biotechnological Innovation Process by Comparative Location Analysis[5]

Under the condition of globalising sets of techno-industrial innovation any assessment of economic effects of an increasing use of new technologies involves comparative studies of locations as high-tech related innovation is not a question of *anywhere* but of limited number of vanguard locations, which will be referred to as *islands of innovation*. The term does not refer to a unified idea of an industrial location but rather stands for geographical entities that may differ in extension. They are based on regional settings of enterprises and research institutes that relate to a given field of technology. The degree of embeddedness into regional, national and international networks of techno-scientific-operation as well as the ability to participate in public research funds defines a location or a region as an island of innovation.[6] While some of these islands in biotechnology are made up of one dominating centre together with near by enterprises and research institutes (Berlin, Munich), others are arrangements of a few neighbouring centres (Öresund Region, the Scottish Belt, Research Triangle Park in North Carolina or the North-German city triangle Braunschweig, Göttingen, Hannover) and or agglomerations (Île de France or the Rhine-Ruhr area).

Studying life cycles of such biotechnology locations unveils that the provision of skilled labour and the orientation on the global set of innovation constitute crucial determinants for a successful development. Regional concentration of innovation processes and the emergence of particularly vital islands of innovation very much depend on the qualification and availability of scientific personal on the local labour markets. Additionally, a high share of scientists from other islands of innovation and out of other research set-ups is an important precondition to get knowledge transferred to the respective locations and creativity unfolded through synergy and co-operation; at the same time, the issues of local education and relation with regional actors of innovation (enterprises) is particularly crucial. The relation between innovation and employment evolves only to that extend that human capital can be introduced as a resource for innovation into the process. Differences arise in relation to the profile of actors: both research and industry locations are impacted in their development by inputs of an existing economic specialisation within a given region -- respectively a given location -- that refers to a certain field of technology. The prospects for innovative processes very much depend on the regional presence -- or absence -- of such

[5] In 1999, a comparative research project on the role of techno-scientific progress in the development of advanced industrial locations was launched at the Chair of Comparative Government. With a focus on the regionalisation of techno-industrial innovation and employment in the field of biotechnology, the project has grown into a major international network that brings together scientific knowledge on major locations in American and West-European biotechnology.
[6] See Hilpert 1992 and 1995.

reference industries (with regard to biotechnology most typical pharmaceutical or chemical industries). Preliminary results from field research in the Research Triangle Park region in North-Carolina, Edinburgh and the Scottish Belt as well as in Jena shed light on locations, which have little relations to reference industries. Accordingly, they constitute a particular group of examples that indicates how innovation can be realised “from scratch” in the field of biotechnology.

The data presented here give a survey on the size of locations and the size of units in terms of overall employment, areas of employment in biotech companies, workforce recruitment, qualification levels and co-operations for the three locations.

Jena, with almost 100.000 inhabitants one of the very small locations in our sample, is characterised by a highly specialised orientation towards an application of biotechnology in bio-instruments. This selective arrangement has so far shown to be too narrow for the emergence of an international island of innovation. At the same time, the attraction of biotechnological research facilities since the early nineties has concentrated a scientific potential (with a focus on fundamental research) ready for participation in European and international networks. In the national German context, has grown into the most dynamic location for biotechnology in Eastern Germany after having received a special vote under BioRegio contest of the Federal Ministry for Research and Education.

The *Research Triangle Park (RTP) in North-Carolina* represents the regions historical shift away from a mono-cultural specialisation in tobacco products towards a diversified and technology-oriented industrialisation. The location is characterised by an absence of relations with traditional reference industries. High-tech development was initiated in the late 1950s by establishing an innovative industrial policy on the basis of a regional competence in research and higher education at the three universities in Chapel Hill, Durham and Raleigh. Without a corresponding industrial tradition, North-Carolina embarked politically on a development path that enabled economic growth in new technologies, and in particular in biotechnology and the life sciences.

Edinburgh together with the Scottish Belt forms a region that has undergone a structural change away from its traditional specialisation in heavy industry towards modern, technology-related industries. Since the early 1990s, life Sciences and the new biotechnologies are playing a prominent in this modernisation process that relies on the research competencies of Scotland’s universities and the emphasis that has been given to education. The innovative capacity of biotechnological progress has lead to a foundation of new biotech firms and a higher attractiveness for established companies. This process has actively been accompanied by a Scottish Government that enjoys more competences since the U.K. devolution process was brought on its way in the 1990s.

2. Maturity of Advanced Industrial Location: Size of Locations, Share of Industry and Size of Units in Terms of Overall Employment

The share of industry in the overall composition of high-tech locations is usually regarded as an indicator for the maturity of a certain technology as it indicates that scientific inventions are close to application and that there are markets demanding for a given innovative product or process. The importance of science-based innovations (fundamental research in universities and research institutes) diminishes, while technology-based innovations (applied research in industrial or semi-industrial environments) gain momentum. Likewise, locations mature with their respective technologies, which can be furthermore measured by their overall size and the size of individual units (companies, research institutes).

Currently, a total of almost 40 companies of different size together with 10 research institutes (including the local university) can be related to the new biotechnology sector in Jena and Thuringia. Among the research institutes, two major institutions of international potential give character to the region's endeavours in biotechnology: the Hans-Knöll-Institute for Research on Natural Products and the Institute for Molecular Biology. According to official figures, more than

3.000 employees are working in Jena's Biotechnology sector, with most of the companies being funded in the second half of the 1990s. (BioRegio Jena 2001)

By the end of 2000, North-Carolina counted for more than 100 biotechnology-related companies, ranging from small start-ups to multinational corporations. Four of the world's ten largest contract research organisations have their headquarters in North Carolina. About 20.000 people work for regional companies that use biotechnology, and about 5.700 work directly with this technology. One of the world's largest pharmaceutical companies in the world, Glaxo Wellcome, has based its U.S. R&D headquarters in the RTP channelling annual investments of $ 2 bn in biotech-related research and development. Agricultural biotechnology has likewise important international actors in the region: Novartis Biotechnology Facility, Rhone-Poulenc and BASF Corporation Agricultural Chemicals focus on exploring more productive crops and effective means of crop protection. (North Carolina Biotech Centre 2001)

Based on a broader definition, the Scottish Biotechnology Cluster links 382 organisations comprising 74 companies, 163 support and supply organisations, 53 academic/research institutions and 92 medical device companies. All together, 18,430 people are employed in biotechnology-related positions after 12,729 in March 1999 (Scottish Enterprise 2001).

In Edinburgh and Jena, the share of employment in public research and education continues to be larger than the business or industrial share, while North-Carolina as comparatively mature location shows a contrasting picture with more than twice the number of employees in biotech companies.

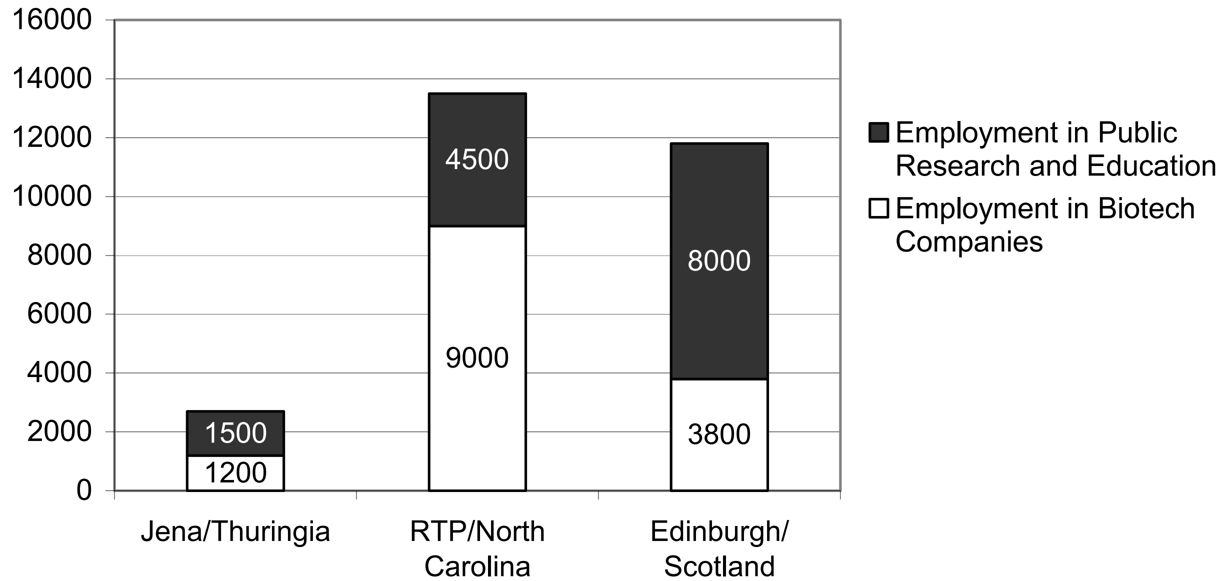


Figure 1 Overall Employment in Biotechnology

Accordingly, the average company size[7] in Jena (34,3) and Edinburgh (45,2) differs significantly from the data for North-Carolina (80,4). As a further maturity indicator, the relative weight of very small companies (with less than 10 employees) shows Edinburgh and, in particular, Jena as relatively 'young' locations with a larger share of smaller units, which are very often new biotech start-ups with limited survival expectations.

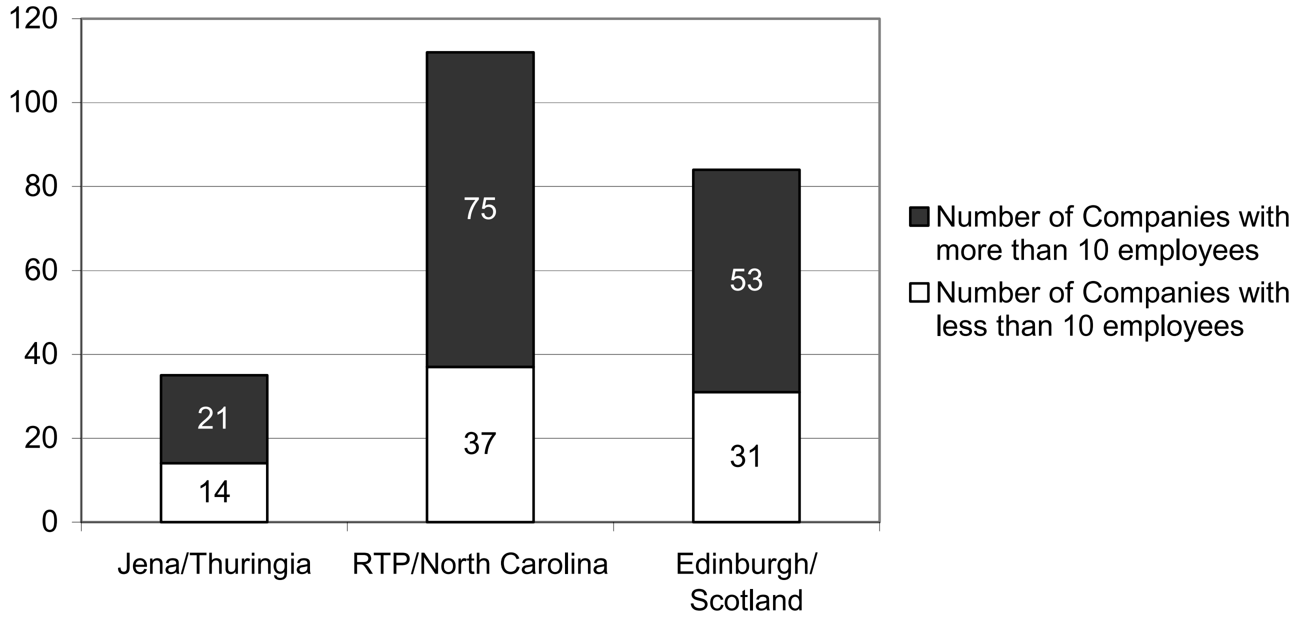


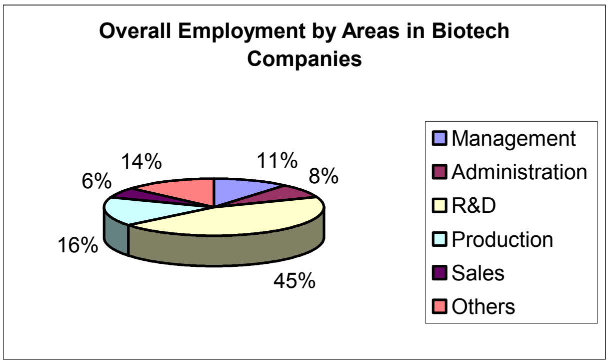
Figure 2 Size of Enterprises in Biotechnology

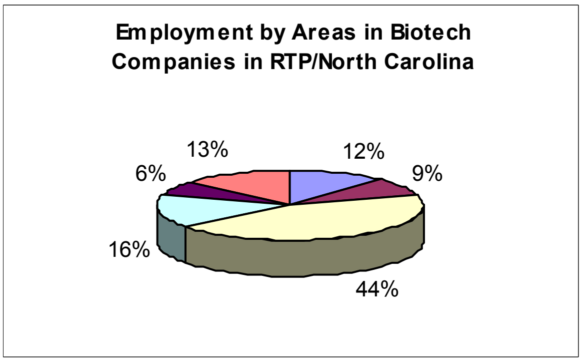
Own field research based on 100 interviews at the three locations covering an average of 30% of biotech companies further substantiates differences between locations with regard to the use of human capital and the international orientation of the locations.

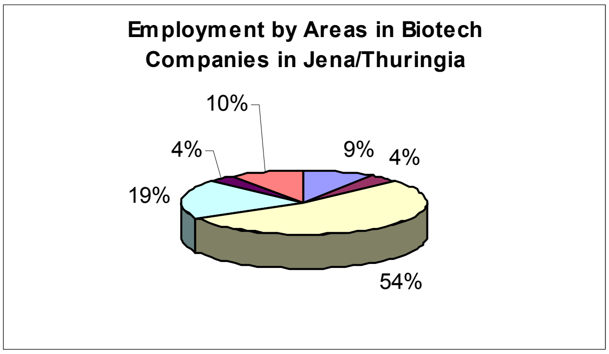
[7] In terms of employees.

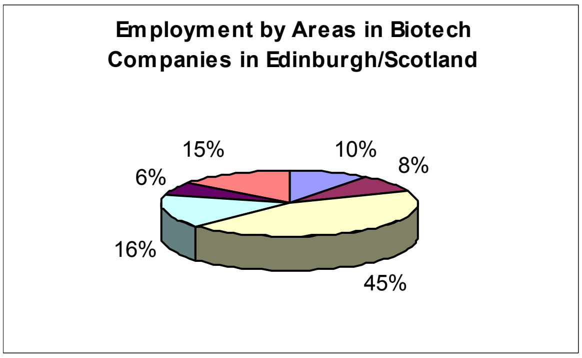
3. The weight of R&D in life cycles of innovative locations: Areas of Employment in Biotech Companies

As a maturing industry, the biotech sector still displays a high rate of employment in R&D activities, while the numbers of employees in production and sales departments are below the share that would be expected in established industries.







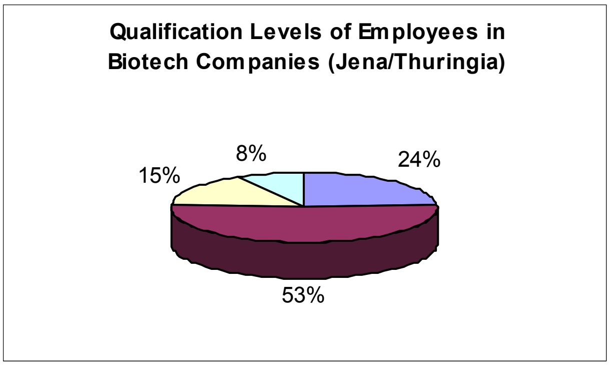


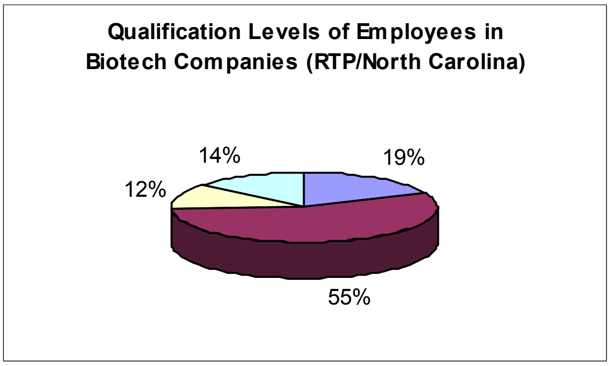
The relative weight of R&D in Jena's biotech companies significantly exceeds the levels measured in Edinburgh and the RTP region, while at the same time their number of employees absorbed in production-related activities is slightly lower than in the case of Jena. Apparently, new locations in Biotechnology depend – in relative terms – more on a concentrated use of human resources in these core activities. Comparatively mature biotech locations display a higher share of management and administrative personnel, as well as a more complex sales procedure demanding for more staff.[8]

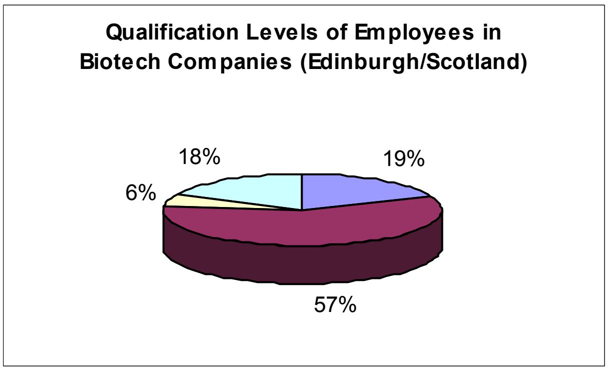
[8] Other areas include quality control, environment, maintenance, services, warehouse, etc.

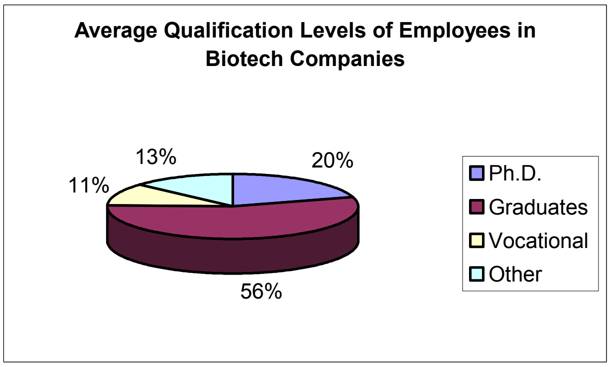
4. Innovation based on the Intensive Use of Skilled Labour: Qualification Levels of Employees in Biotech Companies

High-tech developments require the availability of qualified personnel and in the field of biotechnology the demand for a highly educated workforce with university degrees is particularly striking. In Jena, more than three fourth of the employees dispose of at least one academic certificate and a further third of these hold Ph.D. degrees. Figures for Edinburgh and in North Carolina are nothing more but slightly lower, however, the Anglo-Saxon university tradition knows shorter qualification careers in the form of Bachelor degrees.





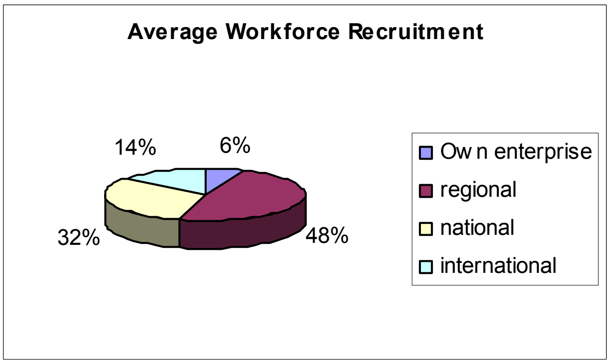


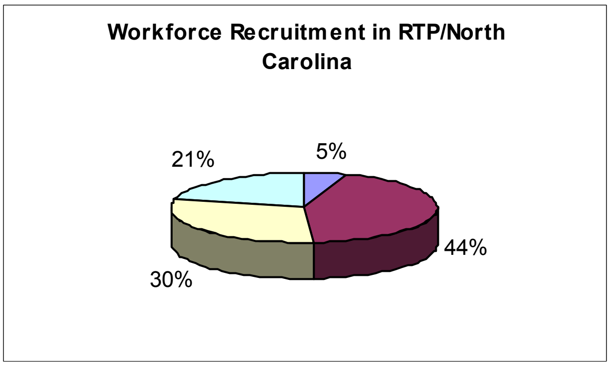


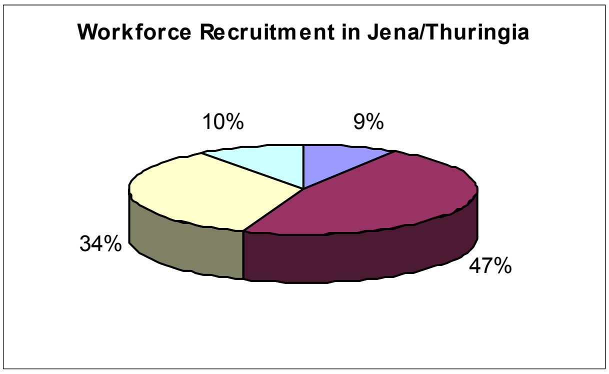
With locations maturing from science-based towards technology-based schemes of innovation a higher share of non-graduates could have been expected. However, the figures for the RTP region indicate that there is no evidence for any such expectation so far. Furthermore, the little differences between the ‘established’ location in North-Carolina and the ‘newcomer’ in Scotland and Thuringia suggest that there is a typical qualification profile for biotechnology locations and that the innovation process requires high average qualification levels of employees even on the long track. If the sector depends on such an intensive use of highly skilled labour, locations with a reputation in biotech-related science and education dispose of a comparative advantage not only in the sun rise period of biotechnology.

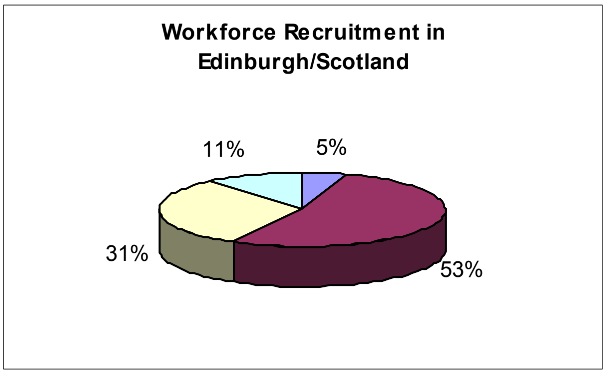
5. International Orientation of Biotech Locations I: The Scope of Workforce Recruitment

As one constituent feature of advanced industrial locations, the international orientation of highly specialised companies and research institutes leads to an increasing demand for employees that can not be satisfied within the region. In the field of biotechnology, the emergence of a global scope of workforce recruitment shows that the boundaries of the national labour markets have become permeable: Every fifth employee in North Carolina biotech industry has been recruited outside the U.S. and one out of ten comes from outside the U.K. (in the case of Scotland) respectively outside Germany (in the case of Germany). Yet, the human resources within the region constitute an advantage for the initial stages of a dynamic process, if not an indispensable pre-condition.









The RTP region might be typical for an empirical trend towards a larger share of personnel recruited from outside the region (and of those originating from outside the nation) with growing maturity of the location respectively the technology. The figures for Jena and Edinburgh display little differences except for the larger share of employees changing their job within the enterprise; a fact that might be prolonged effects of the restructuring processes initiated in the early 1990s.

6. International Orientation of Biotech Locations II: Directions of Co-operations

In order to keep step with techno-scientific progress, advanced Biotech-locations need to be embedded in global sets of interaction through networks of co-operation that are maintained for research and development, as well as in production and distribution in the case of industrial enterprise. Consequently, the level of embeddedness that results from the intensity of co-operations[9] increases with the number of actors with external collaborations. Much more than in absolute figures, location profiles than differ with regard to the relative share of different scopes of co-operation:

[9] In terms of total number of co-operations that are based on a mutually binding contract, irrespective of their character (strategic alliance, project-based collaboration, etc.).

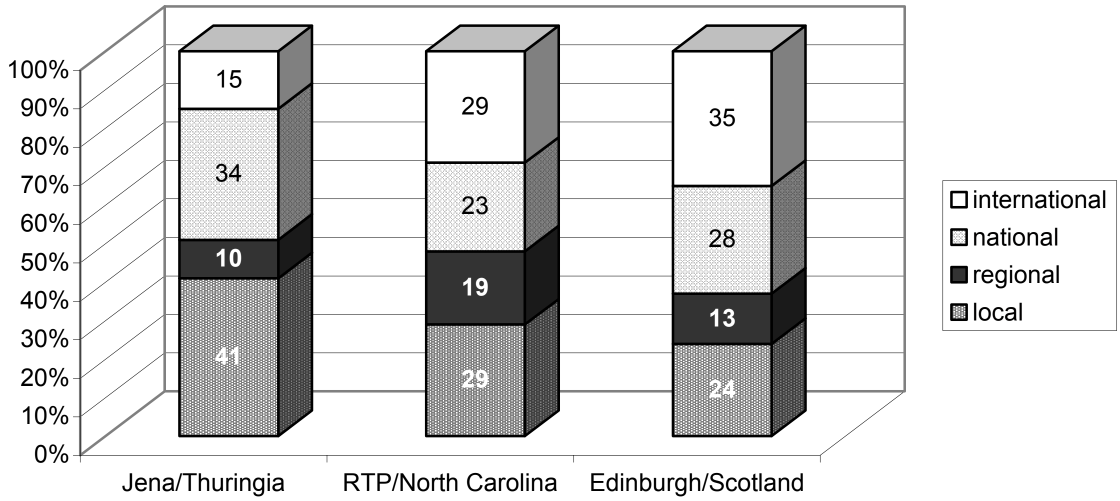


Figure 3 Cooperations

While in the case of Jena a high intensity of cooperation between start-ups (Altenhagen et al 2001) of the same location can be observed together with an orientation towards other German biotech locations, the RTP region and Edinburgh are much more oriented on the international level. At the same time, both locations show a higher share in co-operations with partners from the region (Scotland for Edinburgh; North-Carolina for the Triangle-region). Jena, in contrast, suffers from a lack of hinterland-relations within Thuringia. The share of co-operations with (national or international) islands of innovation, gives further evidence on the maturity of locations as it indicates that linkages are focussed on the most important centres of innovation in biotechnology. Here, the share for Jena (35%) is not too far below the respective shares for Edinburgh (50%) and the RTP-region (60%).

7. Conclusion: Concentration as a Mode of Innovation in Biotechnology – Implications for Public Support Policies

Irrespective of the choice of innovative technologies, advanced industrial locations profit from economics of conglomeration in any stage of their development towards maturity. Yet, all three examples together illustrate that the two main determinants of dynamic growth – the provision of skilled labour and the global orientation – require a specific use of a given location's advantages. An adequate choice of policy instruments, however, needs to be combined with a fine-tuned sequencing of policy steps in correspondence with the location's development. Furthermore, the success of public innovation and technology policies depends on the creation of an enabling perspective for locations with a comparative advantage in one or more technology fields. Such perspectives can be created by support programmes addressing directly R&D institutes and companies, by stimulating the creation of networks or by directly promoting entire locations as under the 1995 BioRegio contest in Germany. (Dohse 2000) As long as concentration continues to be the prime mode of innovation in the field of biotechnology, the location will remain -- more than in other technologies – a useful abstraction of socio-economic reality.

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Framework and means for the efforts in the public sector in connection with biotechnology

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15 years ago I made a small experiment. I induced my youngest daughter to go down to the local library and ask for literature about biotechnology and gene manipulation. This was in the middle of the second wave of public awareness off and concern with biotechnology. The first was in the middle of the 70es and we are in the middle of the third wave now. The result of the experiment was appalling The library had nearly nothing to offer, two pamphlets and two small books. And this was the main public library in a major community. I plan soon to repeat this experiment with my eldest grandchild. I am afraid that the result will not be much better.

This gap between science and society is the main theme of this seminar. The problems under discussion are however not new. You may ask who should be blamed. I have an opinion on that, but I have not been asked to bring this forward. I have been asked to talk about Danish biotechnology R&D programmes. But I want to broaden my subject. I want to broaden it because there is and has to be a strong connection between biotechnology R&D and society. The interface between R&D and the society is important in planning a research policy and in bridging the gap between the research world and society.

I therefore want to discuss research policy for biotechnology and biology – with special emphasis on the role of university research in biology. First I want to clarify a few concepts and to describe the field to be covered.

There is a difference between research on the one hand and development and exploitation on the other hand. But the research relevant to consider in connection with biotechnology is not a sub-field of biological research. Biology as such is of interest. It is a serious mistake and dangerous to talk of biotechnology as something distinct from biology – at least when we are talking about research.

It might be thought that some areas of biology or traditional biological disciplines are unrelated to any exploitation. But if the examples of systematic botany and zoology are considered then it must be realised that these disciplines are strongly influenced by the genomic sequencing. And this is directly connected with use of the results. And systematic microbiology has become of the outmost importance in connection with both biotechnology narrowly defined, with the health sector and with the food sector. I will not risk to give examples of biological disciplines useless outside biology itself. At least not if the quality of the research is satisfactory. In this connection I need to confess that I do not believe in the concepts of pure or basic and applied research. This position is not new. I will just remind you of the classical Pasteur quotation: “Il n’existe pas de sciences appliquées, mais seulement des applications de la science (1872)”.

I also want to stress that there is a division of efforts in R&D between the public and private sector - *and* between the university sector and other parts of the public sector. I will come back to that division. It is important to realise that the discussion about biotechnology is *not* something related to the division between public and private interests.

All research has objectives and customers. The customers may be either inside the research world itself or outside the research world – *or both.* Interest in using the results of modern biological research is present in the private sector in industry, agriculture, and other areas. Interest is also present in the public health sector, the public environmental protection sector, the educational system – on all levels, the regulatory, controlling and legislative system and among the general public. It must therefore be realised that the use of biology is a concern for a very large fraction of modern society.

It is also important to consider the products of the research effort in the public sector, especially in universities. The following list is not prioritised.

- Graduates
- Ph.D.s
- Knowledge, access to knowledge, to several groups of customers. There is often the same demand from customers in the private and public sector.
- Co-operation
- Results to be exploited outside the world of science itself. Spin-off.
- A strong scientific environment.

But it is important to realise that many of the products and the most important products are related to people and to the interchange and flow of people.

Why are publications not on the list? This is because I consider publications in the scientific literature as part of the research process, not as a result of the research process. On the other hand the flow of knowledge from the research world to the outside is important and in this connection publications have a role to play together with several other forms of communication.

There is a traditional division of labour between the public sector, especially the university sector, and the private sector in biological research and education. It may be asked whether this division makes sense. Why can't the customers pay, or why can't the customers provide the products themselves?

Of course many of the products listed above can be procured outside Denmark, on the international market. But how much can we request the customers to procure, maybe on the international market – if we at the same time expect them to continue and strengthen their domestic R&D efforts? Academic research is a public good and there are good reasons for that. But this leads to demands for the research efforts in the university sector. The demands are stated in the following list:

Qualitatively:

- Quality, international quality
- Research groups at the international level and involved in international co-operation
- Adaptability
- Continuity
- Infrastructure
- An active interface to the customers.

Quantitatively:

- To meet the demand for graduates and Ph.D.s
- Breadth, coverage
- Sufficient funding
- Sufficient numbers of position with tenure.

I became involved in research programmes for biotechnology in 1985. The situation at that time was characterised by a defeatist situation at the universities, under-funded research groups not able to compete and co-operate with colleagues abroad, chaos in the funding system, very restricted possibilities for young scientists and the lack of a coherent policy.

As a remedy the big biotechnology programmes were started. The first of these from 1986-1989 involved a large investment, much larger than anything seen before in Denmark. But a ten year programme was proposed whereas only a programme of a little more than 3 years duration was established. In the implementation of the programme a number of new mechanisms were involved, including block grants and centres without walls.

The second biotechnology programme from 1990 to 1994 had decreasing funds through the five year period, thus indicating that no further continuation was envisaged. After that a so-called embedment programme was introduced. The idea was that the universities in the future should finance most of the research from their basic budget and from standard research council grants.

After that we have had a biotechnological instrument centre programme, a national strategy with no priority setting and no considerations about frameworks and means, and a complete neglect of the key area of bioinformatics.

The present situation is very similar to the situation in the beginning of the 80es. We have under-funded research groups, too few tenured positions, too restricted possibilities for young scientists in the university sector, recruitment problems, too small turn-out of graduates and Ph.D.s, a chaotic funding system, no continuity, neglect of bioinformatics, brilliant research, too little volume, and no strategy.

At the same time we have a number of successes. We have an impressive success in the private sector. We have success in reaching and maintaining international quality level. We have success in co-operating with the public health sector.

But we have a serious failure at the interface between the university research and the general public as customers and partners. We have a serious failure at the interface between the university research and the educational system, especially at the primary and secondary school level. We have a big and disappointing failure in developing a coherent research policy. In fact we have a serious failure in fulfilling the university research's part in the division of efforts.

Why do we have these failures? I have an opinion on that subject too. But I will finish only by stating that we cannot afford the failures. We are close to losing our successes. We need to realise that the successes depend on an increased effort in the public sector, especially in the university research.

Why we need indicators for the public benefits of biotechnology

Anthony Arundel - MERIT, NL

Table 1 Indicators for the emerging and applications phases of biotechnology

Policy field	Emerging Phase	Applications Phase
Technology creation	• Private R&D • Public R&D • Venture Capital • 'Core' biotechnology firms	• Industry concentration • Biotech R&D by large, diversified firms
Technology Diffusion	• Research collaboration • Citations	• Marketing collaboration • Technology licensing
Application (few policies)		• Biotech revenues • Types of biotech used by firms • Trade in biotech products
Public costs & benefits	• R&D employment • Safety (efficacy)	• Total employment effects • Environmental benefits • Quality of life (health)

Box 1

Economic or public benefits…

- The economic impacts of biotechnology are likely to be minor compared to ICT:

  – Biotech not applicable to services (70% of employment)
  – Biotech predominantly a process innovation: employment will shift, but not increase

    - Even if we assume that 100% of new drugs were biopharmaceuticals, this would only account for < 0.4% of employment in Europe.

Box 2

Economic or public benefits…

- The economic impacts of biotechnology are likely to be substantially less than its impacts on environmental and quality-of-life conditions.

- By stressing indicators for economic outcomes, we will miss the main story and provide poor guidance for policy

Box 3

The Hazards of Inadequate Indicators…

- We have good data on the number of dedicated biotechnology firms (DBFs) but very poor data on biotechnology employment outside these firms.
- The large number of indicators for DBFs suggests that they matter more than expertise in large firms.

Box 4

The Policy challenge:

- Develop indicators for the application of biotechnology. This is difficult, because biotechnology is not a 'sector'.
- Develop indicators to capture the "non-economic" benefits of biotechnology.
- Feed an evaluation of such indicators back into the policy-making process.

Box 5

The Policy challenge:

- It is NOT the goal of policy to support new technology simply because it is new.
  –Cell phones versus seaside holidays?
- Policy support can only be justified if the technology provides public benefits such as improved productivity or quality of life.

Box 6

Some Major Policy Issues

- How pervasive is biotechnology – barriers to adoption?
- Is ag-bio research developing varieties with clear public benefits?
- Is health biotech producing therapeutic advances?

Box 7

Health biotechnology

- Choice of indicators is not neutral, but can have political implications:
  –Number of new drug approvals for bio-pharm
  –Sales of bio-pharmaceuticals
  Or:
  Measure of the quality of bio-pharmaceuticals

Table 2 Therapeutic value of 2,257 new drugs introduced onto the French market: 1981 to 2000

	81-85	86-90	91-95	96-2000	*Total*
No. of new drugs	306	351	541	1259	*2,257*
Major advance	0.3%	1.4%	0.0%	0.1%	*0.3%*
Important advance	5.2%	3.4%	2.4%	2.5%	*3.0%*
Some advance	10.5%	10.8%	10.9%	5.9%	*8.5%*
Minimal advance	20.3%	23.9%	22.4%	12.3%	*17.6%.*
No advance (me too)	57.8%	47.0%	55.1%	74.3%	*63.2%*
Possible dangers	2.0%	5.7%	3.7%	1.1%	*2.6%*
Inadequate Info.	3.9%	7.7%	5.5%	3.8%	*4.8%*
	100%	*100%*	*100%*	*100%*	*100%*

Source: L'Annee 2000 des medicaments, *La Revue Prescrire* 21:57-64, Janvier, 2000

Box 8

Agricultural biotechnology

- Use GM field release data to track private and public investment into different types of GM crops
- Most public benefits will be from quality and industrial traits
- Seed firms have been stressing these, but what are they actually up to?

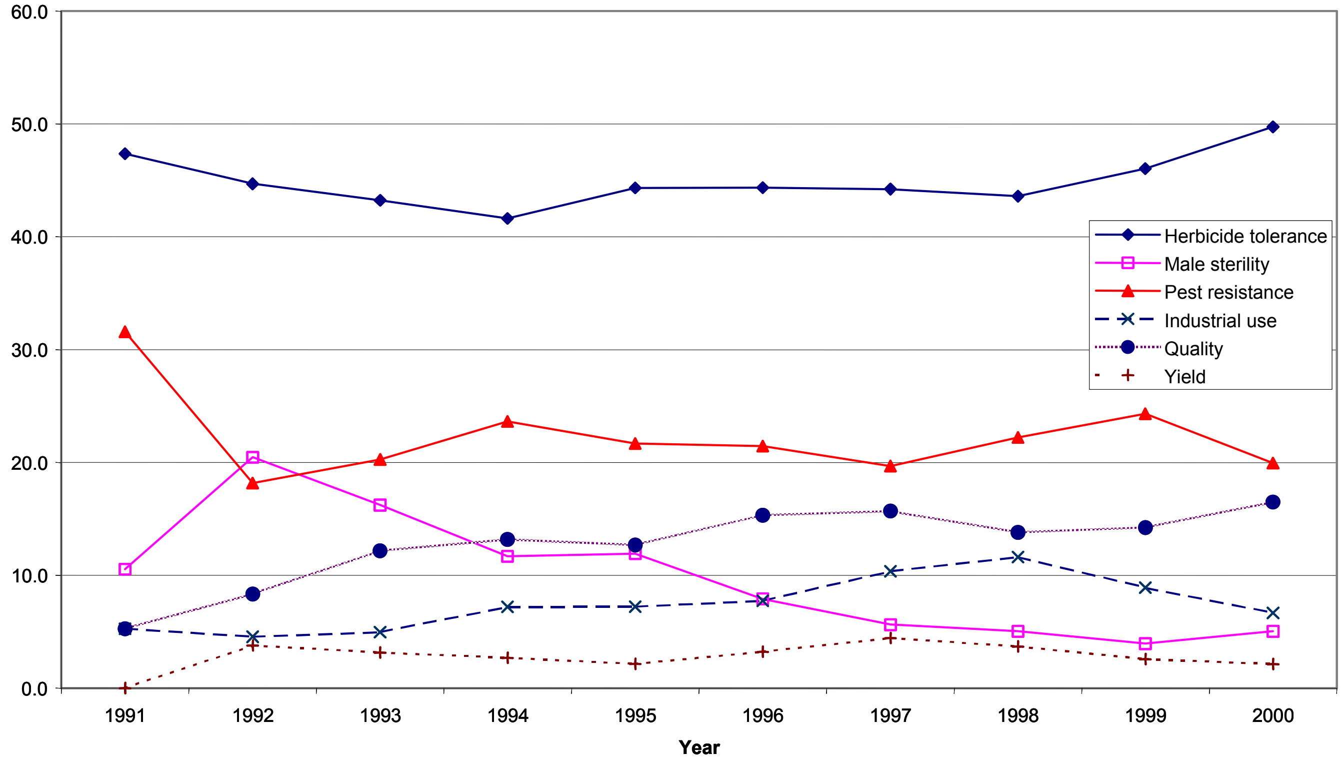

Figure 1 Percent of EU field trials by trair (two-year running average)

Box 9

Conclusions

- For biotech, non-economic benefits will probably be substantially larger than the economic impacts.
- Under these conditions, we need to develop indicators for the benefits and feed the results back into policy making.

From innovation to appropriation: On the politics of technoscience

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Introduction

Over the past thirty years, there has developed a rather fundamental bifurcation, or contradiction, in the ways in which we think about science and technology, and a rather large gap has developed among those who formulate policies for research, development and innovation. In most national governments, as well as in many supranational organizations, such as the European Union and the United Nations, science and technology tend to get integrated into (at least) two very different types of political "discourses", namely one that has to do with economic growth and others that have to do with what are often termed the social and environmental consequences of science and technology.

At times, of course, participants in the different discourses meet and discuss together, but, for the most part, their deliberations, as well as the so-called expert advice that enters into their deliberations, are conducted separately from each other. In most decision-making systems, innovation policy - as science and technology policy has ever more come to be called - is primarily a part of economic, or industrial policy, while all the other societal applications of science and technology are relegated to a kind of residual "welfare" policy sphere. As the experiences of the past ten years in seeking to deal with public concern about the marketing of genetic technologies amply illustrate, it has proven difficult, if not impossible, to do anything particularly meaningful about this bifurcation. There is a huge gap between policies and political discussions that are aimed at promoting the new technologies, and those that seek to address the social and environmental implications of those same technologies. And yet, if science and technology - or technoscientific - policies are to be formulated and implemented in ways that can be of benefit for society as a whole, we must find ways to recombine the now separated discourses and build some meaningful bridges across the bifurcation that exists.

In general terms, we can characterize the bifurcation, or dichotomy, that has emerged as being between economists and sociologists, between those who think of science and technology primarily in terms of economic activity, and those who think of innovation within science and technology as variegated processes of "social construction" (see box 1).

Box 1

What is Technoscientific Politics?

	Economic approaches	Sociological approaches
What's it about?	commercialization	(social) construction
How is it analyzed?	technological trajectories systems of innovation	actor-networks/hybrids contextual tensions
What is studied?	firm strategies learning processes	"laboratory life" mediation/construction
What methods are used?	surveys economic modelling	case studies story-telling
What needs to be improved?	competitiveness policy instruments	public participation accountability procedures
What's it based on?	instrumental rationality	communicative rationality

In the following, I will try to unpack some of the assumptions and biases on "both sides" of the bifurcation, and conclude by outlining a new framework of interpretation that might provide possibilities for synthesis and recombination, and perhaps even fruitful cross-fertilization.

The economic approaches

In our contemporary world, technology is primarily seen as the source of marketable innovations and new products, which has brought into being new fields of expertise in such areas as technology management and industrial innovation, as well as new theories and concepts of evolutionary economics, innovation systems, technological dynamics, learning economy, etc. What is at issue here is not whether science and technology satisfy any particular social or human need or, for that matter, help solve any particularly pressing social, environmental or human problem; the overriding, and more or less exclusive, concern is rather whether a market can be found for new innovations, and, if so, how shares in that market can be increased for the purposes of corporate expansion and growth. In this perspective - what we might call the dominant technology discourse - scientific and technological change is seen as a key factor of economic competitiveness and successful business performance. The discourse is especially dominant in relation to firms that are actively promoting the so-called advanced, or "high" technologies, but its influence is much more general and pervasive. In some formulations, there is the idea that technological change is the core activity of business behaviour in general, and it is only by understanding the "learning processes" and selection mechanisms involved in technological innovation and in the marketing of innovations that companies will be able to survive in an increasingly globalized, or globalizing economy (se Archibugi and Lundvall, eds 2001).

In this sense, the meaning that is attributed to scientific and technological change is essentially commercial, and the processes of technological change are incorporated into the broader processes of economic development, or the accumulation of capital, or, more simply, activities of money-making. This meaning, or role, of technology in our societies has been around for a long time, but it is only recently - in the past fifty years or so - that it has taken on what we might term hegemonic proportions. It is as commerce, as “exchange value”, that technology and technological change is most understandable and meaningful in the contemporary world.

Over the past twenty years, it has been primarily under the political influence of neo-liberalism and globalization that this commercial meaning of technology has taken on hegemonic status. But it is important to recognize that the dominant discourse also reflects important changes that have been taking place within the practices of science and technology.

While certainly not all technological change has become a matter of science-based innovation, there can be no denying that both information technologies and genetic technologies have become significant contributors to economic growth in many industrial countries. And as is readily apparent, these types of technology distinguish themselves from other types of technology in at least three major respects. On the one hand, they are scientific, or laboratory-based technologies, which means that they require major expenditures on scientific research for their eventual development. And unlike the science-based innovations of the early 20th century, which were, for the most part, applications of a scientific understanding of a particular aspect of nature (microbes, molecules, organisms, etc), these new technologies are based on what Herbert Simon once called the sciences of the artificial. Information technology is based on scientific understanding of man-made computing machines, and biotechnology is based on scientific understanding of organisms modified by human intervention.

Secondly, we are dealing with technologies that are generic in scope, which means that they have a wide range of potential applications in a number of different fields, sectors and life-worlds. As opposed to earlier technologies, which were primarily based on finding solutions to identified or, at least, identifiable problems, these are solutions in search of problems. In this respect, both information technologies and biotechnologies are idea-driven, rather than need-driven, which means that, in relation to their social uses, they are supply-driven, rather then demand-driven. That is one of the reasons why they require such large amounts of marketing and market research for their effective commercialization, and indeed for their development. Their generic nature means that the process of innovation is dependent on a particular “trajectory” being defined, articulated, planned and implemented. In other words, there is a need for a rather large amount of strategic thinking.

Finally, these advanced technologies are transdisciplinary in what might be called their underlying knowledge base; that is, their successful transformation into marketable commodities requires knowledge and skills from a variety of different specialist areas of science and technology. In earlier periods of technological development, there were clearer lines of demarcation between the specific types of competence and knowledge that were relevant; indeed the classical categories of engineering are based on the particular types of scientific and technological theories that were utilized (chemical, mechanical, combustion, aerodynamic, etc). Genetic engineering and information technology, however, require expertise and skills from a wide range of scientific fields, and, even more crucially, a competence in combining knowledge from different fields: hybridization. The genetic engineer is neither (merely or exclusively) a scientist or a technologist, but rather a kind of hybrid combination of the two previously separated identities or roles. For this reason, the new technological fields have been characterized as being a part of a new “mode” of knowledge production, which is sometimes referred to as technoscience (Gibbons et al 1994).

Sociological approaches

While economists have tended to dominate the field in recent years, there has nonetheless been a range of quite different activity within the social study of science and technology, or science and technology studies which is broadly sociological. During the 1960s and 1970s, several approaches to the social study of technology developed both within sociology itself, as well as in neighboring fields like history, psychology, anthropology and philosophy. Particularly influential within sociology was what might be called the “rediscovery” of the sociology of knowledge, especially in the book by Peter Berger and Thomas Luckmann, *The Social Construction of Reality*. Together with a number of other contributions, published in the tumultuous 1960s, such as Thomas Kuhn’s *Structure of Scientific Revolutions* and Herbert Marcuse’s *One-Dimensional Man*, Berger and Luckmann helped to open up the previously closed world of science and technology to sociological investigation. In the 1970s, it was primarily the natural scientists who were the objects of this attention, but by the late 1970s, technology also began to be seen as a legitimate topic for sociological scrutiny, and a range of sociological approaches to technology started to develop.

What all sociological perspectives on technology share is an explicit focus on actors, and on their actions, in relation to technological development (see Bijker, Hughes and Pinch, eds 1987). For some, actors are characterized as translators, and their actions are seen primarily in relation to particular projects of hybridization, by which humans and non-humans construct reality. This sociology of translation puts emphasis on actions of enrollment and mobilization, and has been developed by the Frenchmen Bruno Latour and Michel Callon, to show why certain technological projects fail (the French electric car is one favorite example), while others transform society in fundamental ways (Latour’s “pasteurization” of France). The point here is that technological change is a kind of lever, or vehicle, of broader social changes, and to be successful, technological “actors” must build networks both with the non-human things they are interested in, as well as with other humans. Underlying it all is a kind of entrepreneurial model of human behaviour, and a rather instrumental view of social action.

For other sociologists of technology, the actors are seen as pursuing one or another kind of interest, be it personal, political, or religious, and the social construction of technology is viewed as a kind of negotiation process, by which interests are either in a state of conflict, or are combined in one or another compromise. The interest resolution is, for Wiebe Bijker, one of the most influential social constructivists, seen as a process of “closure” by which a particular meaning or interpretation of technology is stabilized. His examples range from the safety bicycle to the electric light bulb and the industrial material bakelite (Bijker 1995). On a more systemic level, the historian Thomas Hughes has focused attention on the actors who construct large technical systems, like electricity distribution and production systems. Hughes and many other historians of technology, such as David Noble and Donald Hounshell, emphasize the actors who work, so to speak, at the interface, or boundaries, between technology and society: the academic engineers and management scientists, the funding agencies of technological projects, the corporate executives who create links between various institutions, etc

In general terms, we can think of all social action in relation to technology as a kind of network-building, by which various brokers or mediators establish connections between different fields of knowledge and different types of people and organizations. As a general term, mediation includes both the translation and enrollment that is so important for Latour and Callon, as well as the flexible interpretation that is emphasized by Bijker. What is primarily involved in mediation is the construction of new kinds of “hybrid” identities, literally new forms of action that cross over previously separated domains or areas of social activity. In this sense, technology as social construction focuses on practices, as well as role and identity formation.

A cultural approach

While most discussions of technological innovation have been framed within the language and terminology of economics, other meanings have recently been given new significance and actuality, particularly with the coming to market of products based on genetic engineering. The techniques of genetic manipulation have brought to the surface of public consciousness a number of critical ideas and perceptions, which we can characterize as a wide-ranging "cultural critique of technology" (see Baark and Jamison, eds 1986). The very real lack of interest and even distaste that many people feel towards genetically manipulated organisms is quite visible, and it is difficult to understand those processes - of rejection, resistance, dissatisfaction, and annoyance - within the vocabularies and theories of economics or even sociology. According to economics, those products should never have been developed if there had not been a recognizable "demand" for them; and according to sociology, they should never have gotten as far as they have without important social groups being interested in them.

But in most of the world, and for a great many people, these technologies are seen primarily in negative terms, threatening traditional beliefs and ways of life, as well as forms of livelihood and employment, particularly in relation to agriculture, but also in relation to the integrity of the human body. What is so characteristic of the opposition to genetic technology - both in Denmark and the United States, as well as in many developing countries - is the feeling of powerlessness, the sense that decisions about technologies are made by far too few people. Also involved of course is the generalized notion of risk and the idea that we are living in what Ulrich Beck has labelled a risk society, which means that these technologies are intrinsically not "goods" that people really need, but they are more like "bads" that simply produce all sorts of dangers and uncertainties (Beck 1992). That is why terms like trust, ethics and accountability are so much a part of the public discussion about genetic technologies, and why so many different kinds of people are seeking to establish new, more direct forms of empowerment and public accountability. If money is to be spent on new technology, then it has to be made clear why; and even more importantly, it has to be shown that those technologies are useful. Technological change, in this context, is seen from the perspective of the user, rather than the producer. Of course, as we see in many of the contemporary debates about genetic technology, this can lead to strange sorts of alliances and campaigns, but what links the third world critics of genetic technology with the representatives of the small farmers and shopkeepers throughout Europe and North America is what might be called an interest in whether these technologies are "appropriate" or not.

What these debates about genetic technologies make abundantly clear is that something has gone wrong in the processes by which technologies are integrated into society. On the one hand, there are problems at a discursive level; the idea of genetic manipulation runs counter to many important idea traditions in our societies, both in relation to the meaning of life, but, even more importantly, to the very notion of human being. If our very beings are reducible to a genetic code, that can be manipulated and recombined and "cloned", then many people react negatively.

On an institutional level, our societies have great difficulty in establishing appropriate organizational forms and, more generally, normative principles to deal with these technologies. There are of course a range of ethical councils and agencies of technology and risk assessment, but the problems with genetic technologies and their acceptance have not gone away for that. Even more significantly, genetic technologies have not entered into everyday life worlds, in terms of becoming integrated into customary behavior patterns, and internalized in personal identities.

What has yet to develop are, we might say, adequate forms of appropriation for these new genetic technologies, and it makes it important to develop frameworks of analysis that can help us understand the relevant social processes. Much can be learned from previous technological transformations - mechanization, electrification, automobility, for example - when similar technologies, frightening at first, were made to fit into society through what might be termed a multilayered matrix of cultural appropriation processes. Understanding these processes of technological change requires insights primarily from the cultural sciences, rather than the economic or social sciences - from such fields as cultural and intellectual history, anthropology, linguistics, etc. It is the discourses and organizational cultures, the everyday life experiences and language games that are essential to grasp, as technologies are appropriated into societies.

Box 2

The Cultural Appropriation of Technology

	Phenomenal Level		
	Structures	**Systems**	**Artifacts**
Analytical Level			
Discursive	Language *Assimilation*	Grammar *Disciplining*	Semantics *Familiarization*
Institutional	Rules, standards *Normalization*	Corporations *Organization*	Media *Dissemination*
Practical	Customs *Habituation*	Routines *Domestication*	Behavior, identity *Internalization*

What is involved, at different phenomenal levels, are different types of appropriation processes, and it is important to recognize these processes tend to occur in a fragmented way; They do not occur all at once; they overlap and interact with one another in complicated ways. Mechanization, electrification, computerization, genetic engineering affect both the ways we talk and think, as well as the ways in which we carry out our practical activities. Our language takes on new words and alters old ones, as technical artifacts are adapted to our discursive codes and frameworks. In our day, information and the genetic code have become central metaphors for all sorts of phenomena, and new words and concepts have entered our vocabularies while familiar ones have taken on new meanings. Our societies develop new forms of organization and interaction, of regulation and governance, as technologies impose their systemic and “infrastructural” requirements on the social order. We now have genetic counsellors and the scientific field of genomics, biotechnology companies and genetic forensic experts. And in our everyday life-worlds, we take on new identities and must learn new skills, as our practices are altered by technological and scientific innovations. We have to learn what is in the food we eat and the seeds we plant, and we have to reflect on the choices we make in the supermarket.

The sheer variety and range of these processes makes it difficult to generalize or identify typical patterns. Much depends on the specific process of technological change that is being discussed. “Science-based” processes, such as atomic energy and genetic engineering, where solutions are developed in search of problems, follow rather different patterns than “needs-based” processes, where problems, be they environmental, health, social, or technical, generate efforts to come up with meaningful solutions. Similarly, we can think of “activity-based” processes, driven, for the most part, by those responsible for particular functional areas in our societies - transportation, communication, sanitation, defense. Here, appropriation is a process of selection, among both ideas and artifacts, and primarily consists of social innovations by which improvements are made to various infrastructures.

Within each of these typical areas, there are characteristic patterns and different stages, or phases of appropriation, as acceptance and familiarization accompany diffusion and increased use. There are also significant geographical differences. Technologies are appropriated not just on a global, or general level, but rather, and for the most part, they are filtered into national traditions and languages, as well as into regional and locally distinctive organizational and institutional cultures.

What is considered appropriate behavior in one neighborhood or community can often be ruled out in another. Energy and transportation use, to take two obvious and current examples, while similar in many respects, nonetheless differ from place to place, due to particular local contingencies, both natural and social, political and economic, but also due to different “ways of life”, different patterns of culture. The effort to change one’s behavior into more ecological directions, for example, are shaped by one’s habitus and station in life, as well as by a range of practicalities. A focus on processes of appropriation is thus a way to bring out the multifarious and multicultural character of technological change.

Conclusions

From a theoretical perspective, it can perhaps be useful to consider these different meanings of technology and these different processes of technological change in relation to what Raymond Williams once termed “cultural formations” (Williams 1977). For Williams, social and cultural change involve at their core the emergence of new “structures of feeling”, new sensibilities, new mixtures of ideas and practices, or what Williams termed “social experiences in solution” (Ibid: 133).

According to this terminology, capitalism, for instance, could be considered an emergent cultural formation that developed in struggle against the dominant, or hegemonic religious culture of the medieval church, on the one hand, and the pre-Christian pagan cultures, on the other. As an emergent cultural formation, capitalism, and somewhat later, industrialism, established what we might term a particular mode of technological appropriation, including a discourse of instrumental rationality and science-based progress, an institutional structure of industrial research and development, and an integration of these ideas and practices into everyday life. In the 19th century, socialism emerged as a cultural challenge to the dominant capitalist formation, on the one hand, and the residual formations of rural life and Christian religion, on the other. But in the course of the 20th century, the socialist challenge was largely incorporated into the dominant cultural formation, even though, in many countries, certain ideas and practices did exert an influence on the dominant culture. In our day, environmentalism has developed as an emergent cultural formation, and like socialism in the 19th and 20th centuries, environmentalism - or what I like to call an ecological culture - faces both the pressures of incorporation from a dominant commercial culture, on the one hand, as well as the resistance of the residual groups of populists and neo-populists, both in Denmark and elsewhere, on the other (see Jamison 2001).

In this sense, we can think of the transnational corporate culture, with its reduction of technology to economic innovation, as our contemporary hegemon, the dominant cultural formation, or technological regime, that seeks to incorporate all technical developments into its greedy, accumulative grasp; and we can think of the “anti-modern” forces of resistance to globalization in its many forms as residual cultural formations, a technological regime which is trying to adapt technological development to older ways of life and belief systems. Where the one tends to adopt an attitude of technological determinism, seeing a kind of fundamental driving force for social change in technological innovation, the other seeks to impose its own values on the pace and direction of technological change. An ecological sensibility can then be considered part of an emergent, or emerging cultural formation, a new sort of regime that, as in the past, must struggle both against the dominant and the residual cultural formations in its efforts to affect meaningful technological change, but which also is neither economic nor cultural in its “determinism”, but more synthetic, contextual, and pragmatic in its relation to technological change.

Box 3

Contemporary Technoscientific Regimes

	Residual	Dominant	Emerging
social process	appropriation	innovation	construction
type of agency	local	transnational	hybrid/synthetic
form of social action	resistance	commerce	mediation
type of knowledge	traditional/ factual	scientific/ professional	situated/ contextual
tacit forms	personal	disciplinary	experiences

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Summary

The various contributions in this report demonstrate the relevance of studying social aspects of modern biotechnology. From different perspectives - and applying a variety of methods - the presentations touch upon differentsocial aspects of biotechnological knowledge production.

The first cluster of presentations was focused on the perception of modern biotechnology amongst different segments of society. As an introduction to this subject, Siune presents the definitions applied in national and international statistics. The divergent definitions emphasize the social contingency of biotechnological knowledge production. Some definitions refer to the interaction between science and industry, others to science and society, and the most recent stress the convergence of biotechnology and knowledge society. The various definitions illustrate the multifaceted interaction between biotechnology and its surrounding context, and further, they show that the meaning of modern biotechnology cannot be unambiguously pinpointed.

The contributions of Lassen and Mejlgaard address the issue of citizens' perceptions of and attitudes towards biotechnology. Based on evidence from seven focus group interviews, Lassen maps the relatively complex processes of attitude formation regarding specific applications of biotechnology, such as genetic modification of food and medical gene technology. Whereas biotechnology within health care is not totally rejected by anyone, the only argument having general appeal in favor of GM food is related to the possible benefits for the third world. It is vital for public support, Lassen argues, that the application in question is perceived to be beneficial to society, meeting actual needs rather than creating new ones. Further, it is important that the perceived risks are acceptable, and it is a necessary precondition that the application is not offending moral values such as justice or democracy.

Mejlgaard presents results of a large-scale survey conducted in Denmark in 2000 that are in accordance with the results of the focus group interviews. The quantitative data reveal similar patterns of attitude formation. The level of public trust in scientists is accentuated as an additional explanatory factor regarding attitudes towards biotechnology. Both Lassen and Mejlgaard stress the importance of constructive dialogue between scientists and citizens as a prerequisite of public support of modern biotechnology. The impact of factors such as risk-perception and trust in scientists on attitudes - as compared to the minor impact of basic knowledge - suggests that one-way communication of research results, in order to increase the average knowledge of biotechnology amongst citizens, is an insufficient strategy with regard to increasing public support of biotechnology. In order to increase the public support of biotechnology, it is vital to create bonds of trust between science and society.

Meyer & Sandøe demonstrate, that there are in fact important obstacles to fruitful dialogue between scientists and citizens. Based upon the results of a research project on communication between scientists and the public, Meyer & Sandøe conclude that there are noticeably divergent perceptions of biotechnology amongst scientists and citizens respectively. Citizens tend to talk about applied biotechnology in a social, economical, and political context, stressing ethical aspects, and using a narrow, moral concept of usefulness but a broad concept of risk. Scientists tend to talk about biotechnology in the laboratory, stressing technical and strictly scientific aspects of science, and using a broad, commercial concept of usefulness but a narrow concept of risk.

According to Meyer & Sandøe, one of the main reasons that scientists retain from participating in the public debate on genetically modified crops and food is exactly the difference in perception of biotechnology present. A distinct finding from a survey amongst scientists within plant biotechnology was that 3 out of 4 scientists agreed that lack of biological knowledge is the main reason for public resistance to genetically modified food and plants. Following Lassen and Mejlgaard, this is not the case. The basic knowledge of citizens is a variable with limited predictive power regarding attitudes towards biotechnology, whereas variables such as risk-perception, moral judgment, and trust in scientist have a greater impact on attitudes.

By examining the media coverage of modern biotechnology, Horst adds an important perspective to the perception of this field of research. Combining qualitative and quantitative analyses of 1600 newspaper articles from 1997 to 2001 on health related biotechnology, Horst provides an insight into the intensity of coverage and the assessment of different technologies. Within the four-year period of the project, 'genome mapping' had the highest coverage rate. The pharmaceutical use of biotechnology and the question of genetic testing received the most positive coverage, whereas the media coverage of human cloning was rather negative. Using reproductive cloning as an example of a controversial story, Horst identifies distinct paradigms of interpretations, represented by the four Danish newspapers examined. The differences in paradigms support the general impression from this cluster of presentations, that perceptions of biotechnology vary, and that it is vital for the validity of the deliberations of the future societal debate on biotechnologies, that these differences in perceptions are rendered visible and are acknowledged.

The second cluster of presentations was focused on the behaviour of private companies within biotechnology. Based on evidence from a qualitative research project, Norus suggests that the small biotechnology firm best can be perceived as a loose entity, a temporary meeting place, solely defined by its portfolio of R&D projects rather than a well-defined unit with clear jurisdictional boundaries. On the basis of profound insight into the history of technology and trial and error learning the small firms have been able to overcome the critical mass problem through strategies that mobilize the necessary knowledge, skills and financial resources in external networks. This has led the small biotechnology firms to hand over ownership of the technology and management authorities to venture capital firms. These formative arrangements are allowing the companies to remain in control over the development of the core technologies, but at the same time they are handing over authority of parts of the company in which the founders are not interested. This calls forth a system of stakeholders in the biotechnology industry that has both the interest in and the competency for taking over the functions that are left out.

Along the same line, Troelsen examines the cooperation between a knowledge-based entrepreneur and venture capital drawing upon the insights of principal-agent theory and resource-based theory, empirically supplemented by in-depth interviews. Motivating the workforce to act in line with the interest of the firm, Troelsen argues, could increase the probability of creating mobility- and entry-barriers through isolation-mechanisms. This is best done by giving ownership to the entrepreneur and other leading people in the new knowledge-based entrepreneurial firm and extending this as the firm grows. Creating incentive contracts to the workforce in the firm is also a way to motivate the workforce to act in line of interest with the firm. Together ownership and incentive contracts can be an effective way for management in a new knowledge-based entrepreneurial firm to build and develop isolation-mechanisms. Hereby mobility- and entry-barriers are created making it possible for the firm to sustain and develop a competitive advantage through continuing access to economic rent.

But who is in fact the entrepreneur in the Danish biotechnology sector? Analyzing the differences between the entrepreneurial set-up in the Rhône-Alpes region and the Medicon Valley (Øresund-region) respectively, Nelund identifies the venture capital company as the real entrepreneur in Medicon Valley. This affects the organising principle inside the organisation and also the constitution of the biotechnology field. The comparison between the two regions shows the impact of the external context on the organizational aspects of the biotechnology field. The relatively limited possibilities of knowledge transfer from the university, together with poor independent business support during the start-up phase, explains the very influential position of the venture capital companies in Medicon Valley. The venture capital companies seek to minimise risks through the selection of management. This is forming the managerial role as an organising principle in Medicon Valley and the typical manager is graduated from the university with a scientific degree or a Ph.D. The experience as manager is achieved through on-the-job training in a pharmaceutical company, rather than in a university, which implies, that the manager is dependent on the venture capital companies' existing knowledge network. The pharmaceutical manager introduces the pharmaceutical way of organising research – a formalised and planned way of research. Thereby the organising principles in Medicon Valley are on several areas similar to those of a pharmaceutical company.

The aspect of management and leadership in biotechnological research is being further examined by Mønsted. Management and leadership in research, Mønsted argues, is characterized by a lack of certainty, transparency and the asymmetric knowledge of the technical aspects of the projects. In order to adapt to the conduct of science, the usual linear project management has to be replaced by other simultaneous developments. Small and new biotechnological firms do not have management in the normal sense. They have to establish a network and create a networking behaviour, generating 'the meaning of management' in their network. They do not start by having specified roles, and this makes the networking as action very important. Tight and loose relations and the combination of these create the organising set-up, the infrastructure in which confidence has to be generated in order to create a positive experience to develop more trust and more positive reference points via the primary network. The role of the manager has to adapt to the many uncertainties and complexities. Also it is important that control of projects is not the power to control in the usual sense of the concept. It is much more a question of negotiation and dialogue. Research management is not steering, but rather a 'yo-yo' of opening and closing relations and project perspectives, Mønsted argues.

The third cluster of presentations was focused on the impact of biotechnology on society. Mortensen approaches the question with particular reference to the subject of finding relevant indicators of intention, input, production, output, impact, and innovation in the field of biotechnology. These are elements of relevance to providing systematic comparative statistics on R&D in biotechnology, and Mortensen assets the presence of such data in OECD countries. His general conclusion is that there is lack of systematic data collection in most countries, and, in addition, the methodology applied is not uniform. The need for a coherent system of data collection, including a common definition of biotechnology and comparable units of analysis, is accentuated. Nonetheless, Mortensen presents a number of comparable indicators of knowledge production within biotechnology such as the government budget, share of R&D expenditures within the public and private sector, number of full time researchers, level of private/ public cooperation, national share of the total number of scientific publications, citations and patenting, and venture capital investments in biotechnology.

Hilpert & Bastian present results from a research project on 'islands of innovation' in biotechnology, which refers to geographical entities that are based on regional settings of enterprises and research institutes. Studying life cycles of such biotechnology locations unveils that the provision of skilled labour and the international orientation constitute crucial determinants for a successful development. Regional concentration of innovation processes and the emergence of particularly vital islands of innovation very much depend on the qualification and availability of scientific personal on the local labour markets. Additionally, a high share of scientists from other islands of innovation and out of other research set-ups is an important precondition to get knowledge transferred to the respective locations and creativity unfolded through synergy and co-operation. Based on evidence from three islands of biotechnological innovation in Scotland, USA, and Germany, Hilpert & Bastian argue that the two main determinants of dynamic growth – the provision of skilled labour and the global orientation – require a specific use of a given location’s advantages. An adequate choice of policy instruments needs to be combined with a fine-tuned sequencing of policy steps in correspondence with the location’s development. Furthermore, the success of public innovation and technology policies depend on the creation of an enabling perspective for locations with a comparative advantage in one or more technology fields. Such perspectives can be created by support programmes addressing directly R&D institutes and companies, by stimulating the creation of networks or by directly promoting entire locations.

In his account of knowledge production within the field of biotechnology, Larsen emphasizes the interface between biotechnological R&D and society not only as an empirical fact, but also as a normative statement. According to Larsen, It is fair to expect biotechnology to contribute, and research policies should secure a research environment that will - in turn - succeed in creating societal benefits. Larsen draws attention to a number of elements in the Danish research policies that need to be improved. According to him, the Danish research system is characterized by under-funded research groups, too few tenured positions, too restricted possibilities for young scientists in the university sector, and recruitment problems, just to mention some of problems Larsen refers to. Nevertheless, brilliant research is still being performed.

Hilpert & Bastian and Larsen are concerned with identifying the adequate choice of policy instruments to secure a well-functioning biotechnological development, which will in turn be economically beneficial to society. Assessing the impact of biotechnology on society, Arundel argues that the non-economic - or quality-of-life - benefits are likely to be substantially larger than the economic benefits of biotechnology. He stresses the need for developing valid indicators to capture the non-economic benefits of biotechnology, indicators of the applications of biotechnology, and the policy challenge of feeding an evaluation of such indicators back into the policy-making process. Further, Arundel argues that the choice of indicators is not politically neutral. Health care related biotechnology could thus be evaluated either quantitatively in terms of sales of bio-pharmaceuticals or, qualitative measures of bio-pharmaceuticals - such as their therapeutic value - could be introduced.

Finally, Jamison provides a more general insight into 'the politics of technoscience' and the development of conflicting technoscientific regimes. Jamison argues that the dominant cultural formation regarding technoscience, characterized by its reductionist equalization of technology and economic innovation, is being challenged not only by a residual technoscientific regime which is trying to adapt technological development to older ways of life and belief systems, but also by an emerging cultural formation, which is more synthetic, contextual, and pragmatic in relation to technological change than the traditional regimes.

List of selected publications from
The Danish Institute for Studies in Research and Research Policy

2002

2002/1 Dynamik og fornyelse på danske universiteter og sektorforskningsinstitutioner
En analyse af hvad der karakteriserer dynamiske og fornyende forskningsmiljøer
ISBN: 87-90698-54-1

2001

2001/1 Science under Pressure. Proceedings
ISBN: 87-90698-40-1

2001/2 Folk og Forskning - Opfattelser og holdninger, 1997-2000
ISBN: 87-90698-43-6

2001/3 Videnskabelighed - Femten portrætter
ISBN: 87-90698-44-4

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ISBN: 87-90698-45-2

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ISBN: 87-90698-45-2

2001/6 Et forsøg på Benchmarking - En analyse af de samfundsvidenskabelige og juridiske institutter ved de højere læreanstalter
ISBN: 87-90698-49-5

For a complete list of publications see: http://www.afsk.au.dk

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