Research in Biology and relevant areas of Biochemistry in Norwegian Universities, Colleges and Research institutes

Report of the Principal Evaluation Committee

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To the Research Council of Norway

The members of the Principal Evaluation Committee for the Review of Research in Biology and Relevant Areas of Biochemistry at Norwegian Universities, Institutes and State Colleges submit the following report, based on the general conclusions and recommendations of Panels 1, 2 & 3.

The views expressed in this report are the consensus views of the Committee. The members of the Committee are in collective agreement with the assessments, conclusions and recommendations presented.

November 30, 2000

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Executive Summary

In recent years the biological sciences have seen unprecedented advances, with the sequencing of the human genome being just one example. These advances have resulted from a combination of rapid developments in technology and from the formation of new linkages between the biological and computational sciences. These changes have also increased the international competitiveness of biological research and have increased the speed at which new discoveries are transferred from the research bench to the society and to industry. This report integrates the findings, conclusions and recommendations of the three independent Review Panels responsible for evaluating the performance of basic research in Biology and Relevant areas of Biochemistry in Norway. The conclusions drawn by these panels were striking for the overall agreement that research in the biological sciences in Norway, with some quite notable exceptions, is performing below international standards. This level of performance was linked to several factors related to both funding and the research traditions in Norway. These factors include:

- A low overall level of funding for basic research in the universities and institutes.
- The practice of funding basic science through programs rather than through merit-based peer reviewed grant proposals motivated by the individual researcher.
- Low mobility of Norwegian scientists, resulting in sub-optimal levels of innovation.
- Insufficient scientific leadership.
- A lack of strategic planning, leading to fragmented research profiles and poor cohesiveness within university departments or other research units.

Despite this critical general assessment we emphasise that the biological sciences in Norway supports some internationally outstanding scientists as well as many others who perform very good, competitive research. As a result there are opportunities to develop the research potential of the biological sciences around these individuals if changes are made to the funding systems and research traditions. To this end we make the following recommendations:

- To foster competitive science at an international level it will be necessary to increase the level of funding for research, targeting this increase to peer reviewed basic research.
- University and Institute departments should develop research strategies and focussed research profiles.
- We recommend that a Molecular Life Sciences Institute be established with a focus on functional genomics and proteomics. The aim should be to develop an outstanding institute that can provide national leadership to the biological sciences and that can give Norway a voice in international developments in science.
- We support the establishment of the proposed centres of excellence, with the aims of developing regional research platforms in which researchers from different institutions act co-operatively rather than competitively, to promote strong disciplinary excellence, and provide competitive training for young investigators.
- It is essential that the mobility of young Norwegian researchers is increased and that they gain broad international experience so that a new generation of competitive scientists develops that is capable of leading scientific research in Norway.

Preamble

The Research Council of Norway initiated this wide-ranging evaluation to get advice on how best to support and foster basic research in Norway, with the view of building the knowledge platforms necessary to ensure continuing economic development. In initiating this review, the Research Council has been addressing much the same set of problems troubling other national funding bodies. This means that this evaluation, although it has the primary objective of assessing Norwegian basic scientific research, will have broader implications and it will become part of the ongoing European and international discussion on how to foster internationally competitive science.

The evaluation of Research in Biology and Relevant Areas of Biochemistry has involved the work of three different and independent Review Panels, and their reports form the basis of this overall assessment by the Principal Evaluation Committee. In general, the Review Panels did not assess research performance at the level of the individual researcher but remained at the level of the University Department or research group. This report therefore address the performance of both the research and the funding systems at the national level and addresses the structural issues that we saw as limiting the ability of Norwegian scientists to compete at the highest international level.

The Role of Basic Research

Before summing up the general conclusions and recommendations of the evaluation we would like to briefly discuss the general issue of the role basic research plays within society. Basic research in science operates with two principal driving forces. One derives from the curiosity of the individual scientists, searching for an understanding of nature for the sake of understanding, and the second from practical needs that motivate a systematic search for new understanding in the relevant science disciplines, with the aim of solving a particular problem. Basic research therefore has both cultural and applied dimensions. Very often, particularly in the short-term, the two driving forces act synergistically and result in a solution being found to a particular problem. However, we must be aware that curiosity driven basic research can address questions well beyond our current understanding of nature, while program bound basic research, motivated by utilitarian objectives, has less freedom to explore because it is restricted by the need to solve a particular problem. This means that curiosity driven and utilitarian driven basic research often ask different questions and operate over very different time scales. Both facets of basic research need adequate support in a society that wants to build on knowledge, and neither curiosity driven nor utilitarian driven research can develop without the support of the other. Too often, national and European research policies ignore this fundamental duality of scientific research. In this respect, the post-war research policy of the United States has been more successful, as reflected in the large number of American based Nobel Laureates.

It is the view of this Evaluation Committee that those who set national research policies must recognise that investigator initiated basic scientific research is a key component of the societies infrastructure. Thus a democratic, knowledge based society must view science as an interactive force in its own right, with the potential to open new perspectives and

opportunities for the people and the society. Too often today this dimension of science is neglected as scientists, through national funding systems, have found themselves directed to apply and adjust existing knowledge to satisfy short-term national needs, rather than having the freedom to question present views and explore and reveal the unknown. Such policies greatly undermine the potential benefits of science for the society because it diverts scientists from participating in the international advancement of science from conceptual, disciplinary and methodological viewpoints.

Strong Basic Research Generates Good Returns

Norway is a highly educated, developed and wealthy nation and yet today it ranks among the lowest in Western Europe in its national investment into basic research[1]. Norway has a resource-based economy heavily dependent on the petroleum and fishing industries. Norway therefore bears a strong social obligation to exploit these resources in a safe, and where possible, sustainable fashion. To be able to do so demands a very strong base of forward-looking basic research (see the discussion above). To choose just one example, the extensive development of the aquaculture industry is currently based on few species with a limited genetic base, yet basic research into fish diseases and fish medicine is dangerously limited. Similarly, research into the potential impact on the genetic diversity and health of wild fish populations of large-scale fish escapes and of releasing fish diseases and parasites into the oceans is not adequate from the perspective of responsibly developing a major industry. The burden of proof in these situations is always with those who wish to exploit the natural resource and for such industries to develop responsibly they need access to qualified scientists who have the training required to ask relevant questions and to make the necessary in-depth studies. An educational system that is able to depend on an infrastructure of forward looking basic science, competing at the highest international level, is the best public investment to meet such present and future needs.

In addition to these shortcomings with respect to the responsible development of Norway's natural resources, resource-based industries have only a limited potential to provide an expanded base for high-income employment. As a result there is an urgent need for Norway to develop new enterprises that are not reliant on the exploitation of natural resources. Given Norway's standard of living and education levels, the only realistic option is to develop new enterprises based on advanced technology, which includes modern biology, biomedicine and biotechnology. If this goal is to be achieved, and it is a realistic goal, there is an urgent need for Norway to begin to invest in developing its basic research and associated research training to meet the highest possible international standard. Such investments in people, which can be regarded as the development of an important component of the nations' infrastructure, will generate substantive returns in economic, societal and cultural terms.

[1] Det norske forsknings og innovasjonssystemet - statistikk og indikatorer (pp.31-32). Norges forskningsråd, 1999.

Today There are Unprecedented Opportunities in Biology

With these points in mind we would like to highlight a number of very important international trends that we see emerging in biology, and to which Norway and other nations have to relate. Globally, biological and medical research is undergoing rapid changes in technology resulting in new linkages developing between biology and the traditional scientific fields of physics, chemistry, engineering and mathematics. These new linkages have led to the development of new technology driven methodologies including genomic analysis, complex systems analysis and computational techniques (e.g. geographical information systems). As a result of these new linkages, biologists are now in a position to address a new suite of conceptually driven questions. These are related not only to the advancement of biology as a discipline but also to various issues arising from human influence on the environment (e.g. ecosystems dynamics, management of human impact on the environment and the effects of climate change on organisms and their ecosystems).

The new technology driven methodologies, such as large-scale DNA sequencing are spawning major research programs with an enormous range of application. The genomic programs currently underway are accumulating more and more DNA sequence data for an increasing number of organisms. This development is now reshaping not only molecular biology but also the various fields of more traditional organismal biology and ecology. Increasingly, research strategies similar to those used in genomic sequencing can now generate knowledge about functional aspects of this genetic information. This development is often called “functional genomics” and it will open new opportunities for the study of complex biological phenomena (evolution, development, stress, adaptation, metabolism, diseases etc) at various levels of organisation from the molecule to the ecosystem. New emerging technologies such as proteomics (large scale protein analysis) and metabolomics (large scale analysis of metabolic products), linked to advances in bioinformatics and computational biology, are set to not only continue this revolution in the way biological questions are addressed but will increase the pace of change.

Similarly, technology driven advances in computer hardware and software such as geographic information systems are increasing our data collection capabilities and our data analysis requirements. One important application that is transforming ecological research is analyses of spatial patterns and relationships, where increased capabilities for data acquisition is allowing a new suite of questions to be addressed in both terrestrial and marine ecosystems.

Concept driven questions are increasingly commanding the attention of the international research communities and in the struggle to address these questions many of the new technologies are being called into play. It is now necessary to organise research to gather together the necessary knowledge and technologies to make use of the opportunities that lie in the combination of global databases and large-scale analytical techniques, all combined with strong computational and mathematical support. With these developments, biology and biomedicine enter a new era to which the academic systems in every country need to adapt. The new tools, and new questions generated by changing societal concepts, are having an enormous effect on the opportunities and progress of basic biological research. Being at the forefront of international biological research means participating in the development and elaboration of these new biological discoveries. To be able to conduct and support research at the leading edge increasingly requires the training of scientists capable of using, and at times developing, these new and rapidly evolving technologies. It

also requires a research environment that is able to maintain both broad disciplinary excellence and a focus on evolving complex questions that cross disciplinary borders.

International Competitiveness is Important

When discussing the research system of small nations such as the Scandinavian countries, one must be aware of the fact that biological and medical research is international and that it is difficult for a small country to make a major contribution in all areas of research. Because of this, it may be tempting to leave the search for knowledge to the major research nations and just pick up the knowledge second-hand and apply whatever happens to be immediately useful. However, such a strategy would be counterproductive because it would not create the stimulating and innovative academic atmosphere that is required for fostering new generations of qualified researchers. The result would be that without high quality basic science at the national level, applied science and clinically oriented research would also become much less sophisticated and less effective. Furthermore, it is simply not possible to conduct either basic or applied scientific research as if reading from a recipe, particularly when dealing with complex scientific and moral issues such as how to use our knowledge about the regulation of our own genes. Thus, it is necessary even for smaller nations to actively participate in the international developments in science. With a research system that produces results of high quality, as measured in an international context, smaller nations can make very significant contributions, including defining research directions, and become integral partners in major international developments in science. In this way global advancements in science, which would otherwise be far beyond the level of national investment, can be fully accessible to smaller countries.

In order to develop such a competitive research system it is necessary to acknowledge and embrace the notion that research is an elitist activity, and it will only be possible for Norway to promote internationally competitive research by providing incentives and rewards for those individuals who excel. In this respect scientific research resembles elite sports. A nation can only excel in international competition if it first provides sufficient reward for excellence to attract and recruit scientists from among the most gifted and motivated members of the society and second provides comprehensive financial, technical and advisory support from an early age so that these outstanding individuals can develop their maximum potential.

How to Become a Winner

With the biological sciences now entering a ‘post-genomics’ phase, there will be an enormous and rapid increase in our knowledge base. An important challenge for Norway and other nations will be how to position themselves both to successfully participate in advancing our knowledge in basic biology and also how to harvest this new resource for applications in medicine and biotechnology. At present it is clear that Norway is not a winner in this particular race but it has the resources, both human and economic, to become one. For example, for Norwegian scientists to become actively engaged in developing and exploiting these new opportunities in biology will require significant national investment into research training and infrastructure and increased co-operation between researchers from traditionally disparate fields. The one structure within society

that can make this investment to support long-term, competitive basic research is the government. This is not the role of industry and it is not the role of special interest groups within the society. The government has a special responsibility to support these new developments in basic research because if this support is not forthcoming it will not be possible to create optimal opportunities for the successful exploitation of new discoveries for the benefit of the nation.

Another strong trend in biology is the increasing involvement of commercial interests. This is not a new phenomenon since medicine, pharmacology, fisheries, agriculture, forestry, horticulture etc all have long traditions of developing in close interaction with science. However, the new developments in biology have resulted in a proliferation of new opportunities, resulting in the development of various types of partnerships between industry and academia. To remain internationally competitive in making and then commercialising new discoveries, it will be essential to develop methods to facilitate the rapid transfer of technology from the research bench to industry. To achieve this increased speed of technology transfer will require an increase in the number of trained specialists, such as patent attorneys. Facilitating technology transfer is not primarily a task for research scientists. It will also require the development of explicit procedures for technology transfer, to clarify issues such as intellectual property rights, to simplify the transfer of technology at the interface between the different research structures in the country and industry. This is important both to maximise the capacity of science for wealth generation and retention by the society and to ensure that the scientists drive the research, rather than having the research being driven by short-term demands of commercialisation. The establishment of the proposed centres of excellence[2] could be used to open up interaction with industry without jeopardising the research excellence that is the strength of such centres. These procedures may also include the establishment of Government incentive programs to promote entrepreneurship and to draw venture capital into start-up companies that can commercialise the discoveries of Norwegian scientists.

The Principal Evaluation Committee is fully aware of the need for a well-developed interaction between basic science and the commercial exploitation of knowledge. Information exchange needs to be two-way because in some instances industry may be ahead of academic institutes in developing new research approaches and technologies, and basic research can draw upon this industrial expertise just as industry can draw upon the developments in basic research. However, it must also be borne in mind that basic research and the commercial exploitation of knowledge operate with different goals that must not be blurred together. The goal of basic science is to lead the exploration of nature and to disseminate its results to benefit the society and its people, while the goal of industry and other commercial enterprises is to generate revenues through exploiting this knowledge. It is therefore important to secure independent but interactive platforms for basic research and the commercial exploitation of knowledge.

[2] Senter for fremragende forskning, Norges forskningsråd, 2000

Overview

The Principal Evaluation Committee was charged with the responsibility to draw up a summary report based on the reports of the three independent panels and to offer an overall assessment of the state of biological and relevant biochemical research in Norway, taking into account its quality and relevance in an international context.

The Committee was requested to evaluate:

1. The scientific quality of Norwegian biological research as a whole in the light of the resources available.
2. Which areas of research have a strong scientific position in Norway in a national and international context and which are weak? Is Norwegian research ahead of scientific developments internationally within specific areas?
3. In view of the scientific importance of the research performed, is the balance between individual fields of research reasonable?
4. Is Norwegian research lacking or under-represented in any particular important area, especially in internationally important fields in which Norwegian groups might be expected to make a significant contribution?
5. The Committee's conclusions should lead to a set of recommendations concerning the future development of research in biology and relevant areas of biochemistry in Norway.

With respect to the overall quality of research in the biological and medical sciences in Norway, the three panels found that approximately one-third of the research groups and departments reviewed were of a standard that was internationally ranked as very good or higher. Furthermore, those groups that performed well on the international scene were dispersed throughout the different research disciplines, although areas of particular strength and weakness were identified (see below). This is a good general level of performance, given the resources that are allocated to basic science by the Norwegian government. However, we would like to emphasise that the level of research funding in Norway is low in comparison with other OECD nations. As a result the level of performance by Norwegian research groups in the biological and medical sciences, as a whole, is also low by international standards. This observation by the present evaluation is also supported by the statistics available for defining scientific impact through international peer reviewed publications[3]. While we note that such broad comparisons of the impact of scientific publications are limited in their potential to identify either areas of weakness or excellence, the statistics show that Norwegian 'biologi og biokjemi' and 'molekylærbiologi og genetikk' have low impact internationally, while 'botanikk, zoologi og veterinærfag' may perform better. However, based on the current evaluation it is clear that performance within 'botanikk, zoologi og veterinærfag' is very heterogeneous and it is difficult to see how this relatively positive ranking can be maintained given that these fields have been slow to adopt the new methodologies flowing from genomics research. In addition to the low levels of funding, we also identified a number of structural issues that

[3] Det norske forsknings og innovasjonssystemet - statistikk og indikatorer (p.117). Norges forskningsråd, 1999.

contribute to this low level of performance and these will be discussed in detail in a later section of this report.

Despite this evidence of a dwindling research capacity in the biological sciences in Norway, this evaluation has shown that there are groups from diverse fields that were performing to an internationally competitive standard and these groups could provide a skilled nucleus around which Norway could build for the future. While it is for the Norwegian government to decide if it is in the national interest to increase funding support to these research groups, it is important to note that the three panels independently recommended that Norway should urgently increase its funding support for curiosity driven, investigator motivated basic research so as to create a more favourable balance between basic and applied research. The Principal Evaluation Committee strongly endorses this recommendation since, as stated in the preamble of this report, we are convinced that a successful knowledge based society needs to rest on a strong infrastructure of basic science. Such an infrastructure must be built around internationally competitive scientists that are given the necessary trust and long-term funding to lead the development towards a strong science base.

Outstanding Research Fields

While we were able to identify many individual research groups conducting very good to outstanding research, two separate research fields stood out as ones where Norway excelled. These were Population Biology and Neuroscience. In these research fields Norway has outstanding groups who have a deep understanding of their subject, with diverse experimental and theoretical approaches, and with several individuals who are international leaders. We identified three major factors that contributed to these two fields performing at an outstanding level: 1) They are lead by outstanding scholars who are strong scientific leaders; 2) These leaders have been successful in attracting talented and ambitious young students and graduates; 3) The groups have managed to find ways to secure reasonable levels of funding. These research fields are fine examples of how long-term research excellence can be built around outstanding individuals if the motivation, incentives and support are available.

Existing Priority Areas in Norway

Marine science is a traditionally emphasised area of research in Norway and all three Panels reviewed various aspects of marine science. This very diverse research area contained many very good to good research groups from both the university and institute sectors but also many groups that were performing well below what should be expected given the resources available. For example, the Panel reports identified marine microbiology as one strongly developed field performing well but they also identified key sub-fields that were under-represented, notably developmental biology, especially including the use of zebra fish as a model organism. Both Panel 1 and Panel 3 identified marine science as an area that requires a detailed, focused, international review in order to utilise better the significant national investment into this research field.

In addition, aquaculture research in Norway in general tends to have an empirical approach to problem solving rather than an approach based on basic research. While this might appear to work in the short-term it is not a sound basis for the long-term development of a major industry. At present the basic research component of this industry is not of a high enough standard to support its stable expansion or to ensure its future economic viability. Related to this, Panel 2 noted that basic research in agricultural and veterinary science is generally very poorly developed in Norway and critical areas of research such as fish medicine and fish diseases, especially basic research into microbial pathology and virology, are definitely under-developed. There is an urgent need for these fields to be developed as strong basic research disciplines in their own right so that Norway develops the expertise and experience that can also be called upon by industry upon request. One approach to begin redressing this deficiency may be to merge the veterinary and agricultural schools and move the research and advanced education into fish medicine to a locus of fish biology, such as Bergen.

Arctic biology is another prioritised research field in Norway. There are excellent facilities available and it is an area of research that is appropriate for Norway to emphasise considering its geographical location. In addition to studies aimed at describing the Arctic environment and the impact of this harsh environment on the organisms found there, there are opportunities for Norwegian scientists to address questions of general biology using the special conditions of the Arctic. At present there is little evidence that any of the research groups engaged in Arctic research are attempting to take this approach. Rather, most Arctic researchers have a very similar descriptive approach with a strong emphasis on monitoring, frequently without specifically defined research goals. This situation may be a reflection of the traditionally low mobility and of the in-house training and recruiting that is prevalent in this research field. It is the Committee's view that what is needed for research in Arctic biology to develop is the creation of a strong core of basic biological research that utilises the Arctic environment to address general questions in biology. The existing more descriptive/monitoring research could then draw support and inspiration from this strong core of basic research, and those working on more fundamental questions could draw on the expertise and data generated by the long term monitoring programs to maintain a focus relevant to the changes taking place in the Arctic environment. All research groups need to aggressively recruit and collaborate with researchers who are not necessarily specialists in Arctic research so that they can begin to use their unique opportunities to address more fundamental questions. As with marine science, there is a clear need for an intensive international review of the many Arctic research programs, which should include experts from relevant fields without specific 'Arctic' research experience (e.g. from the fields of marine science, computational biology, molecular life sciences, climate change etc).

With the present strong emphasis on marine and Arctic biology, often with an associated strong emphasis on short-term utilitarian objectives, we see a clear risk that these areas will develop into protected refuges detached from the vital competition and necessary influence by other fields of science and technology. The Committee hopes that the reviews that we recommend could serve to stimulate these prioritised fields of research so that Norway can succeed in its ambition to become an international leader in these fields.

The Research Institutes

Norway has a very strong Institute sector that responds to the needs of the various Ministries. In general the Institutes have a very low impact on basic science, which may be understandable in view of their objectives to study and find solutions to current problems. However, some Institutes do conduct important basic research and as a result the question of whether the Institutes should have a role in fostering internationally competitive basic research needs to be discussed at the national level. The problem of balancing applied and basic research in mission-driven Institutes is not new and good examples were identified of how this can be addressed by strong collaboration between Institute staff and their academic counterparts. Such collaboration serves many positive functions, including helping Institutes maintain a significant focus on basic research, thus creating collaborative platforms between basic and applied research.

The balance between Institutes and Universities is especially important in both marine science and Arctic biology because of the very high infrastructure costs of owning and operating ocean-going vessels, and because of the high general costs of conducting research in the Arctic. It is therefore important to ensure that projects that obtain ship time or transport and access to the Arctic facilities are of the highest quality. To make the most of the infrastructure for promoting basic research, to make the most of the various long-term monitoring programs and to ensure that applied research is built on the strongest possible base in the future, it is important for marine science and Arctic biology research to be organised jointly by the leading scientists from many disciplines and from both Institutes and Universities.

Weak Research Areas

In addition to these weaknesses identified above in the broad fields of agriculture and veterinary science, marine science and Arctic biology, there were a number of other specific research areas that are important for the development of the society and the economy that were identified as only weakly represented in Norway. As mentioned in the preceding section, there have been very rapid advances in the experimental biological sciences resulting in what amounts to a revolution in the way basic biological research is being performed. This revolution involves the development and adaptation of a range of new technologies in molecular biology, such as genomics and proteomics platforms that are developed in conjunction with transgenic model organisms in both the animal and plant sciences. Norway is lagging well behind its neighbours in Scandinavia and Europe in applying and developing these techniques and without urgent investment in these areas Norway will not be able to capitalise on the commercial developments that come from a range of fields of basic research. We view this as an example of what can happen when too much emphasis is put on directed science at the expense of investigator initiated, curiosity driven science that uses selection criteria focused only on scientific quality.

Related to the poor investment into these new technology platforms, Norway is also very weak in its development of computational biology, including bioinformatics and the modelling of complex systems (from the cell to the ecosystem level). This is a serious limitation for the Norwegian biological sciences and it must be dealt with urgently. Another broad and important area of great national importance is experimental plant

science, which at present seems to be unable to follow international developments. Developments in this field are not only important to Norway's national and regional concerns (i.e. the ability to capitalise on commercial developments in agriculture and forest related biotechnology) but are also important globally in the face of rapid population growth and changing climate patterns.

Balance Between Fields

From the preceding sections and from the reports of all three Review Panels it is clear that the existing balance between investigator initiated research and program directed research is not optimal and we stress the need to change the balance in favour of investigator initiated basic research. However, finding the balance that is appropriate for the country will require discussion and co-operation at all levels in Norway involving active scientists, the Research Council and the Ministries. When attempting to redress this balance it is also important to remember that while additional funding for basic research needs to be allocated to encourage the fields identified as weakly developed, this should not be done at the expense of existing research strengths, such as population biology and neuroscience. The Committee also recognises that simply providing more money to basic research is not the solution. Rather, we see that increased funding must go together with changes to the research structures and the research culture in Norway (see below).

In addition to this general assessment of how research is being funded in Norway, we have also identified various research fields that represent particular strengths and weaknesses. With some exceptions, we have kept our identification of the weak fields deliberately broad because it is the opinion of the Committee that the specific topics and research subjects to be developed needs to be determined by active Norwegian scientists. The Committee has attempted to highlight the new international developments in research and to show where these developments will lead but it is the individual Norwegian scientists who have the experience and detailed knowledge of the problems most relevant to Norway who must lead the development of Norwegian science. It is the view of the Committee that the question of balance between fields becomes an issue of importance only if the strategy is to support basic research primarily through directed programs. However, in a research system where the development of basic research is lead by bottom-up initiatives with an emphasis on scientific quality, complemented by strategic support to prioritised areas that are defined after consultation with active researchers to be of national interest, the "balance between fields" will not be a major issue. When discussing the balance between fields it is also important to remember that basic scientific research is international, although it is usually done nationally. This means that the issue of balance may be viewed in a broader geographical perspective and perhaps it is time for Norway and other Nordic countries to begin to define a Nordic research area for basic science on the European scene.

Structural Issues arising from the Panel Reports

We are conscious of the fact that the following comments dealing with structural problems in the Norwegian academic and funding systems are generalisations and that they will not apply to all institutions, departments or research groups evaluated. However, the issues discussed below are drawn from the reports of the three Review Panels. We feel that extraordinary agreement in the findings of these three independent panels lends credence to the suggestion that these conclusions represent a fair picture of the current state of the research groups and institutions covered during this evaluation.

Management and Research Planning

At the department level there has been a strong move away from the traditional organisation based on individual senior professors, toward a more 'horizontal' model. This has resulted in the individual scientists defending their academic freedom to pursue their own interests at the expense of taking a more collegial approach to developing a highly competitive research department. While it is true that institutions organised along rigid hierarchical lines are rarely innovative, it is also clearly apparent that the 'horizontal' model that has become established in Norwegian academic institutions has frequently resulted in a lack of scientific leadership. Informed, consultative leadership should not lead to a loss of innovation, and international experience has shown that the most accomplished scientists within departments must lead. A department chair who also has clear scientific authority can facilitate many aspects of scientific life, such as negotiating difficult departmental decision regarding reassignment of personnel and facilities, co-ordinating joint efforts to fund core facilities and lobbying for additional external funding. These leaders should have the responsibility to develop research strategies for the department and the authority to promote these strategies vertically within the university administration. The current practice of giving members 3-year administrative leadership is not working and it should be abandoned in favour of creating scientific leadership chairs that are appointed for 5-6 years with the authority to structure departmental research goals.

University hiring policies, which have often dictated hiring to cover teaching needs, have fostered the creation of many small research groups who share limited common interests. These are frequently single person groups that can not be productive and certainly can not be competitive internationally. These hiring policies, in combination with fixed levels of staffing and the shortness of the career path to permanency, means that most institutions are fully staffed with permanent positions and have little or no flexibility to respond to rapid developments in their research fields. Clearly, 'teaching need' should not be used as the sole determinant for hiring policy and the department's long-term research strategy must become an important component of the hiring policy in the future. Equally clearly, departments need to have several independent investigator positions that are of limited tenure, or tenure-track, to provide the necessary flexibility to develop research profiles in rapidly developing, competitive, research fields.

Few departments or research groups presented a strategic research plan. It is important for researchers to recognise that transparency must go both ways – not only must scientific administrators and funding agencies be transparent in their objectives and expectations, but

researchers must also clearly formulate and present their future research objectives and the strategies they plan to adopt to achieve them. There was abundant evidence of a lack of vision and limited evidence of research groups setting priority areas to take advantage of new advances in technology. The emphasis on democracy and individual academic freedom noted above, and the lack of unified departmental research plans, has resulted in unproductive micro-management by administration that could be more easily resisted if departments developed clearly formulated strategic plans.

Rather than actively developing individual departmental research profiles, the research groups generally appeared to be frustrated and resigned to the current administrative and funding situation. They appeared to have little trust in the funding agencies and to feel that initiatives on their part were ignored by the administration of their home institutions. Most important, it appeared that many departments had no plans for working around these problems and were being paralysed by them. This breakdown in confidence may have its roots in the heavy earmarking of funding to prioritised areas that are defined by the Ministries. The frustration may also reflect a failure of researchers to adapt to the changing research funding procedures, as suggested by the fact that some found ways to work within the system and did not necessarily share this negative outlook. Regardless of its origin, steps need to be taken at a national level to reverse this trend.

With this said, it must also be recognised that for this type of bottom-up strategic planning by departments to work, aimed at developing clear research plans and research profiles, it is absolutely essential that there is greater access to merit-based, competitive funding that is investigator motivated and peer reviewed. If this funding is not available, and if researchers and departmental Chairs are not confident it will be available in the long-term, there will be no incentive for departments to generate research profiles and research strategies. The departments will then remain frustrated and continue to be fragmented by the need to chase changing program funding. It is hoped that this review can act as a stimulus for both the Research Council and the departments to support and develop strategic plans in the very near future.

We emphasise that we see this process as being one where open and frank dialogue between the scientific community and the Research Council will be necessary for any progress to be made. Both groups have responsibilities in this process, the scientists to the society they serve and from which they receive their funding, and the Research Council whose reason for being is to support the scientific community in discharging its obligation to society.

Organisation

With this acknowledged need to develop units with clear research profiles and a focus on prioritised areas of research, within the national context, it is clear that the existing structures need to be reorganised on the basis of problem oriented groupings. What is needed is the formation of local research ‘groups’ who should be co-operative, rather than competitive, in order to create the critical mass needed to develop a high ranking research environment and to generate competitive grant funding. The development of such local groups, determined by need and common goals, could then be used to determine new departmental structures. With this ‘bottom-up’ mechanism for setting priorities, the faculty or university would then have a workable tool for setting its research profile within the

national context. With this type of reorganisation, such local developments should flow naturally into the existing plans by the Research Council to establish centres of excellence[4]. These centres are to be awarded on the basis of a national competition, including a detailed internationally reviewed research plan.

In addition to these centres of excellence we recommend that Norway urgently establish a Molecular Life Sciences Institute with a focus on functional genomics and proteomics, which can address scientific questions in the fields of cell and organismal biology. Such an institute could act to provide strong leadership in the molecular life sciences in Norway, provide Norway with a strong voice with which to participate in international scientific debates and provide a base of excellence with which to increase the flow of ideas and personnel between the molecular life sciences in Norway and the leading scientific nations. This institute should be established by open competitive bids between the four Universities, with the bids including the resources and personnel the competing University is willing and able to supply. There should be a focus on young investigator positions, with special employment rules allowing for longer-term temporary appointments, privileged funding and salaries. One of the principle objectives of such positions is that after a period of 5-10 years these young investigators will move out into the faculties and institutes in Norway to provide scientific leadership. It is not envisaged that such positions, including the directorship, should ever be made permanent within the institute. Research groups should have 5 years funding with a review after 3 years to determine whether programs should be continued beyond the initial 5 years, with a possibility to extend the appointment of not more than half the researchers for a second 5-year period. An estimate of the funding that would be required for such an Institute would be in the order of 200 mNOK for buildings and infrastructure and an annual budget of approximately 50 mNOK to support up to 15 research groups. It is essential that the creation of this institute be facilitated by the commitment of complete financial support for its establishment and for the first 3 years, after which it could be expected to supplement a committed budget with some external funding. The institute would require an International Advisory Board whose experience should be utilised to develop the institutes mission statement and management structures.

We have also considered the possibility of the establishment of such a molecular life sciences institute as a network between existing universities. While we do not rule out such a possibility, given the need for immediate action and the sub-critical and fragmented activities demonstrated today at the universities, we strongly recommend the establishment of a single centre. We also note that this institute, while being able to provide leadership for biological sciences research in Norway, is not a solution in itself but will need to be one of several changes to the system of research funding and to the research culture.

Career Paths

As mentioned in the preceding section, in Norway there is a very short career path from graduating with a Ph.D. to receiving or being competitive for a permanent position. We have also seen that the average age of Norwegian Ph.D.s is much older than in most

[4] Senter for fremragende forskning, Norges forskningsråd, 2000

nations with which Norway is competing (approximately 35-37 y.o.[5]). When these factors (late graduation, limited mobility, limited experience with other academic systems and early tenure) are combined they clearly have a strong negative impact on research performance. Norway is now in a situation where many of the current research leaders are nearing retirement and there are very few obvious young leaders emerging. This problem has arisen because, in general, the younger researchers have not had the necessary international experience, they have not adopted or had access to the latest advances in research methodologies and theoretical approaches and they have not had the funding to develop their own independent research programs. This situation is now becoming critical in Norway because it is clear from the material provided by the research groups that many departments have age profiles biased towards tenured staff approaching retirement. While this provides these departments with the opportunity to develop research strategies now that can form the basis of their hiring policy during the next 5 to 10 years, the lack of emerging young research leaders in the country means that Norway will have trouble filling these positions with well qualified competitive individuals. Norway therefore needs to either actively recruit internationally or it will need to urgently begin to develop a new generation of researchers who do have the necessary skills, motivation and international experience. In reality it will be necessary both to develop new Norwegian leaders and to recruit internationally if a dynamic research environment is to develop in Norway over the next 5 to 10 years.

Important mechanisms for developing new scientific leaders will include creating incentives to attract the best students into research, developing a post-doctoral program aimed at sending the best Norwegian graduates abroad for several years and the creation of well supported limited-term positions to attract these post-doctoral researchers back to Norway. The establishment of the centres of excellence and the Institute for Molecular Life Sciences, with their emphasis on young investigator positions, plus an increase in funding support for basic research, will be important support to these initiatives and will hopefully provide the stimulus to encourage the next generation of scientists. Furthermore, if such strategies aimed at developing a new generation of aggressive and internationally competitive scientists is to be successful it will also be essential to implement a program of start-up funding for newly employed researchers in the Universities and Institutes, not just in the centres of excellence. This is especially important for departments recruiting people to develop new sub-fields. It was apparent to all three Review Panels that many of the new staff hired during the last 5 years had failed to develop the promise shown by their early careers. Often this could be attributed to their isolation as single-member 'research groups' and to the fact that no funding was provided for them to establish their research. Many departments also noted that it was difficult to attract top international candidates because of the limited funding available for start-up. If suitable start-up funding is made available, the current system of hiring new staff on permanent posts should also be abandoned in favour of introducing a tenure-track system as described below.

We propose the following as a potential blueprint for progression through the different academic levels:

[5] Det norske forsknings og innovasjonssystemet - statistikk og indikatorer (p.68). Norges forskningsråd, 1999.

- Undergraduate training – 4 years – age of entry ≈19 y.o.
- Graduate training – 4 years – age of entry ≈23 y.o
- Post-doctoral training – 4 years (minimum 2 years abroad) – age of entry ≈27 y.o.
- Assistant Professor – 4 to 6 years – age of entry ≈31 y.o.
- Associate Professor or Senior scientist (permanency) – age of entry ≈37 y.o.

While this time scale is only an ideal one, and it does not take into account those Ph.D. candidates who undertake additional professional training, it is realistic and a time-line common to many of the countries with which Norway has to compete. Furthermore, while a minimum of 2 years of post-doctoral training abroad is recommended, for smaller countries such as Norway even longer post-doctoral training periods abroad would have obvious advantages for the transfer of new methodologies and theoretical approaches. For the proposed system to generate competitive scientific researchers, we expect that the attrition rate as people pass through the levels from graduate student to post-doctoral researcher and from post-doctoral researcher to assistant professor would be of the order of 60% for each step. For the final step to associate professor and a permanent position an international panel would rigorously review the appointee's research program after 4-6 years as an assistant professor. We envisage that approximately 50% of the candidates would pass such a review. One obvious consequence of such a system is that it will require a considerable increase in investment into training doctoral students. However, it will also drive people through the system more rapidly and provide for extensive post-doctoral training under different research conditions, on new research problems and in different academic systems.

Funding

One of the questions that the Ministries and the Research Council need to address is whether the current funding strategy is appropriate for fostering new and innovative basic research in either the University or Institute sectors. We feel that with the present strong emphasis on directed research through the various programs, Norway will have difficulties to foster the type of academic excellence that is the prerequisite for the creation of basic biological science of high quality. One strategy to address this problem would be to change the balance between investigator initiated curiosity driven research and program driven research. Thus, the number of grants and amount of funds available to support merit based investigator initiated curiosity driven research should be increased. In contrast, the amount of money available for applied research, committed to targeted scientific programs or earmarked by the Ministries to support Institutes is already substantial and does not warrant increase. Ideally the increase in funding to support investigator motivated, peer reviewed basic research should be achieved through an increase in the total budget for research.

Throughout this summary report, and throughout the three independent Review Panel reports, there has been repeated reference to the need for increased funding to basic research. This may give the impression that we, as scientists, are merely supporting our colleagues in Norway rather than giving reasoned advice. However, existing funding for

scientific research in Norway is demonstrably low[6]. When this is contrasted to the trend to urgently increase funding for science from all sources (government, industry, private foundations etc.) in the major research oriented industrial nations (United States, Japan, Germany, the United Kingdom, France), as well as to similar trends from Norway's Nordic neighbours in Sweden and Finland, it is clear that other economies recognise the importance of funding long-term basic science. Given Norway's resources it is difficult to explain the reluctance of the government to make this investment in Norway's future.

In addition to increasing the number and size of the grants awarded for basic research, the duration of the award needs to be increased across all granting mechanisms. The goal would be to decrease the number of grant applications that need to be submitted by productive researchers and to decrease the amount of reporting required by the Research Council. This would reduce the inefficient and unjustified administrative burden that is currently imposed on both the scientists and the Research Council.

In any grant review process there are always complaints, justified or not, that inadequate expertise was recruited for the evaluation of particular grant applications. All Review Panels considered that it was necessary for the review process to be transparent, with the composition of the panels being made public before the evaluation. This would allow investigators to voice concern over the composition of the evaluation panels before the review process. Further, all Review Panels were of the opinion that it was essential for the investigators to receive written feedback summarising the strengths and weaknesses of the grant application as identified by the reviewers. Such a high quality peer review system not only ensures that the most worthwhile science is funded but also provides an opportunity for scientific peers to provide input and advice with regard to how a scientific research question is planned and executed.

Equipment

The time limits imposed by the structure of the evaluation process made it impossible for the Review Panels to make site visits. However, in addition to the critical lack of national investment in emerging technologies mentioned elsewhere in this report, concern was expressed that there were problems with getting funding to replace small to medium priced departmental equipment. This suggests a need for mid-range equipment grants in the range of 300-800.000 NOK. In addition, the Review Panels noted several instances where funds had been made available for major equipment purchases but no allocation was made to fund the necessary technical support staff. Frequent concern was also expressed about the reduction in funding for technical support in both the University and Institute sectors. This problem is not unique to Norway and in most countries permanent research technicians have generally been replaced by short-tenure grant-funded positions. Taking a similar approach in Norway may be complicated by Norway's labour laws and, as with the recommendation for longer-term untenured young investigator positions at the suggested Molecular Life Sciences Institute, the problem of how to accommodate such positions will need to be discussed at the national level.

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[6] Det norske forsknings og innovasjonssystemet - statistikk og indikatorer (pp.31-32). Norges forskningsråd, 1999.

Recommendations

Modifications to the Funding System

- For Norway to increase its basic scientific competitiveness will require substantial new investment in emerging technologies such as, but not limited to, genomics, proteomics and bioinformatics. To facilitate this we recommend the establishment of a Molecular Life Sciences Institute for research into molecular cell and organismal biology.

- The Research Council should revise its funding systems in order to improve its procedures to include less bureaucratic control and more input from leading scientists, in order to find a more optimal balance between curiosity driven research and research driven by utilitarian needs. This should include an increase in funding for merit-based investigator-initiated basic research, with grants assessed by a rigorous international peer review system.

- Operating grants are typically too small and are awarded for too short a period. Granting periods should be longer and the amount of reporting required by the Research Council should be reduced to minimise the administrative burden on both the scientists and the Research Council.

- The Research Council should improve the transparency and accountability in the review processes used and provide better feedback to the applicants.

- The Institutes should work to include researchers from the University sector as full partners when developing research programs so as to more effectively utilise their funding and their large investments in infrastructure.

Creation of More Focussed Research Strategies

- Norway has a very fragmented research system, frequently with groups working in related fields in different types of institutes within the same town. What is needed is the formation of regional research groups that should be co-operative rather than competitive in order to create the critical mass needed to develop highly competitive research groups. The formation of such groups would help the University departments and Institutes to clearly formulate their scientific priorities and their strategy should be to develop distinct research profiles in the national context, with the aim of creating national research platforms.

- All Review Panels identified a lack of scientific leadership associated with the 'horizontal' departmental structure and the appointment of administrative departmental chairs with little scientific authority. We strongly recommend that this practice be abandoned in favour of appointing the most accomplished scientists as departmental chairs for a period of 5-6 years. These leaders should have the responsibility and the authority to formulate departmental research strategies.

- The age profiles of most research groups in Norway are biased towards late career scientists, and most University departments and Institutes will need to hire a number of new staff over the next 5-10 years. Therefore University departments and the Institutes should develop hiring policies based on forming strong competitive research units with a clear research agenda.

- University departments need to have more flexibility in the use of block funding. This should include the ability to create short-term investigator positions so departments can respond to rapid changes in their research disciplines.

- We recommend independent in-depth international reviews of both the Marine Science and Arctic Biology programs to assess both the quality and the focus of these prioritised programs.

Careers and Recruitment

With the dual problems of a dwindling national research competence and a faculty with many approaching retirement, it is critical that Norway invests now in developing a new generation of internationally experienced and internationally competitive scientific leaders. To this end we recommend the following:

- The current trend for students to remain at the one institution throughout their training does not optimise training and is detrimental to the development of innovative basic research in Norway's Universities and Institutes. Training opportunities could be improved if more Ph.D. student positions were available and if these positions were awarded to researchers on the basis of competitive, peer reviewed grant applications, with the successful research applicant then being free to advertise positions nationally and internationally.

- The post-doctoral system for Norwegian graduates needs to be overhauled if they are to develop the competence necessary to lead research groups that compete at an international level. Funding urgently needs to be allocated so that Norwegian graduates can apply for competitive grants to undertake prolonged (2-4 years) post-doctoral studies abroad. The Universities, Institutes and the Research Council should actively discourage the current trend for new graduates to stay at the institution where they were awarded their Ph.D.

- A tenure-track system should be introduced for new faculty appointments, with appointees receiving substantial start-up packages and favourable access to peer reviewed competitive funding. An international panel should rigorously review such appointments after 4 to 6 years, with the standard set such that only about 50% are promoted to a permanent position.

- The attractiveness of Norwegian institutions for foreign graduate students and post-doctoral researchers needs to be increased. Creating the centres of excellence and the proposed new Molecular Life Sciences Institute will raise the international profile of Norwegian research and aid in attracting young international researchers to Norway.

Publication Strategies

- All research groups should place an increased emphasis on publishing in the very best international journals available. The focus should be on publishing in general journals addressing fundamental questions in the biological sciences rather than specialist journals. This development needs to be supported by the Research Council by increasing the proportion of funding being awarded on the basis of competitive peer-reviewed grants, where there is a clear emphasis on the scientific quality and the significance of the proposed work.

- The Research Council should end all support funding for Norwegian biological journals. These journals should be able to survive on their own merit and the patronage shown by Norwegian scientists through their publications in these journals does a disservice to Norwegian science by shielding it from a rigorous international peer review.

Statement of Intent from the Research Council

The Committee recognises that the Research Council of Norway has shown an admirable commitment to improving the status of research in Norway by undertaking and organising such a complex and difficult review. However, due to the rapid advances currently being made in biological research it is urgent that the Research Council of Norway, the Norwegian scientific community and the Norwegian government now respond rapidly to the recommendations made by this Committee.

To this end we encourage the Research Council to publicly respond to the recommendations outlined in this final report, within 6 to 12 months, after consulting with the leading scientific communities within the universities and institutes.