The Research Council of Norway

Evaluation of Biology, Medicine and Health Research in Norway (2011)

Report of the Principal Evaluation Committee

Evaluation
Division for Science

The Research Council of Norway

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Executive summary

The draft human genome, published ten years ago, has already had a profound impact on research within biology, medicine and health. The focus has now shifted to human variation, where the exponentially declining costs world-wide will boost the sequencing of entire populations. This development will bring research within fundamental biology even closer to medicine and to health-related research. New types of molecular level data, originating from identifiable individuals, will be integrated with phenotypic data from the health-care sector in novel ways, and it will also increasingly find its way into the clinic, where it will impact treatment and the progression of the underlying research, needed to take advantage of this situation.

This joint evaluation report integrates the findings, conclusions and recommendations of seven independent review panels, covering biology, medicine and health at Norwegian universities, hospitals, university colleges and independent research institutes. As the above mentioned development will accelerate over the next ten year period, it is extremely important to pay attention to potential synergies between the different research areas covered by the review panels. In Norway, the integration of the different research disciplines is far from optimal and this is one of the themes commented on by the principal committee. The rapid development makes it necessary to create more flexible organizational schemes and infrastructures than Norway has implemented presently. The previous evaluation reports have also touched on these problems. In fact, when reading the earlier review reports from evaluations of Norwegian research in 2000 and 2004, it is remarkable how many of the previously identified weaknesses still seem to represent major issues in the Norwegian research environment.

The principal committee has made a number of recommendations, covering funding, career tracks, institutional freedom to operate, the lack of multi-disciplinarity, infrastructures in research, and needs within knowledge management. The committee recommends that:

- a larger fraction of the funding of biomedical research should be available for researcher-driven proposals, with a corresponding decrease of the restricted, thematic research programmes. At the same time, RCN should reserve dedicated funding streams for young scientists. Researchers should be encouraged more to apply for EU, US National Institutes of Health and other international funding, as it also contributes to the internationalization of Norwegian research;
- in order to create better opportunities for the coming generations of scientists, more postdoc positions, as well as a tenured track for postdocs and mid-career positions should be established. The existing MD/PhD and DDS/PhD programs introduced at several universities should be expanded;
- institutional core funding to a much higher degree should be used strategically;
- critical mass within research teams more often is achieved through collaboration across institutions. This will at the same time secure the level of

multi-disciplinarity needed in modern research. A strengthening of research infrastructures is also a way forward to secure critical mass;

- new knowledge management methodology, such as joint data-discovery portals and data integration techniques transcending the molecular and clinical levels, should be considered in future initiatives;
- the research institute organization is reviewed with the possibility to better integrate the institute research with the universities.

Preface by the Research Council of Norway

The Research Council of Norway (RCN) is given the task by the Ministry of Education and Research to perform subject-specific evaluations. According to the plan for these evaluations the RCN carried out a comprehensive evaluation of Norwegian research within biology, medicine and health in Norwegian universities, hospitals, university colleges and independent research institutes during 2010 and 2011.

Norwegian research within biology, medicine and health has a large span. There has been an expressed wish from research institutions to have all the disciplines evaluated in the two former evaluations encompassed in a joint evaluation. Due to the large span in disciplines and the number of scientific groups involved, seven international panels of experts were established;

Panel 1	Botany, Zoology and Ecology-related Disciplines
Panel 2	Physiology-related Disciplines
Panel 3	Molecular Biology
Panel 4a	Clinical Research – Selected Disciplines
Panel 4b	Clinical Research – Selected Disciplines
Panel 5	Public Health and Health-related Research
Panel 6	Psychology and Psychiatry

The disciplines were placed in different panels according to Norwegian Classification of Scientific Disciplines which is a standard decided by the Norwegian Association of Higher Education Institutions (UHR) in 1994 to classify scientific research. Using this standard was not optimal as it led to splitting of university institutes and independent research institutes into different panels, but was judged to be the best approach to enable comparison between disciplines at the various institutions.

The assessments and recommendations from the seven panels are compiled in seven separate reports. The reports will give important input to the individual research institutions, to the Research Council and to relevant ministries and to any other bodies involved in the development of Norwegian research.

The Principal Evaluation Committee was requested to compile a report based on the assessments and recommendations from the seven independent panel reports. The principal Evaluation Committee consisted of the seven leaders of the panels. This principal report offers an overall assessment of the state of the research involved and is presenting a set of overall recommendations concerning the future development of research in biology, medicine and health in Norway.

Oslo, November 2011

Hilde Jerkø (sign.)
Director
Division for Science

Mari K. Nes (sign.)
Director
Division for Society and Health

The mandate for the principal evaluation committee

As Principal Evaluation Committee we were requested to compile a report based on the assessments and recommendations from the seven independent panel reports. The report should offer an overall assessment of the state of the research involved and present a set of overall recommendations concerning the future development of this research.

The Committee was requested to summarize:

1. The overall scientific quality and relevance of Norwegian research within biology, medicine and health. Identify which research areas have a particularly strong scientific position, in a national and international context, and which are particularly weak.
2. The societal impact of the research. To what extent does the research meets the demand for interdisciplinary research and future societal challenges?
3. General assessments related to the institutional structure and situation for Norwegian research in these fields, calling attention to any areas that need special attention. Are there specific institutional features that may enhance or hinder growth and development of Norwegian research and Norway's contribution to the international knowledge base?
4. How the research institutions have followed up former evaluations
5. And comment on any other important aspects of research within biology, medicine and health that ought to be given special consideration.

The committee's conclusions should lead to a set of recommendations for the future development of research in biology, medicine and health in Norway.

These conclusions and recommendations are presented on the following pages.

General comments on research areas

The principal committee summarizes below the findings of the specialized panels covering subareas within biology, medicine and health at Norwegian universities, hospitals, university colleges and independent research institutes. For each of the specialised panels, research areas that have a particularly strong scientific position, in a national and international context, or which are particularly weak, are identified below.

Panel 1 Botany, Zoology and Ecology-related disciplines

Several research groups have international strengths in the areas of ecology, biodiversity and conservation biology as well as the synthesis of ecology and evolution. These combined strengths are important for coping with future challenges in environmental management including the prevention of habitat degradation, controlled harvesting, population conservation, and climate change.

The museums contain collections that constitute both national and international resources, including specimens and type specimens. It is not clear what role those resources will play in the future, or the extent to which they are being catalogued using DNA barcoding technology to constitute a national database or to fit into international databases. A review to clarify the future roles of museums in research should be undertaken.

Panel 2 Physiology-related disciplines

Several fields of neuroscience are with no doubt excellent areas and include research groups at the absolute frontline internationally. There are some advanced groups in developmental biology, especially in marine developmental biology, which is unique for Norway. Fish health is of tremendous importance for aquaculture and there are indeed examples of very good fish health research. However, Norway could play an even more dominant role if several smaller and geographically separated groups in the area of host-pathogen interactions in fish and aquaculture science were forming centers or being merged. Groups within nutritional research and environmental toxicology are performing well with a unique profile which deserves to be highly appreciated.

Panel 3 Molecular Biology

Molecular biology continues to play an immense role in basic biological research, disease etiology investigation, disease prevention and diagnostics, systems biology, environmental biotechnology, plant sciences, veterinary sciences, industrial biotechnology, chemical biology, nanobiotechnology and related fields. It forms the basis for innovation and industrial exploitation and it is clear that its importance will not decline in the foreseeable future. Several institutes host groups working within molecular biology, which carry out research at the highest international level of excellence – truly outstanding research programs. These groups are carrying out either basic research or medically oriented research; however none of the more applied areas belong to the highest quality category. The strong research groups are well distributed

across Norway and could provide a solid base for helping to lift other groups to a higher standard.

It was a general concern that so many groups did conduct research at the level of good, or lower. This indicates that the research is of medium quality often representing incremental work advancing science slowly. The poor state of applied research within molecular biology is a worry given the economic importance of this type of research.

Panel 4A and 4B Clinical Research

The number of Norwegian publications in clinical medicine has steadily increased during the last decade and, more importantly; also the number of citations of Norwegian publications has increased. During the last three decades the citations of Norwegian papers in clinical medicine has increased from the level of the world average to well above. One reason for this compared to the previous evaluations could be the observed trend to form larger research groups performing very good to excellent research in different areas including cardiovascular and respiratory, inflammation and rheumatology research, cancer biology/oncology, orthopedics and neurology.

The evaluation panels are optimistic about the future development of clinical research in Norway provided that some structural changes are implemented. These include improved recruitment and career possibilities for young clinical researchers, increased research time for clinical professors and increased research collaboration and competition for funding at the national level.

Panel 5 Public Health and Health-related Research

In the area of etiological epidemiological research, several Norwegian groups have produced excellent results during long time. They have made successful use of possibilities available in Norway, mainly in terms of personal identities, large, repeatedly screened, population-based cohorts with databanks and biobanks, and high-quality registries of health outcomes. They have established extensive collaboration networks and produced cutting-edge information, which has been published in most prestigious scientific journals.

Some Norwegian research groups in the area of global health are also excellent. In particular, they are impressive with regard to their strategic planning, long-term commitments, choice of important research questions, close cooperation with partners in low- and middle-income countries, and ability to implement their findings in preventive activities in the collaborating countries.

The Norwegian health-care system has been extensively reorganized during the last decade. This could offer good opportunities to evaluate effects of the changes. However, the attempts to study these have not been sufficient to obtain the conclusive information that is needed by the Norwegian and international societies.

In an aging society like the Norwegian, there is a strong need for evidence-based information on care/nursing practices. However, the present Norwegian research in

this area can, with few exceptions, not be expected to supply such information. This is a young and immature research area. However, a strengthening of the research infrastructure, in order to obtain critical mass and stronger focus, are ways forward to secure the supply of high-quality knowledge.

Panel 6 Psychology and Psychiatry

The successful area in Norwegian research in psychology and psychiatry lies within neuroscience, with a special focus on cognition or psychiatric disease presentation, studied with brain imaging methods in normal and psychiatric populations. Thus, the world-wide interest and expansion of neuroscience, with brain imaging techniques becoming increasingly available to researchers, allowing research questions previously not investigated to be studied, is also evident in Norway. These factors have contributed to attracting young researchers, facilitating competition, and, in turn, to excellent scientific quality. To maintain the high scientific quality is not only important from a scientific viewpoint, but also from a practical perspective as it generates critical clinical knowledge concerning brain function, plasticity, and rehabilitation. The future should also be bright for research units utilizing the impressive longitudinal population-based databases and biobanks, which together with national health population registries provide possibilities to do research not possible to do elsewhere. It is important that these assets are fully utilized, maintained, and protected.

Weaker areas of research within psychology and psychiatry are less readily identified. What is evident, however, is that the common features of these are that they are small, lack strong scientific leadership, conduct research with little or no collaboration with other groups, have diffuse and wide research interests, and often are burdened by heavy teaching obligations. Clearly, the fragmentation of research into small research constellations conducting research with unclear focus and objectives is not a successful concept in this area.

Recurring themes from the panel reports

The principal committee assessed the institutional structure and situation for Norwegian research and identified a number of themes, which have relevance across essentially all areas covered by the seven specialized panels. The themes were identified independently of the scientific area and included funding situation, career track, institutional freedom to operate, gender, the lack of multi-disciplinarity, infrastructures in research, and needs for bioinformatics, biostatistics and novel knowledge management portals.

National funding issues

The panels frequently heard complaints that the basic funding for biomedical research in Norway is insufficient and decreasing. However, the panels could not verify that this really is the case. Rather, the resources are higher *per capita* than in most other countries, and have been stable over time. Nonetheless, it seems that the costs for basic facilities and administration are high and increasing. Thus, the funding available for research activities may have decreased.

Compared to most other countries, the funding of research in Norway is to a much higher extent distributed within thematic research areas or programs, which are predefined by mainly ministries and/or RCN. Hence, only 10-20% is an open arena for researcher-driven proposals. The principal committee considers this to be a much too small fraction that will restrict the possibilities to take advantage of the creativity of researchers, which is a major driving-force for scientific development.

As discussed elsewhere, there is a structural problem regarding lack of postdocs/middle position researchers in Norway. One explanation is the lack of predestined funding of such positions.

Most of the funding for clinical research is channeled via regional funding instruments and not through national competition. Regional funding is intrinsically less competitive than national funding and does not necessarily promote the highest quality clinical research in Norway. The different health regions are the major funders and offer "bottom-up"-funding while a majority of the RCN funding is within thematic areas or programs. The differences in the local funding of clinical research at the hospitals, and the national funding of basic research performed at the universities, are prone to decrease collaboration, sharing and optimal use of techniques, research infrastructures, knowledge and other resources necessary for successful translational research. The present strategy of funding clinical research predominantly through grants from the regional health authorities should be redesigned so as to encourage competition and collaboration between groups at a national level and not at a regional level.

Specific recommendations:

- RCN should improve its information to the Norwegian research community of the funding situation, to obtain a better understanding how the resources are distributed and used.

- A larger fraction of the funding of research should be available for researcher-driven proposals, with a corresponding decrease of the restricted, thematic research programs.

- RCN should reserve dedicated funding streams for young scientists.

- A significantly larger part of the funding of research in national and other institutes should be transferred to RCN and distributed in competition; all or some of these resources may be earmarked.

General low level of international funding

Across the scientific areas and the organizations being reviewed, there is a general awareness of the importance of international collaboration and exchange. However, this awareness does not seem to have resulted in an increased number of external grants from international funding bodies. Rather few units reported having applied for grants and even fewer had received grants from, for example, EU or US NIH (US National Institutes of Health). Researchers should be encouraged to apply for international funding, as it would not only have the potential to increase the research budget, but also contribute to the internationalization of Norwegian research. The

grant offices should promote their services and support researchers to enhance the likelihood of successful application efforts. Other incentive programs should also be considered.

Specific recommendations:

- Researchers should be encouraged to apply for international funding, as it would not only have the potential to increase the research budget, but also contribute to the internationalization of Norwegian research.

- The grant offices should promote their services and support researchers to enhance the likelihood of successful application efforts.

- Other incentive programs should also be considered.

The career system

It is of great concern, and also mentioned in several previous evaluations, that there is a lack of a transparent career development schemes with positions in-between postdoc and professor levels, either at the universities or the university hospitals.

The academic staff of the departments and institutes is aging, and a large part of them will retire within the next decade. Very few of the departments and research units have a clear strategy how to handle this problem by recruitment.

There is a general lack of organization of career paths for young scientists in Norway. It is a notable and profound lack of an active system for selection and mentoring of the best junior staff as senior postdocs for the next generation of faculty. Postdocs seem to suffer from this most, with appointments for a maximum of four years. In addition, the funding of post-doctoral and sub-professorial research positions is almost non-existent.

It is a major concern that there is, with some exceptions, a low national and particularly international mobility of researchers at all parts of the research career. The majority of tenured researchers have been recruited locally, and most were awarded their university and PhD degrees from the university where they currently work. Although several of the units provide evidence of actions aimed to improve the situation, these do not appear to be sufficient. It is also evident that international mobility is not regarded as a priority. Efforts to actively recruit new researchers should be encouraged and incentives for both the researchers and the universities for increased mobility should be introduced.

Specific recommendations

- To create successful career structures and opportunities for the coming generations of scientists, it is advised to meet the general need of establishing more postdoc positions as well as a tenured track for postdocs and mid-career positions.

- In parallel, the fraction of the research budget that is earmarked for younger scientists should be increased.

The PhD model

It has been an ambition in Norway during the last decade to increase the number of PhD candidates, and PhD-training is prioritized by most research institutions. Indeed, the number of PhD exams has increased, but the allocation of resources may emphasize the PhD 'production line' too much, resulting in less focus on quality, and effects on research output and career prospects.

The effective time available for completing a PhD, and the requirements for completing a thesis, clearly influences the publication strategy. The over-reliance on PhD students to perform research, coupled with the need to publish many papers for a PhD thesis, is resulting in short-term research goals. In some departments, reporting scientific findings in several acceptable publications is preferred over one high-quality paper. Combined with the heavy focus on PhD students performing research, this reduces the standard of the publication of the whole department.

Another problem is the age of the PhD candidates upon completion of the PhD. In certain areas, the average age when awarded the PhD is too high, which shortens the number of active years as a researcher. This is, for example, the case in clinical medicine (42 years on average) and care sciences.

The quality assurance of PhD training varies between institutions and needs to be harmonized. There is a lack of monitoring of PhD completion rates, and no guidance on the appropriate duration of the PhD study period. There is no clear national system in place to enforce and maintain the quality of PhD degrees. This could be accomplished by introducing or increasing the number of graduate schools at the faculty level, with a clear set of rules for education and training of PhD students.

Earlier completion of PhDs by clinicians could be improved by increasing full-time PhD positions, and 50%/50% PhD/specialist training positions during or directly after MD/DDS graduation, for instance by expanding the existing MD/PhD and DDS/PhD programs introduced at several universities.

The introduction of the industrial PhD programs is also a welcomed addition to the PhD model.

Specific recommendations:

- Preference for quality rather than quantity with regard to publications should be encouraged.

- It is recommended to introduce or increase the number of graduate schools at the faculty level, with a clear set of rules for education and training of PhD students.

- Earlier completion of PhDs by clinicians should be improved by increasing full time PhD positions and 50/50 PhD/specialist training positions during or directly after MD/DDS graduation.

The gender issue

It appeared that most institutions' goal was an equal sex ratio at all levels. The expected proportion of each gender in a unit can be estimated from availability pools. There is a need to introduce an action to ensure that the gender balance at the PhD student level is reflected at subsequent career levels. A disproportion means most likely a waste of research talent. Data on availability pools must be made accessible during recruitment, to provide evidence-based expectations of the sex ratio for units, which can respond accordingly.

The proportion of women who pursue careers in science tends to decrease as seniority increases. The drivers of this pattern are complex. Policies allowing flexibility to care for children and other family members are important, but so is the awareness of the potential for biases on selection committees and among other reviewers. These inadvertent biases may include a tendency for letters of recommendation to refer to future potential of male candidates versus past accomplishments of female candidates. Those involved in recruitment and management should be trained to identify and rectify such biases, and in the implementation of family-friendly policies. Employment for partners is an issue when hiring professionals and, although there is no simple solution, this needs to be confronted by the institutions.

If the gender composition of the recruitment pool does not differ when a position advertisement notes that women are strongly encouraged to apply, protocols must be developed to address the issue. If they are not, the proportional representation of women in Norwegian science may not change over the next decade.

The goal of at least 40% women on university panels is a good one, but if only 20% of professors are women, this must not be achieved by overburdening women with administrative responsibilities, so that available research time is reduced.

Specific recommendations:

- Whereas the principal committee applauds having many women on university boards, we recommend that this is not achieved by overburdening the few women in research with administrative responsibilities and tasks.

Institutional core funding not used strategically

Across the different areas reviewed by the panels, it was frequently encountered that research departments and research units did not continuously undergo restructuring in response to new national or international research trends. The core funding to research institutions in Norway is not low, but the freedom to use these funds is either lower than in many comparable countries, or the freedom given to the institutions is not exploited sufficiently. Countries vary in their research-funding schemes, but Norway seems to have incorporated many constraints, which limit the restructuring needed in order to secure the performance and competitiveness of modern research. It is recommended that analysis is made, clarifying why the institutional management – in practice – has less freedom to operate than in many other comparable countries in Europe and in the US.

An area of particular concern was human resource management. Often there did not seem to be procedures in place for personnel management, in the form of mechanisms

to present and implement alternatives to staff that do not perform in terms of their ability to attract research funding or publish in higher impact journals. Such alternatives could include stimulation to new research directions, repositioning to work under the leadership of another principal investigator or shift to other tasks in the academic system. The leadership does not appear to have sufficient power or competence to deal with such situations.

Worldwide, overheads resulting from external grants are resources which contribute to securing internal freedom to research departments making it possible to act strategically. The panels noticed many cases where it became obvious that researchers did not have a clear picture of how their institutions handled overheads resulting from the external funding received. The principal committee recommends that transparent processes be established in this area.

Specific recommendations:

- The principal committee recommends an analysis to clarify why the institutional management – in practice – has less freedom to operate than in many other comparable countries in Europe and in the US.

- Underperforming staffs should be stimulated and encouraged to explore new research directions, reposition to work under the leadership of another principal investigator or shift to other tasks in the academic system.

- The principal committee recommends that transparent processes be established for distribution of overhead resulting from external grants.

Critical mass in research group organization

In general, most of the successful units were typically large, having researchers at different levels of their career. However, far too often, the research landscape was fragmented and many units lack critical mass.

Critical mass can be achieved through collaboration, often at the same time securing the level of multi-disciplinarity needed. In some cases, collaboration has been increased by merging units, but this has not always changed the way research is carried out. Many researchers still continue as individuals. Effective merging, which increases productivity, requires strong scientific leadership. Such leadership should be in place before mergers are undertaken.

The Norwegian research system contains a larger fraction of national research institutes than most other comparable countries. This could be an advantage in some respects, but it may create limited interaction with other disciplines and competition thus preventing the formation of large, creative research environments with critical mass.

Specific recommendation:

- To a greater extent than is done today critical mass should be achieved through collaboration, which in many cases at the same time will secure the level of multi-disciplinarity needed in modern research.

Bioinformatics, biostatistics and knowledge management infrastructure

Even if Norway via recent programs has made investments in the area of computational analysis of biological data, many other countries have made even more investments in bioinformatics and the related areas of computational systems biology, computational chemical biology and neuro informatics. Consequently, the current situation in Norway is comparatively weak – leaving Norwegian life science research in a suboptimal position. Going forward it is recommended to expand in this area, but at the same time secure a better interface to the general areas of biostatistics, epidemiology and registry-based research. Biobank-associated databases need to be incorporated, and in a sustainable manner maintained better. New knowledge management methodology, such as meta-databases, data integration techniques transcending the molecular and clinical levels, as well as joint data-discovery portals, should be considered in future initiatives.

As more and more data resulting from new experimental high-throughput techniques in the future will be produced locally, training in this area should be a clear priority, not only in bioinformatics, but also within epidemiology, where there is no formal training in the area of methods. The Norwegian research environments should prepare for more decentralized data analysis, integrated into their own data producing environments. Such broadening should obviously be combined with centralized, hub-like efforts, where these are advantageous.

The general area of data repositories, data management and tool integration is also a theme at the European level, for example in the emerging ESFRI infrastructures (European Strategy Forum on Research Infrastructures, http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri), not only within bioinformatics, but also in many other biomedical areas. These efforts should be taken into account in new initiatives, such that Norway can benefit from these developments.

Specific recommendations:

- New knowledge management methodology, such as meta-databases, data integration techniques transcending the molecular and clinical levels as well as joint data-discovery portals, should be considered in future initiatives.

- The Norwegian research environments should prepare for more decentralized data analysis, integrated into their own data producing environments.

- Data repositories, data management and tool integration, also a theme at the European level, should be taken into account in new initiatives, such that Norway can benefit from these developments.

Clinical research and university education

Due to high demand and budget restraints, clinical and educational duties have higher priority than research at the university hospitals and at some university departments. This restrains clinicians and university teachers with shared responsibilities (e.g. Professor II) from devoting time to do research to the extent that their contracts stipulate. It was evident that often both the clinical and educational duties are prioritized over research. As noted also in previous evaluation, the relative increased

load of routine clinical work and lack of research time is a major obstacle for further development of clinical research. There is an urgent need to develop new and flexible models to reallocate time between clinical work, teaching and research, and to allocate substantial amounts of time dedicated to research. This process should be done in close collaboration between universities and university hospitals. The relevance of present Professor II positions (100:20) must be reconsidered.

Specific recommendations

- The role of Professor II positions should be reconsidered.
- New and flexible models for time allocation should be implemented in close collaboration between universities and university hospitals.
- The possibility to focus resources and share expertise for educational programs should be considered.

University research versus research at public institutes

The Norwegian research system contains a substantially larger number of research institutes independent of universities than in other countries. This fact has been discussed in several previous evaluations.

These institutes have a more flexible core funding for research that in practice is lacking at the university departments. It was also clear that there was a redundancy in several research areas between universities and institutes. The organization may prevent the formation of large, creative research environments with critical mass. It is recommended that the institute organization be reviewed with the possibility to better integrate the institute's research with the universities' as has been done in Denmark and Sweden. This may not be relevant in all cases, but it should be ensured that the collaborative links between universities and institutes are strong.

Specific recommendations

- The principal committee recommends that the institute organization be reviewed with the possibility to better integrate the institute research with the universities.

Impact on society

All research of high quality reviewed by the principal committee will have an impact on society, though the time perspective and the part of the society affected will vary widely. Thus, it may take a long time before the results of some aspects of basic research will cause changes, while it will be possible to make use of applied research even in a rather short perspective.

Some of the research reviewed by the panels has had clear impact on the Norwegian and international societies. Examples are aspects of the research in clinical medicine and dentistry, and etiological epidemiological studies, which have supplied scientific

basis for prevention. Also, activities within global health have impacted on the health practices in low- and middle income countries.

To give too high priority to research with a perceived immediate impact on society may, in the long run, be an unwise strategy. Instead, it is important to focus on research quality rather than the type of research.

The principal committee was surprised by the fact that a large proportion of the Norwegian research community was not sufficiently aware of their Technology Transfer Offices. Technology Transfer Offices can play an important role in dissemination of research results and facilitate industrial collaborations in order to better meet future societal challenges.

Specific recommendations:

- The changes in the research infrastructure discussed elsewhere, and better dissemination of results, are needed to increase the societal impact of the applied research, and – in the long run – of basic research.

- The Technology Transfer Office model should be made better known to the researchers and other university stakeholders.

Follow-up on previous evaluations

Two previous evaluations (2000 and 2004) of these research fields listed a number of recommendations. It is clear that considerable efforts have been (and are being) made to respond to these recommendations. Following the last evaluation, the reviewed units addressed the lack of scientific leadership and fragmentation of the research. In some cases, the units responded by merging smaller research groups, strengthening the leadership structure, and developing and implementing strategic plans. This included identifying directions for development and allocating resources (financial and human) accordingly. The implemented changes implied a bottom-up process of formation of flexible and effective research groups.

A lot of strategic decisions were also reported to have been taken, aiming to focus the research, create strong centers and develop strategic leadership. Extensive structural changes have taken place especially in clinical and medical research since the health-care system has undergone major reorganization over the last decade.

However, some of the suggested actions and recommendations have not resulted in notable change, or remain as challenges-like demands for enhanced international collaborations and interaction, increased research time for clinically active physicians, increase of the number of postdoc research positions, and postdoc positions for trained basic scientists to work in a clinical setting, as well as establishing laboratory core facilities in the hospitals**.**

The recommendations of previous evaluations have been followed up closely at the local level of research organizations. By contrast, the Ministry and the RCN have so far only undertaken minor actions in relation to structural problems, flexibility of internal funding, career tracks, funding schemes, and the role of the research-institute-sector.

Unique research possibilities in Norway

Finally, during the overall assessment of the state of research in biology, health and medicine in Norway the principal committee identified the following as examples of unique research possibilities in Norway:

Sustainable aquaculture products. Norway has the expertise and track record for producing aquaculture products for the world. Norway can indeed take the global lead in demonstrating best practices in economically and environmentally sustainable ways. The National Research Institutes are a not fully utilized opportunity for carrying out long-term studies, otherwise impossible to fund under short-term time horizon of RCN, e.g. in the area of environmental toxicology in relation to the global climate change.

Epidemiological research and biobanks. Norway has succeeded in creating large, important and very impressive longitudinal population-based databases and biobanks, which, together with national health registries and the personal identification number, constitute unique possibilities to do excellent research in an international perspective. Some of these facilities are present in other countries, but the combination is unique for the Nordic countries. As said above, in Norway, there is a long-time tradition of using the information in excellent, mainly etiological, epidemiological research.

It is important that this great asset is fully utilized, maintained, and protected, also in the post-genome era, where numerous other types of molecular-level data, characterizing the individual, will become available. Long-term financial support to the infrastructure around these databases would facilitate the utilization of their data and secure maintenance and to develop new registries of health outcomes and intervention approaches.

Knowledge management. The general areas of biology, biotechnology and medicine are in a state of rapid development, characterized by the inability of the infrastructure to keep up with the demands of the science. High-throughput experimental techniques have enabled a wide range of new approaches, which have altered the ways data are produced within biology and medicine. An integrated component in this development has been the adoption of computational methods in almost all phases of wet-lab research projects, from the planning of assays, through to data collection and to data interpretation and dissemination. The necessary knowledge management associated with the analysis of life science related data has become a major bottleneck hindering optimal use of the data produced. The opportunities for recycling, sharing and reuse of data produced by the scientific community are enormous. The 2010 Molecular Biology Database Collection includes well over a thousand databases, many of which describe millions of biological records. This data congestion development obstructs discovery in both the public and private sectors. When attempting to solve these problems, in particular when aiming for obtaining a competitive advantage, it is a must that novel computational tools and data integration infrastructures – in a coherent fashion – interface to infrastructure frameworks created internationally, often as world-wide collaborative efforts covering the US, Europe and Asia. Due to the unique situation in Norway (described above) on registries and biobanks, this area is of strategic importance and represents a major opportunity.

Appendix – Members of the Principal Evaluation Committee

The Committee consisted of the leaders of the seven panels:

Søren Brunak, Technical University of Denmark & University of Copenhagen, leader of the Committee and panel 3

Paul Harvey, University of Oxford, leader of panel 1

Ulf Lerner, Umeå University and University of Gothenburg, leader of panel 2

Kalervo Väänänen, University of Eastern Finland, leader of panel 4a

Håkan Billig, University of Gothenburg, leader of panel 4b

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