Expert report, panel 2

KTH's Research Assessment Exercise (RAE) 2021

Panel chair:
Prof.Dr.Dario Neri

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Introduction

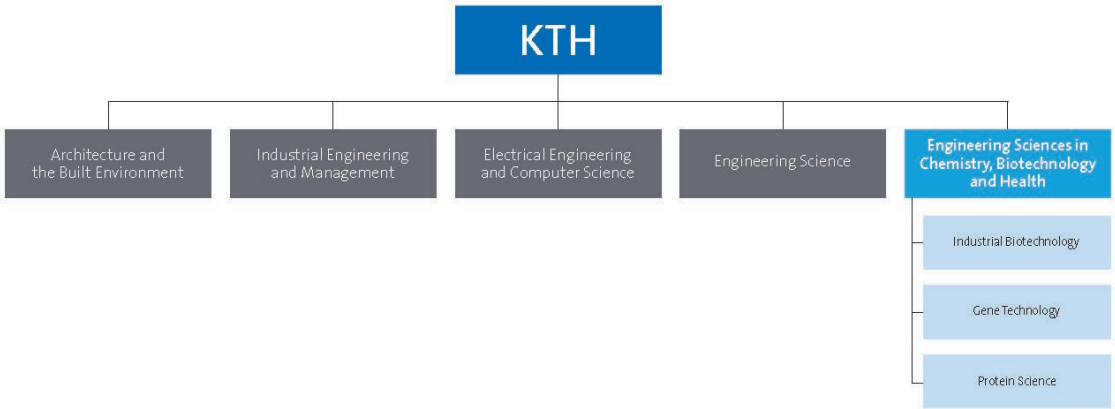
This expert panel report is part of the Research Assessment Exercise (RAE) 2021 at KTH Royal Institute of Technology. The report is based on the self-evaluation on panel 2 and aims to provide recommendations and feedback to the involved departments and KTH.

Expert panellists:

- Prof. Dr. Dario Neri, Philogen and ETH Zürich, chair
- Prof. Dr. Preethi Gunaratne, University of Houston
- Dr. Alvis Brazma, European Molecular Biology Laboratory, European Bioinformatics Institute
- Prof. Emeritus Markku Kulomaa, Tampere University
- Prof. Dr. Roland Wohlgemuth, Lodz University of Technology and European Society of Applied Biocatalysis
- Prof. Dr. Janna Saarela, University of Oslo, Norway,
- Prof. Dr. Nicole Borth, University of Natural Resources and Life Sciences Vienna (BOKU), Austria
- Prof. Dr. Jennifer E. Van Eyk, The Smidt Heart Institute, Cedars-Sinai Medical Center, Los Angeles CA, USA

Panel 2

Coordinator: Prof. Dr. Per-Åke Nygren, KTH Royal Institute of Technology
Vice-coordinator: Prof. Dr. Per Berglund, KTH Royal Institute of Technology



Part A: Summary of the whole panel

1. Strengths, weaknesses, and recommendations

Common to the departments within the research area covered by the panel

The Departments included in Panel 2 Biotechnology are the Department of Gene Technology, the Department of Protein Science and the Department of Industrial Biotechnology, all belonging to the KTH School of Engineering Sciences in Chemistry, Biotechnology and Health (CBH School). The overall research field common for all three departments included in Panel 2 is life science/biotechnology, with an emphasis on development and use of technologies for molecular, structural and bioinformatic analyses of cellular macromolecules such as nucleic acids, proteins and carbohydrates as well as metabolites in healthy and disease living matter. Several of the research areas addressed involve the generation and handling of large scale proteomic, genomic and transcriptomic data. The development of biomolecular reagents and materials for research, diagnostic, environmental, industrial and medical applications, as well as cell-based production of a wide range of products, including therapeutic proteins, chemicals, viruses and biofuels, addresses important industrial needs.

The topics covered by research and teaching activities in Biotechnology correspond to relevant societal problems, from Health to Environment. The three Departments had as a priority to develop methodologies which, in many cases, provide practical and tangible solutions both to the research community and industrial partners. Correspondingly, the industrial relevance of activities in Biotechnology are particularly relevant for Sweden, in view of the country's leading position in the healthcare (e.g., pharmaceutical industry) and bioprocessing (e.g., wood industry, fine chemicals) sectors.

As a whole, the research activities performed at KTH in the Biotechnology field are world-leading and cutting edge. More than 50% of the high-impact factor publications of the whole KTH stem out of these three Departments. The Departments (as detailed with more precision in the following sections) have developed programs of international relevance and visibility, providing fertile ground for breakthrough method development, for the solution of problems of high societal and industrial relevance, as well as for the creation of spin-off companies (some of which have been very successful).

The Departments should also be commended for the excellent work atmosphere that they have managed to establish, with an inclusive collaborative environment, flat organization and approachable PIs.

Researchers in the Biotechnology sector at KTH have been the driving force for the creation and growth of extremely successful Projects and Platforms, including the National Genomics Infrastructure (NGI), the Human Protein Atlas (www.proteinatlas.org). The latter is an internationally valued resource established in collaboration with Karolinska Institute and other Swedish Universities, with a substantial financial contribution from several agencies, including the crucial role played by the Wallenberg Foundation), as well as Science for Life Laboratory (SciLifeLab; www.scilifelab.se). KTH acts as Leading House for the Human Protein Atlas. Activities in the Biotechnology sector enable the Departments to play a leading role in national and international Flagship programs, to successfully compete for international grants and to attract leading researchers from all over the world.

It would be very hard to find weaknesses in the Department of Gene Technology or in the Department of Protein Science. The Department of Industrial Biotechnology is somewhat subcritical in mass and specific aspects are described in more detail in later sections of this document. Here, however, we should mention some problematic aspects, which are more structural in nature, impact all

Departments and represent an obstacle towards reaching the full potential of KTH in this important sector.

While the Departments have a clear vision in terms of priority areas and hiring strategies, procedural aspects often hinder the recruitment of the desired candidates (in part due to unnecessarily slow activities, such as the process of collecting recommendation letters) with timelines which are not globally competitive. The subcontracting of this activity to an outside entity is highly undesirable since confidential insight into the pros and cons of a given candidate is most effectively derived through personal contacts of other scientist colleagues of the members of the selection committee and their colleagues at KTH. This is an important factor to look into because the investment on a new faculty member has long term impact and repercussions on the Departments and KTH. Moreover, since PIs receive only part of their salary from KTH (approximately 50%), they may have to integrate their salary from grants which (at least in Europe) are not designed for this purpose (i.e., are meant to provide funds for PhD student and post doc salaries and consumables). This undesirable situation (which is common to other Departments) should be addressed by KTH, as it is a cause of substantial distraction and stress for PIs. Perhaps, the basic principle could be retained (as it may represent an incentive for PIs, if structured properly), but the percentages should be changed (e.g., 75% basic funding / 25% accessory funding to be earned through grants).

The high dependence of the Departments on competitive third-party funding is both a strength and a threat at the same time and therefore balanced carefully by the Institution: should the level of this funding avenue (which is, by definition, uncertain) decrease, then certain important operations would be at risk.

Finally, it has to be mentioned that challenges in the hiring procedures (e.g., need to demonstrate financial coverage for a period of multiple years, if a collaborator is hired for longer than 2 years) limit the possibility to retain the current expertise, to grow and to exploit funding opportunities that would, in principle, be available. We understand that this weakness is not totally linked to Swedish law, but is indeed made more acute by certain human resources strategies of KTH, which could and should be changed. More flexibility in hiring matters would help all three Departments, as well as other Departments, too.

2. Feedback on the formulated visions and strategies

That can lead to increased quality of research at KTH and increased impact

The quality of Research and impact in the Departments of Gene Technology and of Protein Science has reached a level of global excellence, where it is difficult to do even better. In the next phase of development the recommendations from the Panel are focused on establishing metrics and investing resources for “sustainable excellence” (i.e., continue performing as well in the future). Certainly, the foundations laid down in the past few years warrant a “harvest time” for the years to come. The Department of Industrial Biotechnology is run by very competent PIs and has shown substantial growth in a short period, but has a margin for improvement and this is detailed in dedicated sections.

It may sound trivial, but a very important contributor to the maintenance of excellent performance is to continue the Institutional support for faculty and researchers to make creative contributions to cutting-edge technologies and ensuring that instrumentation and the personnel who manage and operate high-end instruments have a career development plan, with suitable goals and incentives in order to maintain state-of-the-art and milestones already achieved. Moreover, the importance of hires of strategic positions (including at the Senior Level) cannot be underestimated.

The Panel sees opportunities of further growth (with a direct consequence on productivity and impact) related to judicious implementation of Data Science/Machine Learning/Artificial Intelligence (AI) in Gene Technology and Protein Science as a discipline with its own dignity and structure. Perhaps, AI activities could be grouped under a virtual umbrella of a 'Data Science Institute', connecting KTH experts in the field. Moreover, a growth of mass spectrometry-based proteomics activities for the whole Biotechnology sector would be desirable to advance the milestones achieved to the next level to stay on the cutting-edge.

3. Ideas and recommendations for essential steps to be taken to renew research areas

As mentioned above, the development of Data Science/Machine Learning/Artificial Intelligence, that work in close association with the problem-generating activities in the Biotechnology field, could be transformational for the Biotechnology sector at KTH. The Panel wants to remind KTH of the revolution which has happened in the very recent past in the Life Sciences field, which is best exemplified by the possibility to predict protein 3D structure based on protein sequence (DeepMind; www.deepmind.com). DeepMind is a Google-developed platform, which is highly impactful in the Life Sciences sector and which would have been unthinkable without the participation of Artificial Intelligence experts.

The role of biological Mass Spectrometry (MS), nowadays, is too important to be ignored. MS approaches will nicely complement on-going activities in genomics, transcriptomics, proteomics and Precision Medicine. The Panel strongly recommends hires and investments in this sector.

4. Potential links and synergies between the departments within the research area covered by the panel and other parts of KTH

A number of important links and synergies are already in place, as the Departments collaborate much and well. However, the Department of Industrial Biotechnology could seek more links with the Departments of Protein Science, Gene Technology and Sustainable Production Development, as well as with the KTH Industrial Transformation Platform. The exciting area of 'Structural Biology' for instance appears to be very well positioned to have many potential synergies across the departments.

5. Recommendations for strengthening the departments and their future potential

The main recommendations relate to:

• Investing Institutional resources to absorb the Human Protein Atlas which has provided a resource of fundamental importance and brought global visibility to KTH as an infrastructure resource is warranted. HPA, which was started as a research project, has become a part of a recognized international life sciences infrastructure, and is difficult to run based on funding from traditional research grants (typically aimed at funding short-term postdoc projects). Considering the broad relevance of this Resource to multiple fields in the basic science and clinical domains investing in the continued transformation of this platform as a highly valued infrastructure of KTH is also highly desirable.

- Facilitating a better dialogue between Departments in the Biotechnology sector and the leadership of SciLifeLab. More broadly, the Board of KTH can play an important role, ensuring that SciLifeLab continues to benefit from breakthrough method development at KTH, and vice versa. If not properly managed, the interplay between SciLifeLab activities and discoveries in the Biotechnology sector could lose that synergy, which has been so important and productive in the recent past.

- Performing strategic hires in Data Science (also at the Senior Level) and in Mass Spectrometry, as outlined in previous sections.

- Ensuring that adequate funding is provided, in order to take care of the lifecycle management of instrumentation and data analytics platforms.

6. Recommendations applicable to the whole of KTH

- Improve procedures for hiring staff and, in particular PIs. The due diligence procedures for obtaining reference should remain in the hands of faculty.

- Reconsider the percentage of salary that PIs need to secure, on top of their basic endowment. The Panel feels that PIs can use their time more productively.

- Retain the good and open spirit of collaboration with Industry: a pragmatic attitude that can be extremely useful and fruitful for both KTH and industrial partners.

Part B: Report for each department

Department of Gene Technology

Major findings

1. Strengths and weaknesses of the department

Concerns and recommendations for improvement

The Department of Gene Technology is a world-leading research center with a focus on genomics (DNA) and transcriptomics (RNA). The Department has enjoyed a track record of excellent productivity, international standing and broad collaborative networks. In the last few years, the Department has been not only continued to be very productive (e.g., high-impact factor publications), but has also been phenomenal at securing excellent funding. The role played by the National Genomics Infrastructure (NGI; www.kth.se/ngi/national-genomics-infrastructure-ngi-1.913949), which is intimately connected to the Department, cannot be underestimated.

The Panel commended the very nice complementation of topics (from healthcare to environment). Some groups could consider focusing their activity more, and the computational groups could be even better interconnected with other groups, but overall the Panel had a very positive impression of how the Department is run and performs. Groups of the Department “speak the same language” and share instrumentation and methods. Most groups have produced excellent achievements and it is rather difficult to select a particular one, still it is also hard not to note the international visibility of KTH in relation to the developments in spatial transcriptomics.

The Panel also felt that the Department has made great hires. Good hires in the future will be crucially important for “sustainable excellence”

Bioinformatics was central in many activities of the Department. Probably (also in light of the mission of KTH on digitalization), even more Bioinformatics activities (Data Science/AI/Machine Learning) could be considered, with the dignity of a discipline that can drive discoveries and connect disciplines.

2. Relevant and forward-looking objectives

Are the goals relevant and forward-oriented?

Sweden and KTH have a great tradition in the discovery and development of instruments, new chemistry, advanced therapeutics, chromatography supports and technologies, often under the umbrella of world-class integrating activities (such as Human Protein Atlas and Science for Life Laboratory). Break-through developments of the Department (e.g., Spatial Transcriptomics) that is already transforming science and staying on the cutting-edge with the appropriate investments in personnel and instruments will be foundational for many future activities on a global level.

The Department is well-poised to address “big questions” for the future and to continue discovering transformational approaches, which can positively impact on basic research and translational activities. The widespread adoption of technologies will continue to be a good measure for the value of the innovative potential of the Department.

3. International Community engagement

It is difficult to imagine a Department with more and better collaborations than this one, both at a national and at an international level. This collaborative dimension (which provides, among others, samples for biomedical and environmental research) was and will continue to be crucial for the success of the Department.

The Department participates in many international programs, including many European Union projects and is an active participant in the international high-profile Human Cell Atlas project.

4. Future potential of the department

For a positive development towards fulfilling their goals, operating on the front line of international research, and exerting a beneficial impact on society

The Panel unanimously felt that it is "time for harvest", considering the tools, infrastructure and cohorts that the Department has established thus far. Collecting the fruits of the excellent work of the Department will crucially require that the available infrastructure is adequately maintained and rapid advances in technology and computational platforms are added on in order to maintain the current level of excellence. Instrumentation **must** be kept available and **supported** with an adequate life-cycle plan, for example by incorporating into the infrastructure of KTH. Sharing instrumentation in well-managed facilities ensures that money is spent wisely and effectively. Top-notch research requires top-notch instrumentation. A well thought out retention plan for the staff that supports the instruments and computational support is established with attractive career development plans in place. "The todays harvest should be followed by effective and active planting of novel seeds for the future harvest".

The Department of Gene Technology addresses important problems of medical or environmental nature, develops innovative methods and provides solution (e.g., improved diagnosis, validation of new targets). Therefore, this Department has a huge potential towards fulfilling goals, which are beneficial for society and industry.

5. Recommendations

Based on your overall observations and analysis of the department, please provide the recommendations that you find most useful to the department for the future development of high-quality research and research environments

As mentioned above, KTH should actively support this excellent Department. It will be important that Life Sciences are well represented within the Board of KTH and within KTH-run activities (such as SciLifeLab). Importantly, the Department should be allowed to continue contributing to innovative methodology at SciLifeLab, through synergistic collaborations rather than only as a user. The need to initiate a constructive dialogue, with the help of the KTH Board, to incorporate the three Departments in the broader vision of KTH, is broadly felt by members of the Department and is shared by the Panel.

Considering the quantity and quality of biological data generated by the Department, there is an obvious potential for growth of Data Science / Machine Learning (together with Protein Science, as there are obvious synergies between the two Departments).

Further integration of genomics and transcriptomics with proteomics technologies (including Mass Spectrometry-based approaches) would further enhance the potential of this excellent Department.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

The Department of Gene Technology studies genomics (DNA) and transcriptomics (RNA) with state-of-the-art instrumentation and methodologies, often invented at KTH. Scientists at the Department identify important scientific questions in, for example, medicine or environmental research that cannot be solved with available technology. In order to solve these problems, they use their skills in technology and method development to establish novel methods, which are subsequently used in applied research. Thus, in a broad sense, the knowledge gaps that are identified and addressed at the Department correspond to important scientific questions in medicine, biology and environmental science, for which a technical solution is lacking.

The main research activities relate to the development of novel molecular and computational methods, as well as to the application of these methods to solve important scientific questions.

The main research activities can be broadly categorized into four interconnected categories:

- Technology - development of new molecular concepts, ideas and tools;
- Application - use of the latest molecular tools to provide new biological knowledge to advance the life sciences;
- Bioinformatics - large scale investigations of rich sets of biological data;
- Computational Biology - development of new computational frameworks and models for life science data.

b. Contributions to the advancement of state of the art within the research fields of the department

Given that the ten research groups belong to different sub-disciplines within the gene technology field, a broad palette of research questions and knowledge gaps are addressed at the Department, as exemplified for three of the research groups:

GENOMICS. The need for precise analysis of gene expression in specific parts of tissues has been a major knowledge gap for biological studies and clinical diagnosis. With the development of the spatial transcriptomics technology, this knowledge gap has significantly advanced the field. This cutting-edge technology has grown enormously in popularity and is now applied to analysis of a wide range of tissues and to the Human Cell Atlas projects.

EXPERIMENTAL GENOMICS. Molecular methods within genomics, transcriptomics and DNA-assisted proteomics, and bioinformatics tools are tailored to handle the generated data. Developments in this field enable, for example, a better approach to study genetics of cancer. This requires the identification and functional characterization for genetic variants in the two sets of chromosomes.

EVOLUTIONARY BIOLOGY AND FORENSICS. A research theme focuses on the origins, evolution and dispersal of the domestic dog. The knowledge gaps that are addressed include the identification of the geographical origin of the dog (a highly debated topic), the routes and dates for the global dispersal of the dogs, and identification of genome evolution coupled to domestication and feralization. In addition to this highly popular area of curiosity-driven research, genetic tools are also used to aid forensics, in relation to “difficult-to-solve” criminal cases. For example, the possibility to extract precise genetic information from a single hair is extremely relevant in the field and crucially-relies on state-of-the-art methodologies.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The Department has a very strong publication track-record, with high impact publications in a variety of top international journals. This rich research output has also contributed to society by the development of important tools for medical research and environmental monitoring, by applying medically important biological findings, by the development of sustainable forest and food production, by innovations and patent applications, and by considerable outreach, especially concerning dog history and evolution to a curious general public. Collectively, the department has demonstrated its excellence in all these areas, through the publication of highly cited papers in leading journals like *Science*, *Nature*, *Cell*, *Nature Methods*, and *Nature Biotechnology*.

The strong publication record and positive trend can be further illustrated by statistics on the actual number of articles published in high impact factor journals (Impact Factor>9.4, to include the *Proceedings of the National Academy of Sciences of the U.S.A.*). In the period 2012-2020, totally 53 articles were published in high impact factor journals, giving an average of 5.9 per year, or 0.65 high impact publications per group leader and year. There is also a notable steady rise in the number of articles, up to around 10 articles yearly (more than one article yearly per group leader) in high impact journals the last three years.

d. Follow-up from previous evaluations

In the RAE of 2012, the Panel indicated that:

"Projects such as the *de novo* sequencing of the economically important species and surveys of the Baltic Sea ... have huge potential and are economically and societally of great importance. The application of high-throughput sequencing in the context of human genetics and the Science for Life Laboratories could make a substantial contribution to the basic understanding of biology which is largely needed these days. In our opinion this is one of areas where the university can generate the impact they seek to have for society".

It is pleasing to see that the Department of Gene Technology has performed very successful research activities in all these areas. Notable examples include the sequencing of the Norway spruce genome, surveys of microbiomes in the Baltic Sea, as well as studies of spatial gene expression in human tissues (“spatial transcriptomics”).

The RAE also recommend that:

"Further reinforcement both of the side of maintaining platforms state-of-the-art and investment into development of forward-looking activities, such as investment into advanced bioinformatics, e.g., development of a bioinformatics professorship in pathways and network analysis".

The National Genomics Infrastructure (NGI), hosted by the Department of Gene Technology, has continued to provide DNA sequencing service using state-of-the art instrumentation, and has established highly optimized bioinformatics pipelines with excellent reporting. Notably, several of the methods used by NGI have been developed in collaboration with research groups at the Department. The Department has now also recruited a foreign professor, Tuuli Lappalainen, a strategic hire who is expert in human genetics and functional genomics and who is well positioned to contribute to ensuring an adequate link between the Department of Gene Technology and NGI. Professor Lappalainen has joined in May 2021, even though we understand that she is still in the process of transferring certain activities from the U.S.A. to Sweden, as it is natural and understandable.

The Department has also recruited several postdocs with good bioinformatics and computational skills. The Panel recommends further growth in the areas of Data Science/Machine Learning and Artificial Intelligence, with a focus on Gene Technology and Protein Science.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The department of Gene Technology is one of nine departments at the School of Engineering Sciences in Chemistry, Biotechnology and Health (CBH), which is one of the five schools at KTH. The department of Gene Technology consists of ten research groups (one of which started in December 2020, and is therefore not included in this assessment), and also hosts two national infrastructure platforms at SciLifeLab: the National Genomics Infrastructure (NGI) and Clinical Genomics. Head of Department (Prefekt) is Professor Peter Savolainen. The number of faculty was nine at the time the self-evaluation report was written (now ten with the hire of Professor Lappalainen) and the total number of employed persons, including Postdocs and PhD students, is 55. We suspect that this number does not contain the NGI or Clinical Genomics admin personnel, but we could not be sure on the basis of the RAE document.

The yearly budget of the Department in 2020 was 159 million SEK. This budget was possible also thanks to the success in acquiring strong external funding, including in international competition (e.g., EU funding) and industrial funding.

b. Academic culture

This is a balanced and inclusive Department, with a flat organization and approachable PIs (as the other two Departments in this evaluation). It enjoys a broad international network, as well as intense local collaboration activity. In order to access biological and medical samples (as well competence), the Department has sought and established collaborations internationally when required, and locally when applicable.

The Department enjoys an excellent international reputation, which has been achieved thanks to the development of high-impact and cutting-edge technologies, which are now used worldwide. This technology excellence has facilitated a number of collaborations, both in the healthcare and in the environmental and forensics sector.

The academic culture is further stimulated by seminars and by the organization of *ad hoc* Symposia. Scientific questions are discussed at two weekly seminar series about "DNA/RNA science" and "Gene Technology", where the daily experiments and the latest literature are discussed. However, participation by group leaders is normally low, and other formal sessions for group leaders and students to discuss science are missing, which is thus a point for improvement. There are also opportunities at SciLifeLab for seminar activities, and for activities among PhD students and Postdocs such as the "Thursday pub". There is a wish, however, to increase Department activities and formal scientific sessions, thus an even more intense social interaction.

Both faculty and staff (PhD students, postdocs and other staff members) are very international.

c. Current faculty situation and composition of the research team(s)

The Department consists of 10 research groups, whose topics and compositions are listed below:

Genomics, PI Professor Joakim Lundeberg [1 Professor, 2 Senior Scientists, 3 Postdocs, 10 PhD students, 2 Research Engineers]

Experimental Genomics, PI Professor Afshin Ahmadian [1 Professor, 2 Postdocs, 2 PhD students, 1 Research Engineers]

Evolutionary Biology and Forensics, PI Professor Peter Savolainen [1 Professor, 1 PhD student, 1 Research Engineer]

Statistical Biotechnology, PI Professor Lukas Käll [1 Professor, 2 PhD students, 1 Research Engineer]

Environmental Genomics, PI Assoc. Professor Anders Andersson [1 Assoc. Professor, 2 Postdocs]

Expression Bioinformatics, PI Assoc. Professor Olof Emanuelsson [1 Assoc. Professor, 1 PhD student]

Regulatory Genomics, PI Assoc. Professor Pelin Sahlén [1 Assoc. Professor, 2 Postdocs, 2 PhD students]

Applied Genomics, PI Assoc. Professor Patrik Ståhl [1 Assoc. Professor, 4 PhD students]

Spatial Biology, PI Dr. Stefania Giacomello [1 Senior Scientist, 1 Postdoc, 2 PhD students, 2 Research Engineers]

Molecular Genomics, PI Assistant Professor Anniina Vihervaara [1 Senior Scientist]

The department also hosts two national infrastructure platforms, the National Genomics Infrastructure (NGI) and Clinical Genomics. As new Head of the NGI, Professor Tuuli Lappalainen (as new Professor of Functional Population Genomics) has been appointed.

d. Recruitment strategies

Three new faculty members have been recruited since the last RAE. This was possible thanks to government/ERC starting grants.

The Panel learned that a certain number of hires will be made in the frame of the Data-Driven Life Science initiative, but whether these positions will be affiliated with this Department (or with the Department of Protein Science) was not completely clear to us. The Panel urged the Department to formulate a clear strategy for new recruitments that would further enhance the ongoing efforts and strengths for maintaining ‘sustainable excellence’. It should be mentioned that the Faculty of this Department is young and retirements will not happen in the foreseeable future. Thus, growth will probably only happen if KTH makes new positions available, or in the frame of SciLifeLab hires, or within the NGI Platform, or as a result of success in Flagship programs.

e. Infrastructure and facilities

Thanks to the integration within NGI and the Clinical Genomics Facility, the Department has access to state-of-the-art and massively parallel DNA sequencing. NGI also offers sample QC, library preparation and high-throughput sequencing followed by data processing and best practice analysis for a variety of well-established applications. The Clinical Genomics Stockholm Facility provides a dedicated research infrastructure for projects utilising massively parallel/next generation sequencing technologies. All projects are carried out in close collaboration with the Swedish healthcare system.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

As mentioned in previous sections, the Panel believes that the next few years will represent “harvest time” for the Department. The strong foundations established through the seeds planted in the past few years, both through sample collection and through methodological development, will continue to deliver results, which are likely to be published in high-impact factor journals (provided that the facilities are kept and run at the highest possible standards).

The scientific success of the department is heavily based on application-driven method development and academic freedom. Typically, researchers in the Department identify important scientific questions that need novel technological methods to be solved. The methods are then applied to real life problems within, e.g., medicine and environment. Scientists' curiosity and their engagement in societal issues and the humanities, like medicine, environment, evolution and history, in combination with their excellent technological know-how, drives research at the Department.

The Panel anticipates that research in the Department will be impactful for medical studies. This is especially the case when considering the transformational potential of Spatial Transcriptomics and Capture Hi-C technologies.

Bioinformatic methods developed to analyse bacterioplankton genomes are now applied to ecological studies of the Baltic Sea. An increased impact of this research line is expected, in line with the growing interest of KTH for environmental issues.

Research activities will continue using genomic and transcriptomic technologies to study plant development and plant infection processes, with long-term impact on forest ecology and industry and on food production.

Research in Space Biology has recently been added to the Department, investigating the impact of spaceflight microgravity on mouse heart in collaboration with NASA.

Several projects are also changing to a more applied focus. For example, the research about dog evolution is focusing increasingly on the behavioural and morphological difference between dogs and wolves and among different types of dogs. Results are likely to be of interest for a curious general public and to dog owners and breeders, but also for veterinary and human medicine.

The Covid-19 pandemic has stimulated research projects in the biology and medicine of coronaviruses, which are likely to continue, at least for the foreseeable future.

b. Congruence with university-level goals

Activities of the Department of Gene Technology are aligned with the objectives of KTH, regarding excellence in research and teaching.

Research results relevant for healthcare and environment correspond to topics of high societal importance. Moreover, the massive amount of data generated from genomics and transcriptomics studies (“Big Data”) lend themselves to smart Data Analysis / Machine Learning / Artificial Intelligence approaches, which nicely fits with the focus of KTH on Digitalization.

c. Leadership structure and collegial structure

The Department has a flat organization, with good gender distribution and inclusive hiring policies. This multinational environment not only facilitates the attraction of talented staff, but also provides a good and productive work atmosphere.

During the interviews with Staff members, the “pride of helping each other” and the collaborative nature of the Department members became apparent. PhD students were both happy and proud to be part of this Department and of KTH.

Maternity and paternity leave provisions facilitated the life of those members of the Department, who had children (even at PhD study time). The Panel felt that KTH adequately supports maternity and paternity. Reconciling maternity/paternity and career becomes more difficult when research activities are financed through external grants. Decreasing the fraction of faculty salary that is grant-dependent will further strengthen the commitment from KTH to this very important cause.

d. Strategies for achieving high quality

The strategy can be summarized in few simple, but important, bullet points:

- Good hires (at all levels)
- Maintain a cooperative environment, with state-of-the-art infrastructure and reliable methodologies
- Keep asking good and relevant scientific questions, in a curiosity-driven environment
- Work with scientific rigour
- Benefit from the stimulating environment in the Stockholm area (e.g., interaction with KI and Stockholm University)
- Maintain the international dimension of research and staff, often in collaborative network
- Secure adequate funding for research

In summary, the main strategy (for the present and for the future) is to maintain the current level of funding and to “keep asking the important (scientific) questions”, in a productive and collaborative environment.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

There is a clear synergy between research and teaching at the department of Gene Technology.

At the Bachelor level, the main courses offered by the Department include Genetics (BB1070) and Gene Technology (BB1190).

At the Master level, the main courses include Bioinformatics (BB2441), Advanced Microbiology and Metagenomics (BB2560), Analysis of Data from High-throughput Molecular Biology Experiments (BB2490/BB2491), Applied Gene Technology and Large-Scale Data Analysis (BB2255 and CB2040).

A meeting of the Panel with PhD students revealed that (as for other Departments in the Biotechnology sector) they would like to have more flexibility in choosing topics for their higher education courses. Apparently, it is possible to take courses from other Universities or other disciplines, but the procedure seems to be cumbersome. Moreover, the PhD Credits requirements for KTH students appears to be higher as compared to other Universities in Stockholm. This asymmetry is not optimal and may be particularly penalizing for Medicine students, who want to enrol in certain programs at KTH. In particular, an opinion was expressed to develop graduate level courses on interdisciplinary subjects, such as AI or machine learning, jointly with other relevant departments (e.g., computer science or mathematics). The panel supports this idea aimed at interdisciplinarity.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

Gene technology is extremely relevant for society at large. Many biomedical and clinical applications rely on gene technology methodologies. For example, the Clinical Genomics platform performs DNA analysis on patient samples for the Karolinska Hospital and other hospitals in Sweden on a daily basis.

Biomedical and clinical applications is one of the major outcomes of the Department. Spatial transcriptomics technology, pioneered at KTH, allows to create maps of gene activity in human organs, which in turn can be leveraged not only by other research institutions, but by pharmaceutical companies and in the long run public authorities in the health care sector.

The impact of the spatial transcriptomics technology is also exemplified by a spin-off company of the Department, which has recently been acquired by 10X Genomics.

The Department has also produced very popular data analysis and processing software tools for proteomics applications (e.g., Percolator, Quandenser), which are broadly used on a global basis.

The Droplet Barcode Sequencing method is used to haplotype genomes of colon cancer patients.

Research on the history and evolution of the domestic dog is of obvious interest for dog owners, but is also practically important for dog activities related to guarding, hunting, herding, rescuing, tracking, and as aid for the disabled. Future research efforts, aimed at connecting the evolution of breeds, genetic changes and the emergence of traits, also promises to be of practical importance.

Important applications are expected also for Spatial Biology and for environmental studies (e.g., plankton in the Baltic Sea).

b. Research dissemination beyond academia

The Department actively works to disseminate the research results beyond academia through press releases, public lectures and popular science articles, and strives to be available to the news media. The Department also strives to publish all articles as Open access. Professors of the Department have also participated at a large number of radio and TV programs.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

The Department of Gene Technology is clearly very active in healthcare research (SDG3 - Good Health and Well-being), but also in SDG14: Life Below Water and in SDG15: Life on Land, through a focus on biodiversity.

Forensic studies are in a good fitting with SDG16: Peace and Justice Strong Institutions.

d. Plans and structure for increased impact

The scientific success of the Department is heavily based on application-driven method development and academic freedom.

It is expected that the Department will continue to focus on real life problems within, e.g., medicine and environment. Curiosity-driven research in medicine, environment, evolution and history are likely to continue being impactful in the future.

6. Recommendations for strengthening the department and its future potential

As mentioned in previous sections, the recommendation of the Panel goes more in the direction of "maintaining excellence", rather than fixing problems (which, in reality, do not seem to exist within this Department).

Considering the excellence reached by the Department of Gene Technology in its sector, the first priority is to maintain and increase the current level of funding and to ensure that state-of-the-art instrumentation is available, with an adequate management of the life-cycle of small and large devices. Central support from KTH is crucially important for this task, as research grants are usually not designed for the purchase of instrumentation.

A close interaction with NGI, in which the Department is allowed to contribute with method development (and enjoy adequate financial support) appears to be of fundamental importance.

The establishment of programs in Data Science/Machine Learning/Artificial Intelligence, as well as the expansion of genomics and transcriptomics studies as to include also mass spectrometry-based proteomics technology, promises to further enrich the scientific and biomedical potential of research at the Department.

Formulating a clear strategy for the next hires, in close alignment also with Flagship programs and SciLifeLab activities, will be important, even though it was not completely clear to the Panel whether resources for more hires will be available in the near future. It would be well invested money for KTH, considering the success and the output of this Department.

7. Final remarks

In addition, state if the panel lacked any material relevant to making adequate observations and recommendations.

The Panel would like to congratulate the Department of Gene Technology for its excellence, for its output, for the quality of its Faculty and for the inclusive productive environment, that Department members have been able to create.

Department of Industrial Biotechnology

Major findings

1. Strengths and weaknesses of the department

Concerned and recommendations for improvement

The Department of Industrial Biotechnology operates in sectors of considerable industrial and societal relevance. Such activities span from the production of therapeutic proteins using fermentation methodologies to the discovery of methods for the production of fine chemicals, using biotransformation procedures and biocatalysis. In particular, the production of therapeutic proteins has gained in importance over the last few years, as currently eight out of ten of the best-selling prescription drugs globally consist of therapeutic proteins (the remaining two are based on small organic molecules). Sweden is particularly successful in the pharmaceutical sector and in healthcare. Thus, skilled personnel are needed to operate biological production facilities (e.g., upstream processing, downstream processing, quality control and quality assurance).

The Department is heavily involved in teaching activities. This is an important aspect that should be mentioned, also in relation to the relevance of this topic for the Swedish industry.

The discipline of Industrial Biotechnology is intrinsically broad and diverse. In contrast to the other Departments, it is more difficult to have a common “language” and to share equipment. Under the leadership of Ton van Maris, the Department has grown in cohesion and in performance. Nonetheless, the mass of the Department is subcritical. Support from KTH is urgently needed, in order to facilitate this transition.

As the output of the Department may be different compared to less applied areas (e.g., processes rather than only publications), funding opportunities may be difficult to get. However, the Panel is impressed by the competence and the industrial relevance of the research groups and of the research topics.

2. Relevant and forward-looking objectives

Are the goals relevant and forward-oriented?

The goals of the Department of Industrial Biotechnology are highly relevant for the discovery and development of sustainable production routes from bio-based resources, for safer and more benign reactions, for contributing to a carbon neutral society and to minimizing further climate change. The goals are also forward looking and key for connecting the KTH Action plan for the university-wide sustainability objectives 2021-2025 with Industrial Transformation and Sustainable Production Development.

As mentioned in the previous sections, the goals and research topics are important, both from the industrial and societal perspective. The Panel does not see problems with the goals, but rather with the subcritical dimension of the operations at the Department.

3. International community engagement

Professors at the Department of Industrial Biotechnology are involved in international programs (e.g., EU Projects). However, the subcritical mass of the Department prevents an even higher engagement in international collaborative programs.

4. Future potential of the department

For a positive development towards fulfilling their goals, operating on the front line of international research, and exerting a beneficial impact on society

A Department of Industrial Biotechnology that works well and that trains the next generation of industrial biotechnologists is not only crucially important for Sweden, but has considerable potential for harvesting gene technology and protein science achievements towards desired catalytic properties in the protein function space and for operating on the front line of international research on protein structure-function relationships. The full potential in the field of therapeutic proteins and in other biotechnology areas, with the many and successful spin-off companies which are constantly created, would be at risk, if skilled personnel was missing. In addition to protein production in mammalian cells or in prokaryotic systems, also the field of biocatalysis and biotransformation is very relevant for Sweden, in consideration of national operations in the chemical industry and in the wood industry.

Environment-related research activities are also run at the Department, which would however benefit from a closer interaction with the Department of Sustainable Production and with the Industrial Transformation Platform.

5. Recommendations

Based on your overall observations and analysis of the department, please provide the recommendations that you find most useful to the department for the future development of high-quality research and research environments

- If Industrial Biotechnology is expected to grow to an adequate size and output, support from KTH is needed in many different forms: (i) more security for professors (who, surprisingly for the Panel, need to cover part of their salary through funds); (ii) staff positions to facilitate contracts with industry (which can stimulate growth and bring more money and people to the Department); (iii) a profound reconsideration of hiring guidelines (i.e., difficulty in hiring persons for more than 2 years, if funding is only available for 2-3 year projects)

- Structural Biology should be more integrated, both within the Department and with the Department of Protein Science. It appears important to exploit the obvious synergy which is available, with a competent Structural Biology lab present in house. Similar recommendations had been made also during the last RAE, but do not appear to have been properly addressed

- Mammalian Cell Biotechnology may seek even closer dialogue with regulatory authorities (moving perfusion production methods to the next level) and with industrial partners. The growth of industrial collaborations should allow to secure more funding, allowing to hire more students and staff

- Industry needs good industrial biotechnologists, who will easily find jobs after their study (especially after having been trained with “hands on” activities in bioprocessing). The set up of a Master Study program and the opening to additional industry contacts (e.g., through *ad hoc* Adjunct Professorships) is expected to be highly beneficial for the Department

- The Panel is confident that the reach of a critical mass (both in group size and in funding) will further boost the positive developments of the Department. KTH needs to play its part, as the financial and administrative support to the groups (as the support to certain groups of Protein Science) appears to be below international standards with Technical Universities of comparable standing

- The judicious selection and nomination of Adjunct Professors from the industrial environment (in the capacity of collaborators, consultants and visiting lecturers) could represent an efficient instrument to expand the network of the Department and facilitate industrial collaborations, thus contributing to an organic growth and to the implementation of industry-relevant projects

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

The Department of Industrial Biotechnology has undergone a process of renewal, with the aim to both improve the scientific quality and impact, as well as the ability to acquire external funding, whilst maintaining excellent contributions to the education programs of KTH. Four out of seven faculty members present in 2016 left KTH, have retired, or will retire during the coming two years (Humble 2018; Larsson in 2019; Veide in 2021 and Nyrén in ±2022). As part of this process, a new head of department has been recruited externally (van Maris 2016) and four additional new faculty members with diversity career stages have been or will be recruited, thereby either anchoring existing topics amongst the faculty or open new strategic opportunities. The positive effects of the leadership of Antonius van Maris have been evident to (and appreciated by) the Panel.

The Department operates in five main areas, corresponding to the activities of five PIs:

- **Mammalian-cell-based Bioprocess Technology** focusses on the bioproduction of therapeutic biologics (i.e., therapeutic proteins or cell-based therapeutics) using mammalian cells.

- **Biocatalysis and Enzymology** concentrate on improving enzymes for industrial transformations, with a special focus on transaminases, lipases and acyltransferases. Enzyme stability and methods for enzyme immobilization are also investigated.

- **Integrative Structural Biology** focuses on solving the 3D structure of enzymes of importance for metabolic reactions relevant to health and environmental, with a special emphasis on enzymes which act on glycans or glycolipids.

- **Environmental Biotechnology** focuses on the removal of pharmaceutical residues from waste water streams and valorization of residue streams.

- **Microbial Bioprocess Technology** focusses on metabolic engineering and process development for production of fuels, chemicals and proteins.

b. Contributions to the advancement of state of the art within the research fields of the department

- **Mammalian-cell-based Bioprocess Technology** focuses, inter alia, on the development and implementation of mammalian cell-based production systems featuring perfusion procedures, rather than the conventional fed-batch modalities. Even though perfusion-based production methods are not (yet) the method of choice in the field of therapeutic proteins, they have the potential of delivering increased productivity with smaller volumes (and hence cheaper and easier-to-operate infrastructure). The topic is attractive and is run by a PI with extensive industrial experience, but would benefit from more industrial implementation and a closer dialogue with regulatory authorities.

- **Biocatalysis and Enzymology** concentrate on improving enzymes for industrial transformations by molecular modeling-guided rational design of enzyme specificity, engineering and molecular-level understanding of enzyme stability, with a special focus on transaminases, lipases and acyl-transferases. Research in the area of novel multicatalytic one-pot reaction cascades for the synthesis of capsaicin have led to a patent on multi-catalytic transformation of alcohols into amines which has been acquired by the company Organofuel

Sweden AB, which is now offering capsaicin. Methods for enzyme immobilization are also investigated and have led to the very successful start-up company EnginZyme AB, which has been founded by a KTH Biocatalysis graduate.

- **Integrative Structural Biology** features research activities, mainly focused on the determination of the 3D structure of glycan- and glycolipid-processing enzymes, including those involved in wood bioprocessing.

- **Environmental Biotechnology** focuses on the development of methods for the removal of pharmaceuticals from waste water and from the Baltic Sea.

- **Microbial Bioprocess Technology** develops new methods for the bioproduction of fuels and for bioprocess engineering, in topics of industrial relevance.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The activities of the Department of Industrial Biotechnology are of good quality, even though the mass of the Department is subcritical and should be improved/expanded. It is difficult to achieve a huge productivity with only 12 PhD students for a total of seven professors (four full professors, two associate professors and one assistant professor in 2020), with a cumulative yearly budget of 36 million SEK.

There was an average of 10 publications per year (range: 9-13) between 2015 and 2019, with an average impact factor (WoS) slightly above 1. This is too low and should be improved. It must be said, however, that the scientists in Industrial Biotechnology at large often publish in biotechnology journals which (with the exception of *Nature Biotechnology*) tend to have a low impact factor. Structural Biology represents an exception in this matter, as protein structures can be published in a variety of high-impact factor journals.

The national Vinnova Competence Centre for Advanced BioProduction by Continuous Processing, AdBIOPRO, provides novel technology for manufacturing of therapeutic biologics. AdBIOPRO is a consortium of five teams at KTH, Lund University and the Karolinska Cell Therapy Centre (KCC) at Karolinska University Hospital together with seven industrial partners, Sobi, Cobra Biologics, BioInvent, GE Healthcare, Valneva, Lab-on-a-Bead, and CellProtect Nordic Pharmaceutical.

The Integrative Structural Biology team is actively performing research at a large number of national and international infrastructure facilities and platforms. The Formas Bioraf project was a national collaboration network between three different research groups at KTH, the Research Institutes of Sweden (RISE) and the University of Borås with support and strong interest from an industrial panel including Ragn-Sells, AKZO Nobel and Lantmännen.

Several scientists at the Department of Industrial Biotechnology have been and are engaged in various successful ITN applications (innovative training networks, “European Marie Curie”-type of networks) in recent years.

There is a recent trend towards the expansion of collaborative efforts with Industry. This trend should increase, as it will be highly beneficial to the Department in many ways. It is likely that a Department-based Staff Position, focused on the search and finalization of research contracts with industrial partners, may contribute to the desirable growth of industrial collaborations.

d. Follow-up from previous evaluations

The only direct comment for the Department of Industrial Biotechnology was: "Cooperation within KTH is not optimal. Here an optimization would bring much benefit with respect to exchange of experience and enlargement of the critical mass."

Within the Department, cooperation has already improved, benefitting from joint seminars and better communication. Under the leadership of Professor von Maris, other important activities have been started (e.g., PIs read each other's grant applications prior to submission). Also, cooperation with other departments within KTH has been intensified through joint supervision of PhD students with the departments of Chemistry (with financial CBH support), Chemical Engineering, Protein Science and Intelligent Systems (EECS). Where needed, new faculty recruitment has been used to strengthen the critical mass on strategically important topics (e.g., mammalian cell-based biotechnology).

It appears to the Panel that the Department has improved and continues to improve. An increased level of support from KTH (e.g., matching funds for new grants secured by the Department) may be crucially important in order to allow the Department to reach the necessary critical mass.

Another comment was made at the school level, but is also relevant for the Department of Biotechnology: "On a more specific note the School needs to think more strategic with respect to its access to prime competence in Structural Biology."

In the opinion of the Panel, Structural Biology activities within the Department of Industrial Biotechnology (in spite of being of very good scientific level) are still isolated and would benefit from a closer interaction within the Department and/or with neighbouring Departments (e.g., Protein Science). This synergy would be beneficial to both, as 3D structures can add value to novel protein-based therapeutics, and protein structural biology may be exposed to new exciting research projects (and benefit from increased funding).

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The subcritical mass of the Department is linked, in part, to a subcritical financial support from KTH. The Panel perceives the presence of a "vicious circle", that makes growth difficult, in spite of the efforts made by the new Head of Department and his colleagues. The Panel recommends an increased level of financial support (ideally with matching funds for successful PIs, which gain new resources through EU projects or industrial collaborations). On one hand, KTH will want to see the Department actively seeking an increasing amount of internal and external funding, but on the other hand KTH cannot leave the Department alone without financial incentives, in case of good performance.

As publications in Industrial Biotechnology, for the very nature of the discipline, tend to appear in scientific journals which do not have a very high impact factor, other aspects have to be considered when evaluating performance. The ability to secure internal and external collaborations, thus increasing the level of funding, scientific activities and number of staff members, could be used as parameter to evaluate performance at the next RAE evaluation.

The research funding of the department over the past seven years (2014-2020) has on average been 34.5 MSEK per year with a small increasing trend. The sources for this research income were on average: 38% from basic KTH funding, 50% external funding from research grants, 8% from contract research and 4% other sources. Together with the funding for teaching (which is not in the figure on research funding; >6 MSEK/year), to which the Department of Industrial Biotechnology makes a very significant contribution in both quantity and quality, this provides a viable basis for the current

number of faculty. However, to realize the research ambitions of the Department, it is important to substantially increase external funding after replacement of retiring faculty members and continued development of existing faculty members. The applied funding agencies Formas and Vinnova are the quantitatively most important funding agencies. The Department declares an increase in external funding by 50%-100% over the coming 5 years as a desirable (and concrete) objective and the Panel concurs with this assessment.

b. Academic culture

The Department enjoys a good cooperative atmosphere, but the subcritical mass prevents a full exploitation of synergies. The organization of coffee-lunch tables and of Departmental seminars is important and should be continued/expanded.

c. Current faculty situation and composition of the research team(s)

The composition of the research teams on the five focus topics (defined in previous sections) is as follows:

- **Mammalian-cell-based Bioprocess Technology** is led by Dr. Chotteau (Rec 2008; Bioprocessing, Automatic Control) with one lab manager, three post-docs, six PhD students and a lab technician.

- **Biocatalysis and Enzymology** is currently led by PIs Prof. Berglund (fine chemicals synthesis) and Dr. Martinell (polymer synthesis) and will be supplemented by the Assistant Professor in Biocatalysis and Green Chemistry under recruitment.

- **Integrative Structural Biology** is led by Prof. Christina Divne whose team currently includes three PhD students, and one junior researcher.

- **Environmental Biotechnology** is led by Dr. Kuttuva Rajarao with assistance from Prof. van Maris with five (exchange) PhD students. For a large part of the evaluated period, this team also included Dr. Björlenius who left at the start of 2019. Prof. van Maris is also a member of the board of the crossdisciplinary KTH Water Centre.

- **Microbial Bioprocess** technology is led by Prof. van Maris (Rec 2016; Biochemical Engineering), Assoc. Prof Veide (ret. 2021; Biochemical Engineering) and Assist. Prof. Gustafsson (Rec. 2019; Industrial Microbiology) with one lab manager, one post doc and four PhD students.

d. Recruitment strategies

Other than the Assistant Professor position in Biocatalysis and Green Chemistry, which is under recruitment, no obvious additional hire plan was visible for the Panel. Considering the industrial relevance of microbial and mammalian cell production of biologics, the Department could consider an expansion in this important area, thus complementing the positive developments associated with the recent hires of Prof. van Maris and of Dr. Chotteau. Reaching a critical mass in this sector (which is very important for teaching and for industry) should be a priority.

e. Infrastructure and facilities

The Department has made or is making various investments in the maintenance and upgrading of the pilot plant, bioreactors and acquisition of mass spectrometers for analysis of gas-streams leaving the bioreactors. It is foreseen that other big investments will either be made through applications for specific grants or future strategic resources from KTH.

Investments in small equipment can routinely be made from project budgets or through the shared departmental overhead. The main challenge is to replace or expand the infrastructure that falls in between these categories, but is essential for current operation, such as analytical infrastructure, or future competitiveness, such as liquid handling robots for automated work flows and high throughput screening. As for other Departments, the Panel urges KTH to consider adequate strategies, on one hand for the life cycle management of instrumentation, on the other hand for the sharing of equipment (which leads to savings).

3. Strategies and organisation

a. Goals for development 5–10 years ahead

The Department has declared a vision of advancing the sustainability development of industry and society with critical mass on five thriving fundamental, application-inspired research themes (section 2b) each anchored in the organization by one or more faculty with increased quality and quantity of both external funding and research output, whilst maintaining an excellent contribution to the core educational programs of KTH. The Panel concurs with this vision.

The Department has also identified education, training and research in the field of mammalian-cell-based bioprocessing as being highly relevant for both the international large industry, as well as start-ups, in the greater Stockholm area. As mentioned in previous sections, this sector is currently not represented amongst the faculty of KTH, but had previously been identified and supported as strategically important by Vinnova and KTH. Over the past years, Dr. Veronique Chotteau has proven her still growing potential as very talented independent researcher, who runs an almost completely externally funded (e.g., Vinnova Centre of Excellence AdBioPro) research group. Given the strategic value of a faculty position in mammalian-cell-based bioprocessing this topic has been prioritized by CBH for faculty recruitment and has recently been completed with the promotion of Dr. Chotteau to the ranks of an Associate Professor. The Panel believes that growth in the field of mammalian cell biologics would be both desirable and important. The implementation and/or expansion of Master study programs to adequately address Industrial Biotechnology topics should accompany the expansion of the faculty.

There appear to be planned recruitment activities for biotechnological processes associated with clean water. While the topic is of clear societal and environmental relevance, such recruitment plans have not been discussed in detail with the Panel.

b. Congruence with university-level goals

The ambitions of the Department of Industrial Biotechnology are aligned with the goals of KTH, with a special focus on well-being (e.g., production of biopharmaceutical products), environmental issues (e.g., green chemistry, clean water) and sustainable growth (derived from better industrial processes).

c. Leadership structure and collegial structure

The organizational structure of the Department is flat and collaborative. The leadership of Prof. Antonius von Maris has been positively perceived, both by the Panel and by members of the Department.

The Panel feels that, notwithstanding the recent positive developments, additional efforts should be made to increase communication and collaboration, both within the Departments and with its neighbours.

d. Strategies for achieving high quality

In addition to the obvious role played by good hires, the Panel believes that an increase in budget, in industrial and academic collaborations and in the "critical mass" of the Department will be crucially important not only for "quantity", but also for "quality". A judicious support from KTH on deserving activities, for example in the form of matching funds, could be transformational for this Department, which operates on important sectors. The extent of collaborative projects with Industry is still suboptimal and should be substantially improved.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

Research and teaching at all three cycles are strongly integrated within the culture of the Department of Industrial Biotechnology. All faculty members thoroughly enjoy teaching and view the combination of research and teaching as an essential part of being a faculty member at a university. Additionally, many of the topics of expertise of the staff are also important for the students participating in the KTH education programs, their future employers and society. PhD students provide assistance during various 1st and 2nd cycle teaching activities, thus gaining precious experience in teaching. In addition to theoretical knowledge, practical skills (laboratory work as well as protein and cell production) are essential to students at all levels.

The Panel urges the Department to carefully consider whether the Master Study Program in Industrial and Environmental Biotechnology should be expanded in scope, either with the sole forces of the Department or in collaboration with other Departments.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

A common theme and strength in the research of the Department of Industrial Biotechnology is the development of knowledge and concepts that contribute to achieving and improving sustainable production of chemicals, fuels and pharmaceuticals. The Department also develops concepts for cleaner water and environment. This drive towards sustainable production is itself highly relevant to society at large. The collaboration with many different industrial and academic partners is particularly important and should be further expanded. For instance, the KTH Water Centre, of which van Maris is a board member, creates a network of research groups across KTH together with local government, non-governmental organizations and many large- and small companies.

The global impact of improved sustainable production benefits all societal groups. Although improved equality is not the main focus of the research of the Department, there are specific research examples that contribute to this: (i) Improved efficacy and lower cost of production of biopharmaceuticals can lower the cost of drugs for rare diseases and thereby reduce inequality. (ii) development of environmental biotechnological solutions for (waste) water treatment that are suitable for operation in developing countries. (iii) decreased dependence on fossil oil decreases the dependence on a scarce and geographically unequally distributed resource.

b. Research dissemination beyond academia

The Department of Industrial Biotechnology is naturally well-poised to interact with industrial partners (e.g., production of biologics and of chemicals) and with regulatory authorities. As stated in previous sections, an increased interaction with industrial stakeholders will be beneficial for all involved parties.

Considering the relevance of GMP manufacturing of biologics, the positive activities associated with the hire of Dr. Chotteau would benefit from an even higher level of dialogue and engagement with regulatory authorities. If perfusion-based manufacturing activities are to become a reality (in alternative to fed-batch strategies), this will only happen if regulatory authorities and companies are convinced of the ability to produce biologics (i.e., therapeutic proteins and therapeutic cells) at reproducibly high quality.

A number of teaching activities for children and for the general public have also been implemented.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

Virtually 100% of the research activities of the Department are related to sustainable development. This includes Sustainable production (UN #12) of chemicals, fuels or pharmaceuticals, thus contributing to climate change (UN #13) and life on land (UN #15). Increased efficacy and decreased cost of pharmaceutical production can boost health for a larger group of people (UN #3) and reduce inequality (UN #10). Other research lines address removal of pharmaceuticals and excess nutrients from municipal waste water which improves quality of life in surface waters (UN #14), as well as availability of suitable drinking water (UN#6). Research activities at the Department of Industrial Biotechnology are also highly relevant in connection with the KTH Action plan for the university-wide sustainability objectives 2021-2025.

d. Plans and structure for increased impact

The Department did not state specific goals to increase impact, other than a continuation of the activities started under the leadership of Professor van Maris and the wish to secure more funds through external collaborations (mainly industrial in nature). These goals are important, but need to be accompanied by adequate measures (see next section).

6. Recommendations for strengthening the department and its future potential

The Panel believes that the best way to further increase the impact of the Department of Industrial Biotechnology is to:

- Support the positive growth triggered by the hire of Professor van Maris
- Support groups which are able to secure additional funds (e.g., through industrial collaborations) by means of matching funds
- Add Industrial Biotechnology as Enabling Technology to the KTH Industrial Transformation Platform
- Create strategic links between Industrial Biotechnology, Sustainable Production Development and the KTH Action plan for the university-wide sustainability objectives 2021-2025.
- Ensure that an adequate life-cycle plan for instruments (with KTH support) is in place.

With these instruments, the Department will reach a critical mass, will have more (and better) output, with benefits for KTH, science, industry and society. The PIs are professional and competent. It is all

about setting the right conditions, in order to exploit the full potential of this highly important and forward-oriented research topic.

7. Final remarks

In addition, state if the panel lacked any material relevant to making adequate observations and recommendations.

While the Departments of Gene Technology and of Protein Science have been very successful, the Department of Industrial Biotechnology deserves more attention. It would be a pity not to support the recent positive developments which have happened at the Department under the leadership of Professor van Maris. On the other hands, the support may best be given in the form of matching funds, thus rewarding groups which have been successful in securing external grants (either academic or industrial in nature). A more balanced support from KTH to the salary of PIs (e.g., 75/25) may allow them to concentrate more on their core business (i.e., research, teaching and search of funding opportunities for the group).

Department of Protein Science

Major findings

1. Strengths and weaknesses of the department

Concerned and recommendations for improvement

The Department of Protein Science is a leading research center, which enjoys an international prestige, thanks to its excellence in technology-driven developments and the ability to generate products of practical scientific and industrial relevance ("from concepts to prototypes").

The Panel has witnessed breathtaking developments at the Department, with many large-scale projects, amazing productivity, international visibility and huge impact. The Department and its activities are a model which is unique in the world (alongside many of its creations, such as the Human Protein Atlas Project and Science for Life Lab). This is the result of a smart, well-planned and meticulously executed "grand" Project.

The role and vision of Professor Mathias Uhlén have been tremendously important for the Department and for Science in Sweden. At the same time, many associates have been crucially important for this success story, which continues to produce new technologies (e.g., spatial transcriptomics) and new chemistry (e.g., affibodies and other affinity reagents). The various groups have successfully developed their own identity and exciting research lines. The Panel is confident that, above all, the "philosophy" of the Department is now firmly rooted and will stay in the future.

The Department is actively involved in Flagship projects (such as The Human Protein Atlas, Next-Generation Biological Drugs) and has strong relations with both public and private sector, exemplified by several multipartner competence centers being managed by the Department (such as VINNOVA-funded centers: CellNova and AAVNova; Novo Nordisk Foundation-funded KTH CHO Cell factory group, Center for Biosustainability; Wallenberg Centre for Protein Research (WCPR) and KTH Center for Applied Precision Medicine KCAP). The Department has contributed to the creation of successful Spin-Off Companies and enjoys a Top Ranking in international standings, as a result of its performance.

The Department operates on a budget of 25 Mio $ funding per year (of which 60% comes from external sources). This is a sign of strength, but also a potential vulnerability.

The Department has 20 Faculty persons, 180 employees and six Research Divisions, spread across floors and buildings (which sometimes can be a problem). Collaborations are facilitated by Retreats and Seminars (more difficult at times of COVID-19). Recruitment happened in both directions (a former Faculty Member left to become the CEO of a company). There is no female faculty at the Assistant and Associate Professor level, and no female faculty at all with diverse background (non-Swedish), indicating that certain gender and diversity strategy is needed.

2. Relevant and forward-looking objectives

Are the goals relevant and forward-oriented?

The main goals of the Department are relevant and forward-looking, such as the ambition to expand the current Flagship projects (with a focus on data-driven life science), attract new sources of funding, diversify faculty composition and further improve success rate (which is already outstanding). Overall, the impression is that the Departments can be particularly impactful in data-driven precision medicine and diagnostics, as well as in the generation of new therapeutic products and prototypes.

3. International community engagement

The level of international community of the Department is outstanding. The rich and high-impact publication track-record ensures maximal visibility. For example, the Department of Protein Science at KTH has led a pioneering effort to create the Human Protein Atlas (HPA) and other related atlases. This effort has resulted in more than 600 scientific publications by consortium members, including many in high-impact journals, such as Nature and Science. The resource is publicly available for the wider life science research community. Due to its fundamental importance, this KTH-based map of human biology has been selected by the EU-based organization ELIXIR as a core database resource. The atlas is one of the most visited biological databases in the world, with more than 150,000 visits by researchers from numerous countries each month. HPA has also triggered the *Cell Atlas* and *Pathology Atlas*.

4. Future potential of the department

For a positive development towards fulfilling their goals, operating on the front line of international research, and exerting a beneficial impact on society

It is “harvest time” for the Department, thanks to the seeds that have been planted over the last two decades. If adequately managed and supported, the Department will continue to bear fruits and increase its applicative activities, in a number of different pathologies.

5. Recommendations

Based on your overall observations and analysis of the department, please provide the recommendations that you find most useful to the department for the future development of high-quality research and research environments

It will be important to retain not only Faculty, but also staff with invaluable knowledge and technical skills. It will be exciting to see which hires are planned, and the Panel welcomes the positive developments in gender balance and diversity.

Traditionally, the Department has grown a good proportion of its operation thanks to the integrated generation and use of innovative affinity reagents (e.g., antibodies, affibodies, and chemistry). The importance of generating “good” reagents cannot be underestimated. It is likely that the Department will continue along this path, adding even new modalities (e.g., DEL technology, activities at SciLifeLab) for the discovery of binders and the creation of functional materials. The Panel feels that Mass Spectrometry could play an important role and further enhance the genomics and transcriptomics facilities. Modern MS techniques and instruments have revolutionized biomedical research and could benefit from the knowledge and the reagents available at KTH.

Excellent examples of data analytics were presented. There is probably a huge opportunity for Data Science, which has a dignity of being an independent discipline, but is best implemented in close interaction with the experimental needs, addressing relevant scientific questions. Good or bad hires could make the difference between adding value to the huge amount of experimental data which is available, or running the risk of creating less relevant data. Again, an important topic for discussion in connection with future hires, also in the context of the KTH focus on digitalization.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

The Department of Protein Science is organized in seven divisions (Affinity Proteomics, Cellular and Clinical Proteomics, Drug Discovery and Development, Nanobiotechnology, Systems Biology, Protein Engineering, Protein Technology) and in five facilities. Operations are based at the AlbaNova campus and at SciLifeLab. The latter started out in 2010 as a joint effort between four universities: Karolinska Institutet, KTH Royal Institute of Technology, Stockholm University and Uppsala University, with a leading role played by Professor Mathias Uhlén.

Research activities include the engineering of proteins (in order to modulate or optimize their function), the development of novel therapeutic concepts through the discovery of novel prototypes, as well as the development of novel methods for protein engineering (display technologies, directed evolution, mammalian cell production systems, affinity-based assays, spider silk engineering, antibody validations, microfluidics). Collectively, these efforts are aimed at advancing knowledge in basic research and in finding solutions to practical problems (mainly for human health, but also for environmental issues).

The breadth and quality of the activities of the Department can hardly be covered in this small section. Here, it may be good to illustrate three activities, which give an impression of what has been achieved over the last few decades:

- The Human Protein Atlas Project has generated more than 50,000 antibodies and has used them to characterize tissue sections, in health and disease. This immense amount of data has been made freely accessible to the public through suitable Web platforms, which are visited and interrogated daily by thousands of users all over the world (more than 150,000 visits per month!!).

- The quest for an even more detailed characterization of how and where proteins are expressed in tissues and cells has led to pioneering developments aimed at characterizing the subcellular localization of proteins

- Proteins are used not only as staining reagents (antibodies), or as antigens for the generation of antibodies, but also as therapeutics. Novel classes of therapeutic proteins (e.g., Affibodies™) have been invented here and have been developed in clinical trials, in a successful and fruitful collaboration with spin-off companies

b. Contributions to the advancement of state of the art within the research fields of the department

Given the immense productivity of the Department, it is difficult to summarize the many contributions to the advancement of the state of the art, within Protein Science. For illustrative purposes (without the ambition to produce an exhaustive list), it may be good to mention (i) the characterization of protein expression and localization in health and disease; (ii) contributions in the field of Precision Medicine; (iii) the engineering of novel classes of therapeutic proteins and of molecular binders for diagnostic purposes; (iv) the generation of novel materials; (v) the exploitation of knowledge related to protein localization in cells and tissues to advance knowledge, both in basic biology and in molecular pathology.

Due to its fundamental importance, the KTH-based Human Protein Atlas represents a map of human biology and has been selected by the EU-based organization ELIXIR as a core database resource. The

atlas is one of the most visited biological databases in the world. The project has also generated an enormous resource of antibodies which are useful for technology development, research of human biology and disease, and development of precision medicine. The potential is huge, both for preserving well-being and for a better understanding of disease (from cancer to diabetes, from neurological conditions to cardiovascular diseases).

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The bibliometrics for the Department of Protein Science for 2012-2019 showed a very high productivity, with a total of 586 published peer-reviewed articles. The Department hosts Professor Uhlén, who is one of the most cited scientists in Sweden. The Department has published multiple articles in very high impact journals, such as Nature, Science and JAMA, since the last RAE evaluation 2012. The Panel considers that the productivity of the Department has been exceptionally good.

In addition to the publication track-record, the Department has been exemplary in engaging both the scientific community at large (for example through the open-source sharing of data within the HPA project) and through dedicated communication activities.

The Panel believes that it would have been almost impossible to do better, not only for dissemination activities, but also in terms of national and international collaborations.

d. Follow-up from previous evaluations

In the previous evaluation, the Panel had rightfully commented that the Department of Protein Science should “take advantage of this unique position in its succession planning” and that “KTH could be become the "CERN" of Biotechnology in Europe”.

The general recommendations related to the recruitment of international tenure-track assistant professors, work actively on gender balance, as well as restructuring research areas and divisions, have largely been addressed. Structural biology activities remain fragmented, as also commented for Department of Industrial Biotechnology.

The specific recommendations for the Department of Protein Science mainly related to (i) maintaining state-of-the-art platforms; (ii) investing in forward-looking research activities; (iii) having at least two affinity reagents for each target in the HPA project; (iv) encouraging international mobility; (v) strengthening Nanobiotechnology through specific hires. These recommendations have been taken very seriously and have been addressed very professionally. The importance of maintaining and reinforcing the state-of-the-art platforms remains very important, in spite of the impressive developments associated with SciLifeLab. Similarly, the Panel sees the value of the international mobility (to both directions).

Overall, the Panel is both impressed and satisfied by what has been done.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The budget of the Department is substantial, in relation to the research-intensive nature of its operations. In 2020, the total revenues were 217,103 kSEK (approximately 25 million USD), of which 58% from external funding. Governmental support has decreased in proportion, from 38% in 2016 to 32.6% in 2020. Private foundations represent a majority of this, especially KAW (Knut and Alice

Wallenberg foundation), Erling-Persson family foundation, Schörling foundation, Tussilago foundation (Liechtenstein), Novo Nordisk Foundation (Denmark), the Swedish Cancer Society, Heart and Lung foundation, and the Brain foundation. The Governmental funding agencies, such as the Swedish Research Council (VR), VINNOVA, and FORMAS, are also very important for the Department.

While the success in winning competitive funding can be seen as a strength of the Department (and it is a strength), this fact highlights the potential vulnerability, as fluctuations in funding schemes or other unpredictable events (e.g., delays in EU calls) may endanger operations for a very successful institution. The Department of Protein Science is one which depends massively on third-party funding.

b. Academic culture

As for the other Departments in the Biotechnology sector at KTH, the Department of Protein Science is proud of a well-rooted philosophy of sharing and supporting each other. Journal clubs and coffee-meetings (BIO-fika, KTH-fika) contribute to a stimulating atmosphere of collegiality and of scientific exchange. Through the interviews with Faculty, with Staff, with Postdocs and with PhD Students, the Panel was impressed by the quality of work, by the openness of communication and by the culture at the Department, which was much appreciated and valued by all involved parties.

c. Current faculty situation and composition of the research team(s)

The Department has 20 faculty positions and about 180-200 employees (including PhD students). The many researchers are explained, in part, by the National facilities hosted by PRO (Translational Plasma Profiling, Autoimmunity and Serology Profiling, Cell Profiling, Human Antibody Therapeutics, and Protein Expression and Characterization) and the Human Protein Atlas flagship project. Some research groups are very large, but that critical mass is crucially important in order to reach the extremely high academic standing and the excellent productivity of the Department. The Panel recommends not to change a “winning team”, but warmly encourages KTH to consider how to best ensure continuity for a system which serves as role model internationally.

As noted also for other Departments, a higher proportion of KTH funding for faculty positions (perhaps 75-25) would seem appropriate, also in consideration of the fact that most grants are not designed to support the salary of professors and PIs.

d. Recruitment strategies

The Department has made excellent hires in the past. For the future, the Panel could not get complete visibility on the immediate recruitment plans, as some of the hires were in conjunction with the SciLifeLab (associated to KTH). The Panel has made recommendations to consider growing Data Science activities (also in conjunction with Gene Technology operations) and mass spectrometry-based proteomics, which would nicely complement the genomic, transcriptomic and proteomic activities already present within the Biotechnology sector.

The procedures followed for hiring were performed at the highest standards and the Panel has no doubt that this professionalism will continue in the future.

e. Infrastructure and facilities

The infrastructure at the Department is world-class. This is due, to a large extent, thanks to the fruitful interaction with SciLifeLab (for which faculties of the Department have been founding members, including Mathias Uhlén as Founding Director) and with the Human Protein Atlas Project. Hosting National facilities helps the Department maintain state-of-the-art methodologies and instrumentation. KTH should help the Department maintain an adequate life-cycle plan for instrumentation. A closer interaction of the Department with the management and with strategic decision made at SciLifeLab appears to be fundamentally important. The Department should continue to innovate and generate

technology (which is essential for a bright future of SciLifeLab), rather than gradually transforming into mere users. An adequate representation of Life Science within the KTH Board may be important in this context.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

The Department has critically defined four main goals for the future: (i) expanding flagship projects; (ii) attracting new funding; (iii) improving success rate in national technology-driven competition; (iv) maintaining and advancing instrumentation and infrastructure. When these goals are analysed in the context of the exceptional productivity of the Department, they reflect the wish to maintain an international leadership in the field of Protein Science, but at the same time a concern of how to keep the highest standards of research and technology, in view of the dependence on third party funding.

The seeds planted with the HPA Project and with the SciLifeLab activities appear to be ideally suited for even deeper translational activities (e.g., focused flagship projects in individual areas of pathology). Nonetheless, a solid KTH support will be crucially important to ensure that this model, which is admired and copied internationally, continues to do well and prosper.

b. Congruence with university-level goals

The activities of the Department fit well with the university-level goals. A solid human health research focus is aligned with sustainable development and well-being goals. The KTH focus on digitalization is matched by the extensive data analysis and graphical representation activities, which could be further expanded by strategic hires and expansion in the areas of Data Science and Artificial Intelligence (thus building an even stronger bridge with Department of Gene Technology).

Numerous programs have a credible track-record of impact, in terms of discoveries and industrial output (e.g., spin-off companies).

c. Leadership structure and collegial structure

There is excellent leadership and collegial atmosphere at the Department. Still, faculty is always present and approachable, as confirmed during the meetings with PhD students and staff. The physical division between AlbaNova labs and SciLifeLab does not facilitate exchanges, but the sharing of resources and the regular meetings (including meetings among faculties) ensure a good, fruitful and transparent communication.

d. Strategies for achieving high quality

Maintaining (rather than achieving) the excellent quality of the Department remains one of the most important goals for the future. This will be a combination of hiring (and retaining) good people (as in the past), ensuring continuity of funding and nurturing a stimulating environment, with state-of-the-art instrumentation.

Since a substantial proportion of the funding (also for new hires) comes from third-party projects and from SciLifeLab budget, the future continuity of operations at the Department has to be seen in the broader context of how KTH wishes to retain (and possibly further stimulate) Protein Science excellence.

Hires in the fields of Data Science/Artificial Intelligence, Mass Spectrometry-based Proteomics, as well as in activities aimed at valorizing the use and interpretation of biological/patient samples (thanks to sophisticated and validated binding proteins and antibodies), will be important for the future of the Department.

Support of faculty (which at present often has to secure 50% of its salary from third party fundings) and of basic operations (e.g., life cycle management for instruments) would be highly desirable.

As mentioned in previous sections, transforming the Human Protein Atlas project into a national infrastructure may be a necessary transformation, if Sweden does not want to disperse (e.g., to an international commercial institute) the knowledge and resources accumulated in more than 20 years of hard and smart work.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

The Department is extremely active in teaching at all levels. The courses and programs which are offered are so numerous that it would be impossible to mention all relevant activities in such a restricted space.

As mentioned in the Self-Assessment document, the topics of the courses are designed based on what a graduate in the respective program is required or expected to know when entering the workplace (whether in industry, governmental agencies, or academia). The faculties develop the courses and shaped them around the research front where they are active. This ensures an up to date, near the research front level of the course.

Dissemination and training activities are well exemplified by the education tools offered by HPA and SciLifeLab, but go much beyond, if one considers the multitude of courses and modules which students can take. Still, PhD students of this and other Departments have requested some flexibility in the choice of educational modules for credits (including easier procedures for taking courses that are of direct interest for specific research tasks, closely related to the PhD program). The Panel welcomes some flexibility in choosing modules, as PhD students are mature enough to follow their passions and interests. At the same time, the Panel feels that a good mix between project-specific training activities and broader educational activities may be the best way to train the scientific leaders of the future.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

A major focus of research at the Department of Protein Science is to improve public health and to invent solutions related to a more sustainable world. This includes providing a large number of fundamental tools (databases over the human molecular landscape) useful for other researchers and research-intense pharma companies, as a base for research efforts and hypothesis building. The impact on human health can be considerable, as well exemplified by the following examples:

- The Human Protein Atlas information (e.g., immunohistochemistry data, gene expression information) is readily available to researchers all over the world through a used-friendly web-interface (see www.proteinatlas.org). This site is visited daily by thousands of researchers from all over the world, thus contributing to the prestige and visibility of KTH.

- The innovation in terms of methodology (e.g., spatial proteomics) and of reagents (e.g., ingenious Affibody-based therapeutics and other types of binders) has been incredibly impactful, both in terms of global adoption of the methods and in terms of products that have

gone into clinical trials, with strong results emerging from Phase II clinical trials (e.g., psoriasis, IgG-based autoimmune conditions).

b. Research dissemination beyond academia

Faculties are engaged in dissemination at all levels, from web portals to Academy activities, from media presentations to museum activities, from TV to newspapers. The performance of the Department has been just excellence and the Panel is confident that KTH leadership will acknowledge and appreciate what has been done.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

Most of the activities of the Department, being focused on applicative healthcare aspects are well aligned with SDG3 (i.e., good health and wellbeing). In practice, a measurable impact is demonstrated not only in terms of highly visible publications, but also Precision Medicine tools, new products and prototypes, as well as all activities which provide a deeper fundamental understanding of health and disease.

d. Plans and structure for increased impact

The Self-Assessment document indicates that "in order to maintain and increase our impact, it is critical that we have a structure that values and encourages curiosity-driven research, engagement with society, and ensures that our faculties and researchers can work at optimal conditions. The latter includes both physical conditions (access to state-of-the-art instruments, labs) and non-physical conditions, such as having enough time dedicated to research, support in achieving funding, limitations of administrative tasks, and that we have an including, open, and supporting atmosphere". The Panel strongly agrees with these statements and urges the KTH Board to undertake all possible actions, in order to avoid a further increase of bureaucracy. One can "die compliant", because of an excessive quest for compliance.

The Department of Protein Science has demonstrated, over the years, an impressive ability to organize itself very well, to make wise hires, to attract a substantial amount of funding and to implement highly-productive programs, which are admired by the international community. Trusting the leadership of the Department and supporting their requests appears to be a reasonable recommendation for the leadership of KTH.

6. Recommendations for strengthening the department and its future potential

As previously mentioned, recommendations primarily aim at maintaining the level of excellence that has been achieved. The tradition in "valorizing" tissue specimens and patient-derived material with state-of-the-art technologies and reagents should continue in the future, with a potential to continue yielding applicative success stories. Sweden is exemplary in collecting and documenting healthcare resources (e.g., anonymized information and samples). However, the Panel heard that it may be difficult, in some case, to adequately use these resources, because of unclear interpretations on what confidentiality of patient-derived data and samples means. Finding "reasonable" solutions and providing constructive regulatory expertise will be important, in order to avoid jeopardizing projects that could have a profound impact on healthcare and precision medicine. This may be a national (or even Nordic) challenge, as the interpretation of GDPR still varies between institutions and people, and while in some universities the legal teams are actively trying to find suitable solutions to the problem, in other they just forbid everything for the sake of security.

Establishment of Data Sciences as discipline of its own dignity, in close interaction with Protein Science and Gene Technology, is recommended by the Panel, and so is an intensification of Mass Spectrometry-based Proteomics.

Staff plays an important role in the success of the Department. Adequate measures (e.g., career paths, recognition, titles, opportunities for salary increase) may have to be implemented, in order to adequately motivate and recognize the crucial role played by staff in the success story of the Department.

Facilitating international exchange programs (e.g., sabbaticals for faculty and staff) would be encouraged. At the same time, the Panel was pleased to hear that PhD students are encouraged to participate and present at international conferences. Hosting the world leaders in Protein Science may be a nice additional way to expose the young generation to the trends of the future. As one Panel member stated, the only sabbatical that Fred Sanger had made throughout his entire career (otherwise entirely spent in Cambridge, UK) was in Sweden. The two-times Nobel Laureate acknowledged this in his autobiography, published in Annu. Rev. Biochem. With the vibrant activities running at KTH and at Karolinska, Stockholm remains a very attractive destination, particularly in the area of Protein Science.

Keeping good relations with industry and facilitating translational activities (as is currently being done, thanks to a wise IP legislation and smart support for technology transfer) will continue to be important. Allocating central infrastructure positions in the immediate proximity of research labs (i.e., where those functions are needed) may also be good.

7. Final remarks

In addition, state if the panel lacked any material relevant to making adequate observations and recommendations.

The Department of Protein Science is a truly outstanding Department, with world leaders in their field. We recommend that the Leadership of KTH acknowledges this excellence and makes all possible efforts to ensure continuity for what has been created (and continues to be created on a daily-basis, starting from curiosity-driven research, but with a sharp eye on what is needed and useful in practice). Continuity for HPA activities, an increased support of faculty salary (e.g., 75-25 model) and a strong representation within SciLifeLab may be the most urgently needed actions, which are expected to have a positive impact.