

PERSONALISED MEDICINE IN THE NORDIC COUNTRIES

NOS-M REPORT WITH CONCLUSIONS AND RECOMMENDATIONS
FOR JOINT ACTIONS IN PERSONALISED MEDICINE
IN THE NORDIC COUNTRIES



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EXECUTIVE SUMMARY

Background

The Joint Committee of the Nordic Medical Research Councils (NOS-M) is a cooperative body for the medical research councils of the Nordic countries. The organisation aims to coordinate and promote medical research in the Nordic countries, to monitor its progress, and to facilitate information exchange among the countries. NOS-M has published two white papers (2011 and 2014) with recommendations on actions needed for the Nordic region to maintain a competitive global position in medical research by responding to scientific, health care and economic challenges. In the NOS-M white paper from 2014, personalised medicine was identified as one of the areas where cooperation can enable the Nordic countries to become world leaders. The theme was explored further in a workshop organised by NOS-M in November 2016 and by a mapping exercise aimed at providing an overview of current strategies and initiatives related to personalised medicine in the Nordic countries.

White Papers on Personalised Medicine

In the white paper from 2014, NOS-M gave several recommendations for advancing the added value of Nordic cooperation in medical research and put forth several suggestions for concrete actions.¹ Utilisation of biobanks and registers as well as personalised medicine were identified as areas where the Nordic countries have an opportunity to become world leaders through cooperation. As a result of the recommendations of the white paper, NOS-M arranged a workshop on personalised medicine in Stockholm on November 2016.²

Workshop on Personalised Medicine

The aim of the workshop was to discuss the potential of Nordic research cooperation targeting personalised medicine, including e.g. networking, academia-industry cooperation and joint research funding opportunities. A report from the workshop is presented in appendix 1.

Conclusions from the Workshop

- Personalised medicine may lead to major improvements in health care, but there are a number of major ethical, societal and legal challenges that need to be tackled before this can be accomplished.
- Policy directives need to be aligned at the Nordic level.
- There are several Nordic advantages, including a number of unique registers, cohorts and biobanks; high quality epidemiology and clinical research; public-funded health care and a population that is generally very positive towards participating in research.
- Rare diseases and cancer are appropriate focus areas for Nordic cooperation.

1 Nordic Potential in Medical Research – Cooperation for Success (NOS-M, 2014).

2 <https://nos-m.org/news/nordic-common-strengths-and-future-potential-in-the-field-of-personalised-medicine>

Mapping of Personalised Medicine Initiatives in the Nordic Countries

To follow up the workshop, NOS-M decided to map personalised medicine strategies and initiatives within the Nordic countries as well as some of the major international initiatives. The focus of the mapping exercise was strategic and public funding initiatives in personalised medicine at the Nordic and national level. A brief survey of the state of personalised medicine at the European and global levels was also included. The complete mapping exercise is presented in appendix 2.

National Strategies

There are currently national strategies specifically dedicated to personalised medicine in Denmark and Norway, although personalised medicine is an essential component of national strategies and initiatives in all the Nordic countries. However, these strategies vary both in how they define personalised medicine, and in terms of financial commitment.

There are national genome centres and/or initiatives in all the Nordic countries. Iceland has the world's most genotyped population, largely due to the pioneering work of deCODE genetics. This is in line with a current global trend of large-scale genome sequencing initiatives. Although more ambitious genome sequencing initiatives are currently being undertaken both at the European level and in major economies such as the US and China, the Nordic countries have a unique ability to combine genome data with comprehensive data from registers and biobanks.

Common Nordic Initiatives

At the Nordic level, several initiatives have been taken to coordinate efforts in the field of personalised medicine. NordForsk has played a crucial role in the establishment of many of these by providing financial support. Many of the recent initiatives deal with data handling and sharing, e.g. Nordic Alliance for Clinical Genomics, the Nordic Society for Human Genetics and Precision Medicine, the Nordic Biobank Network, the Nordic collaboration for sensitive data, the Tryggve project under the Nordic e-Infrastructure Collaboration, and the Nordic Commons for Health Data project at NordForsk.

There are currently no specific funding initiatives for basic research in personalised medicine at the Nordic level. The Nordic Programme on Health and Welfare at NordForsk has announced several calls focusing on utilisation of register data in health and welfare research. The calls have been broad in scope and have not directly targeted personalised medicine. A call for innovations in personalised medicine was launched in 2018, and was organised as a virtual common pot co-funded by the national innovation funders.

Conclusions from the Mapping Report

- There are national strategies in all Nordic countries directed either specifically towards personalised medicine or to closely related areas.
- It is clear that the Nordic countries have a number of advantages to facilitate the realisation of personalised medicine, e.g. high-quality epidemiology and clinical research, unique health data infrastructures in registers, cohorts and biobanks.
- The many similarities between the Nordic countries, e.g. similar public health care systems, a population that is generally very positive towards participating in and has trust in research, etc., implies a strong added value in collaboration between the Nordic countries in personalised medicine.
- The unique Nordic biobanks and health registers have the potential to make the Nordic region competitive at the global level. There are several ongoing initiatives at the Nordic level addressing handling and sharing of health data, clinical data as well as large data generated from genomic/omics projects.
- A number of obstacles to Nordic cooperation need to be overcome. One such obstacle is the utilisation of data from registers and biobanks at the Nordic level.

Recommendations Based on the Performed Exercises

During 2018 the NOS-M committee has discussed and finalised common themes that may bring the Nordic countries together in efforts to sustain research in the field of personalised medicine. One action has been to financially support several Nordic initiatives such as workshops between scientists and organisations to establish research networks.

NOS-M has also identified some areas of common interest which we recommend as a starting point for the Nordic countries to join forces towards becoming a key player in personalised medicine.

- There is need for a jointly funded initiative on research in personalised medicine. The call could focus on the utilisation of health data from registers and biobanks or other health data resources, including omics data. The use of a common pot is preferred as it will allow participation from researchers from all Nordic countries on similar grounds.
- There is a need for joint Nordic efforts and competence networks in, for example, rare diseases and cancer. NOS-M could play a role in funding strategic network activities in such areas.
- Utilisation of health and register data at the Nordic level should be remain a high priority on the Nordic cooperation agenda for research funders, data providers, health care and politicians.

Appendices

1. Workshop Report – Nordic Common Strengths and Future Potential in the Field of Personalised Medicine.

2. Mapping Report – Personalised Medicine in the Nordic Countries.

All currencies were converted to Euro using the currency rate of 15 June 2018.

**WORKSHOP REPORT – NORDIC COMMON
STRENGTHS AND FUTURE POTENTIAL IN THE FIELD
OF PERSONALISED MEDICINE. APPENDIX 1**





Illustration: arthinspiring/stock.adobe.com

WORKSHOP REPORT – NORDIC COMMON STRENGTHS AND FUTURE POTENTIAL IN THE FIELD OF PERSONALISED MEDICINE. APPENDIX 1

Introduction

The Joint Committee of the Nordic Medical Research Councils (NOS-M) arranged a workshop on *Nordic common strengths and future potential in the field of personalised medicine* in Stockholm, Sweden, on 23 November 2016. The workshop was the result of the recommendations in the 2014 NOS-M white paper on medical research.³ The aim of the workshop was to discuss the potential of Nordic research cooperation targeting personalised medicine, including e.g. networking activities, academy-industry cooperation and joint research funding opportunities. The workshop attracted more than 70 participants, including representatives of Nordic research financing organisations, policymakers, and experts on personalised medicine. The workshop was chaired by Professor Jan-Ingvar Jönsson, Secretary General of Medicine and Health at the Swedish Research Council and Chair of NOS-M.

Proceedings of the workshop

In the first part of the workshop a number of presentations were given on the current state of personalised medicine in the Nordic countries and in Europe. The second part consisted of presentations on Nordic added value and future potential in personalised medicine including existing Nordic cooperation, each with the potential of moving the field forward. The final part of the workshop was a panel discussion on Nordic common strengths and the ways forward.

1.1 Personalised Medicine in the Nordic countries and in Europe

1.1.1 Personalised medicine may radically improve health care within the next decade

(Professor Mikael Benson, Linköping University)

A current key health care problem is the fact that up to 90 % of all medications are ineffective in 50 % of the patients. In the US alone, the annual cost of ineffective medication has been estimated to around USD 350 billion. Personalised medicine aims to solve these problems by enabling early diagnosis and treatment, as well as individualised treatment. For many disease conditions, diagnosis and treatment are currently impeded by late appearance of symptoms and the involvement of multiple genes. The emergence of *-omics and single cell technologies* has been of crucial importance for the diagnosis and treatment of multigenic disorders. Combining information from multiple sources, e.g. proteins, mRNA, DNA, and environmental factors, into network modules makes it possible to understand disease mechanisms, find biomarkers and therapeutic agents, etc. However, there are a number of major ethical, societal and legal challenges that need to be tackled before this can be accomplished.

1.1.2 Reports on Personalised Medicine initiatives in the Nordic countries

(five speakers gave a short overview of the current state of personalised medicine in the respective Nordic country).

³ Nordic Potential in Medical Research – Cooperation for Success (NOS-M, 2014)

Denmark (Professor Torben Falck Ørntoft, Aarhus University): A lot of activities have recently been undertaken in the field of personalised medicine. Political initiatives include a total of DKK 5 million for a pre-analysis of the state of personalised medicine in Denmark and internationally. From a legislative perspective, a working group on ethics and legal issues has been appointed with representatives of ministries, agencies, patient organisations, ethical councils etc. One major challenge of this working group is to find a pragmatic way of interpreting the EU personal data act.

Finland (Dr. Jarmo Wahlfors, Academy of Finland): There are ongoing major reforms of the national social and health system and coordinated attempts are being made to better utilise social and health data in research. A health sector growth strategy roadmap for 2016–2018 was recently published.⁴ There are currently eight biobanks in Finland and the biobank act⁵ from 2013 stipulates the legal framework for the operations of the biobanks. Another recent strategic initiative is the National Genome Strategy⁶ in 2015 which sets key measures for ensuring that genomic data will be effectively used in health care and in the promotion of health and wellbeing in the future. The Finnish Government decided in April 2016 that a national genome centre and a national cancer centre will be set up in Finland.

Iceland (Professor Magnús Karl Magnússon, University of Iceland): More than half of the adult population has been genotyped and 25 000 whole genomes have been sequenced. Together with detailed genealogy data this enables imputation of the genotypes of the whole population to a varying degree of accuracy. A number of cancer risk genes have been mapped to the genotype data; e.g. it has been estimated that some 1,250 Icelandic women carry the Icelandic *BRCA2* deletion mutation associated with a 15-fold risk of ovarian or breast cancer. Whether the health care system need to proactively intervene in these cases is currently being discussed by the Ministry of Health.

Norway (Senior advisers Hege Wang and Kari Steig, Norwegian Directorate of Health): A Strategy for Personalised Medicine in Healthcare 2017–2021⁷ was commissioned by the Ministry of Health and Care Services. The focus of the strategy is on treatment and diagnostics, not on research. Key recommendations include development of expertise, a coordinated national development of the personalised medicine field, and development of ICT systems and registries. Storage and sharing of data are important questions, and sharing must be considered both for clinical purposes and for research purposes.

Sweden (Professor Mikael Benson, Linköping University): There are many resources available for personalised medicine, but they are divided between different funders, underscoring a need for national coordination including funding. Since health care is challenged by increasing costs, proof-of-concept studies including health economics are also needed. Current major initiatives include the national programme in protein research and biopharmaceutical drugs, with a total budget of SEK 320 million for 2016–2023. National resources include biobanks and registers, Bioinformatics Services to Swedish Life Science (BILS), Biobanking and Molecular Resource Infrastructure of Sweden (BBMRI), Science for Life Laboratory (SciLifeLab)/Biobank Sweden, and the national super computer in Linköping.

4 Innovating together: Growth Strategy for Health Sector Research and Innovation Activities: The Roadmap for 2016-2018. ISBN 978-952-327-142-5.

5 <http://www.finlex.fi/en/laki/kaannokset/2012/en20120688.pdf>

6 Improving health through the use of genomic data. Ministry of social affairs and health 2015:34. ISBN 978-952-00-3605-8.

7 Summary of The Norwegian Strategy for Personalised Medicine in Healthcare 2017-2021. Helsedirektoratet. Publication number: IS-2146 E.

1.1.3 Report on European Personalised Medicine initiatives

(Dr. Irene Norstedt, European Commission)

Research and innovation is a growing priority for the EU and Horizon 2020 is the major funding tool. The three pillars are personalised medicine, rare diseases and the innovative medicines initiative. The International Consortium for Personalised Medicine, IC PerMed, was launched in June 2016. The consortium is a collaboration of research funders and policymakers from EU Member States and beyond, and the vision is to establish Europe as a global leader in personalised medicine research. A SRIA was published in June 2015⁸ and the first action plan is to be published in late 2016. Also, EU Health research is funded by many different instruments, and many of these have a personalised medicine aspect.

1.2 Nordic Added Value and Future Potential in Personalised Medicine

1.2.1 Personalised medicine and the development of life science

(Anders G. Lönnberg, Swedish Life Science Coordinator)

To maintain welfare and growth, efforts need to be focused on the areas with highest yields, and there is no sector with higher added value than life science. Life science is therefore among the Swedish Government's top priorities. Although the sector is very dynamic, no long-term life science strategy has yet been developed and Sweden currently lacks a national agenda for personalised medicine. To maintain welfare and growth, efforts need to be focused on the areas with the highest yields, and there is no sector with higher added value than life science. So far, five priorities are suggested:

- Digitalisation.
- Reimbursement system (hospitals have to consider short-term budget).
- Meriting system (research/health care/industry).
- Government has to be clear in its priority. Too often, the health care system sees research as an obstacle.
- New knowhow.

1.2.2 Infrastructures for personalised medicine

(Dr. Janna Saarela, Institute for Molecular Medicine Finland)

The Institute for Molecular Medicine Finland, FIMM, is located in the largest hospital campus in the country and it is part of the Nordic EMBL Partnership for Molecular Medicine. FIMM contains a biobank infrastructure, as well as a technology centre enabling various aspects of molecular medicine research beyond genomics, e.g. metabolomics, imaging and clinical informatics. Personalised medicine is an important part of the translation of this novel technology into clinical practice. FIMM coordinates the Sequencing Initiative Suomi (SISu) search engine⁹ which offers a way to search for data on sequence variants in Finns. A common Nordic database would be very useful because of accumulation of patients with rare diseases.

1.2.3 Nordic Commons for Register and Biobank Data

(Professor Juni Palmgren, Karolinska Institute)

The total population of the Nordic countries is around 27 million. Nordic advantages include a high number of unique registers, cohorts and biobanks, allowing high quality epidemiology and clinical research, and a population that is generally very positive towards participating in research. However, the lack of a Nordic perspective for research data implies a risk of developing policy directives which are not aligned on the Nordic level. The challenges and obstacles to Nordic cooperation on data resources are illustrated in a report from 2012 by the Nordic Council of Ministers.¹⁰ These challenges are presented from six perspectives: political, organisational, legal, financial, ethical and technical. *Nordic Commons* is a vision of a shared virtual space where scientists can work with the digital objects of biomedical research. A Nordic commons could

8 The PerMed SRIA: 'Shaping Europe's Vision for Personalised Medicine' (2015).

9 www.sisuproject.fi

10 Reinforced Nordic collaboration on data resources – Challenges from six perspectives. TemaNord 2012:514. ISBN 978-92-893-2342-0

rely on a clear legal and ethical framework for sharing data and tools across borders, transparency and an open access policy, and involvement of a broad range of key Nordic stakeholders. This will be associated with a number of possible financial, organisational, technical, legal, ethical and cultural obstacles, that need to be solved.

1.2.4 Risk screening and personalised therapy in cancer: a personalised medicine example

(Professor Torben Falck Ørntoft)

Genomic medicine is the use of genomic information in the clinic to enable a more precise stratification of patients and citizens, for the purpose of surveillance, prevention, diagnosis and treatment. Sequencing can be used in a clinical context to identify inherited syndromes and diseases, to identify citizens with a high genetic risk of disease, to develop novel and more precise stratification of diseases based on cell biology, to choose appropriate treatment etc. GWAS can be used to identify risk SNPs for prostate cancer in individuals with elevated PSA levels. From an economic point of view, a lot of money can be saved by focusing on the high-risk groups. Sequencing can be used to select therapy based on mutations in cancer tissue. Solid tumours release DNA into the blood and sequencing may identify cancer from a blood sample. Molecular profiling can be used to choose the most appropriate treatment.



Panel discussion members, from left to right: Jan-Ingvar Jönsson (moderator), Anders G Lönnberg, Magnus Karl Magnusson, Mia Bengtström, Dag Erik Undlien, Troels Rasmussen, Irene Norstedt (Photo: Tor Martin Nilsen).

1.3 Panel Discussion – Way forward

The presentations were followed by a panel discussion on the Nordic common strengths and the way forward, moderated by Professor Jan-Ingvar Jönsson. The panel members were Mia Bengtström, Senior Adviser at Pharma Industry Finland; Magnus Karl Magnusson, Dean, Faculty of Medicine, University of Iceland; Irene Norstedt, Head of Unit Innovative and Personalised Medicine, EC; Troels Rasmussen, Special Adviser, Danish Agency for Science Technology and Innovation; Dag Erik Undlien, Professor, Department of Medical Genetics, Oslo University Hospital; and Anders G. Lönnberg, the Swedish Government's national coordinator for life science. The panel was asked to address *the biggest needs and bottlenecks within personalised medicine*:

The importance of *political will* was raised, and the fact that the Nordic countries in many respects have very similar systems will probably entail fewer challenges at the Nordic level compared to e.g. at the EU level. Apart from the registries, the *government-funded health care* etc. in the Nordic countries is a great advantage, as there are many fewer obstacles than in countries with private actors. Moreover, the mindset towards research among Nordic citizens is in general positive.

Cooperation on care of *rare diseases* was emphasised as one good starting point for personalised medicine in the Nordic countries, since several successful examples have been implemented in health care for decades. One of the most well known is neonatal screening. However, these examples are based on monogenic diseases, which affect a small portion of the population. Therefore, a key research challenge is implementation of personalised medicine in the diseases that are the main causes of ill health and death in the population, like cancer, inflammatory, cardio-vascular and metabolic diseases. There are already promising clinical examples of personalised medicine in cancer. Rapid technological advances, like genome-wide single cell analyses, and large-scale research efforts are likely to contribute to personalised medicine in cancer, and pave the way for clinical implementations in other common diseases.

One current bottleneck is data sharing and the related *legal* and *ethical* questions. Technical solutions and safeguards are often in place. Sharing data can prevent reinventing the wheel, but from a health care perspective, individual data are also necessary. Data sharing is especially relevant for rare diseases, where sample sizes are small. It was also pointed out that data sharing is not the only solution; interoperability of data is equally important, since poor data management is a major issue at the moment. Another important issue is the question of *consent*. Ideally, each patient should be asked for consent for research. However, it is important for the patients to have an option of reservation as well. Sharing data should not be compulsory; rather, patients should be made aware of the importance of their contribution. Economic models as well as incentives for innovation and sustainability in health care costs are also relevant to consider. It is important to engage the health care providers. Rare diseases would be an appropriate way to begin due to the unique nature as monogenic diseases which is difficult to address in an individual country.

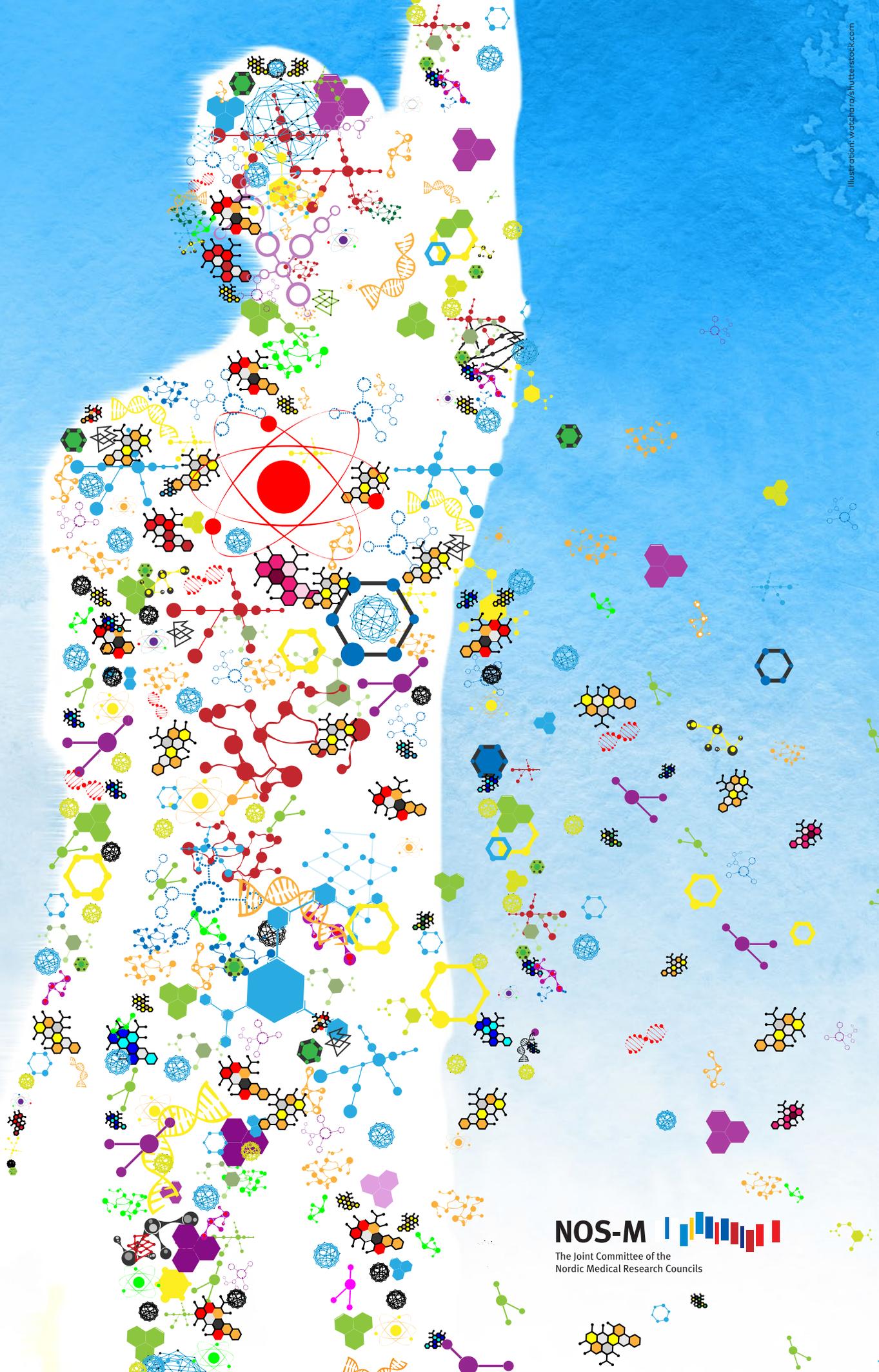
The workshop was closed by the Chair who summarised the discussions of the day and asked the participants to submit recommendations on the future path of personalised medicine in a Nordic context.

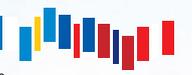
Conclusions

- Personalised medicine may lead to major improvement of health care, but there are a number of major ethical, societal and legal challenges that need to be tackled before this can be accomplished.
- Policy directives need to be aligned on the Nordic level.
- There are several Nordic advantages, including a number of unique registers, cohorts and biobanks, high quality epidemiology and clinical research, public-funded healthcare and a population that is generally very positive towards participating in research.
- Rare diseases and cancer are appropriate focus areas for Nordic cooperation.
- Overcoming the current obstacles related to data sharing is highly important, especially for rare diseases, where sample sizes are usually small. Computational resources and skills are crucial.
- It is important to have a common definition of personalised medicine. In the US, precision medicine is very much focused on genomics, whereas personalised medicine in Europe is more holistic.
- Personalised medicine is about making health care smarter and better by using multiple information sources about the person, his/her environment and lifestyle focusing on prediction and prevention shifting from treating disease to managing health. To achieve this it is necessary to work together across disciplines, organisations and countries.

**MAPPING REPORT – PERSONALISED MEDICINE
IN THE NORDIC COUNTRIES. APPENDIX 2**





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MAPPING REPORT – PERSONALISED MEDICINE IN THE NORDIC COUNTRIES. APPENDIX 2

INTRODUCTION

What is Personalised Medicine?

There is no commonly agreed definition of the term *personalised medicine*. The European Council conclusions on personalised medicine for patients (2015/C 421/03) has a broad definition of the term, stating that "Personalised medicine relates to the broader concept of patient-centred care, which takes into account that, in general, health care systems need to better respond to patient needs." The term *personalised medicine* is sometimes used interchangeably with *precision medicine*, although the latter is usually given a more narrow definition. According to the US National Research Council, "precision medicine refers to the tailoring of medical treatment to the individual characteristics of each patient. It does not literally mean the creation of drugs or medical devices that are unique to a patient, but rather the ability to classify individuals into subpopulations that differ in their susceptibility to a particular disease, in the biology or prognosis of those diseases they may develop, or in their response to a specific treatment."¹¹ However, use of the term *precision medicine* may also extend beyond treatment selection to cover creation of unique medical products for particular individuals. Hence, the terms in practice are often used interchangeably. Finally, the term *stratified medicine* refers to the use of a medicine that is targeted at a patient subpopulation (a group or a proportion of patients, e.g. having a particular disease, age group or disease stage), instead of using one medicine to treat all patients with that disease.¹²

Why is Personalised Medicine a Strategic Priority for the Nordic Countries?

The Nordic countries have a number of strengths to facilitate the realisation of personalised medicine. The high-quality biobanks, health care registers and population-based administrative registers spanning over long time series are a unique research resource. The personal identification number for each citizen makes it possible to carry out longitudinal research and research based on a combination of data from different data sources including health and social registers. Furthermore, the Nordic countries share similar health care systems, and a population that is generally positive towards participating in research. In the Nordic White Paper on Medical Research¹³ (NOS-M, 2014) personalised medicine was identified as an area where cooperation can enable the Nordic countries to become world leaders. The recommendations of this white paper resulted in a workshop organised by NOS-M in late 2016, focusing on Nordic common trends and future potential in the field of personalised medicine.

11 Timmerman, Luke (4 February 2013). "What's in a Name? A Lot, When It Comes to 'Precision Medicine'". Xconomy.

12 Peck R and Smith P. Beyond Genetics—Stratified and Personalised Medicines Using Multiple Parameters. *Pharmaceuticals (Basel)*. 2010; 3(5): 1637–1651.

13 Nordic Potential in Medical Research – Cooperation for Success (NOS-M, 2014).

Aims and Scope of this Report

The main aim of this mapping exercise was to get a picture of the current state of personalised medicine in the Nordic region until spring 2019. The focus has been on strategic initiatives at the Nordic and national level, and on public funding initiatives related to personalised medicine. The state of personalised medicine at the European level and the global level is also described briefly. The report is by no means an exhaustive overview of all personalised medicine initiatives, but rather an attempt to describe the current personalised medicine landscape in a Nordic context. While the industry is an important player, it has not been the focus of this mapping exercise and the precision medicine industry has been recently described elsewhere for e.g. Sweden¹⁴ and Finland.¹⁵

14 Precision Medicine – The Swedish Industry Guide 2018 (SwedenBIO).

15 Lähteenmäki, J., Ervasti, M., Fagerström, R., van Gils, M., Pajula, J., Ruutu, S., ... Ylén, P. (2018). *Data-driven precision medicine ecosystem - stakeholder needs and opportunities*. (Research Report; No. VTT-R-03318-18). VTT Technical Research Centre of Finland.

**CURRENT TRENDS IN
PERSONALISED MEDICINE**





CURRENT TRENDS IN PERSONALISED MEDICINE

It is clear from the mapping exercise that the potential of personalised medicine is being globally recognised. Several nations and regions are currently undertaking ambitious genome sequencing programmes as a step in preparing for the integration of genomic medicine into the health care systems. Several countries have also defined, or are about to define, national strategies on personalised medicine. The Nordic countries are in many respects at the forefront here, but there are still many opportunities to learn from each other and to initiate coordinated actions.

Strategic Initiatives and Funding Strategies

It is clear from the inventory that a number of strategic initiatives related to personalised medicine are emerging at both national and international levels. Not all of these are connected to funding initiatives, but rather suggest how to coordinate efforts at national and/or international level to facilitate the realisation of personalised medicine. Most of the Nordic countries have published national strategies or roadmaps that are either exclusive to personalised medicine, or where personalised medicine is an essential component. At the Nordic level, particularly at NordForsk,¹⁶ there are several common initiatives aiming at coordinating efforts and tackling shared challenges. There are currently a number of strategic initiatives and networks at the Nordic level, as well as joint Nordic calls for proposals aiming to fund transnational research and innovation projects related to personalised medicine. The Nordic national research councils, which are also members of NOS-M, are co-funding a number of NordForsk calls. At the European level, all Nordic countries except Iceland are members of the International Consortium for Personalised Medicine (ICPerMed), and participate in the associated ERA-NET Co-fund, ERA PerMed.

Challenges for Nordic Collaboration

The added value of Nordic cooperation in the field of personalised medicine is obvious: the cumulative population of the countries is comparable to that of a major European country, and we have a tradition of strong medical research, similar funding and health care systems etc. However, there are a number of barriers that need to be overcome before personalised medicine can lead to major improvements in the health care sector. Coordination of registries and biobanks at the Nordic level is one major challenge. A report commissioned by the Nordic Council of Ministers in 2012 concluded that the six most significant challenges to reinforced Nordic cooperation on data resources are at the political, organisational, legal, financial, ethical and technical level.¹⁰ A policy paper on joint Nordic registers and biobanks published by NordForsk in 2014 concluded that harmonisation of the national registers should provide a solid basis for multiple types of research of high international scientific value, benefiting society at large.²⁷ However, a number of legal, ethical, technical and organisational constraints need to be overcome to accomplish cross-border utilisation of research infrastructures.

¹⁶ <https://www.nordforsk.org/en>

Knowledge Gaps

Although the Nordic countries have a goldmine for research in their data infrastructures there are still some obvious information gaps. In order for researchers to utilise data from several national data sources the data must first be findable and described with high-quality metadata that makes it possible to understand whether the data are comparable. The researchers use a lot of time on understanding the meaning of data. This could be solved by better metadata documentation of the contents of registers and biobanks on the internet. Use of the FAIR principles (Findable, Accessible, Interoperable and Reusable data) will make registers more available to researchers.

STATE OF PERSONALISED MEDICINE IN THE NORDIC REGION



The Joint Committee of the
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STATE OF PERSONALISED MEDICINE IN THE NORDIC REGION

The Nordic countries have a number of advantages for the realisation of personalised medicine, e.g. high quality epidemiology and clinical research, a number of unique registers, cohorts and biobanks, and a population that is generally very positive towards participating in research. There is also clear added value in collaboration between the Nordic countries for personalised medicine. For instance, whereas the individual populations of the Nordic countries are relatively small, the cumulative Nordic population size is around 26 million. Furthermore, Nordic collaboration is facilitated by the many similarities between the countries, e.g. in the public health care systems. Nevertheless, there are a number of challenges that need to be met when it comes to e.g. sharing of research data,¹⁷ and there a number of ongoing initiatives to tackle these challenges. Below is an overview of current or recent strategic and funding initiatives at the Nordic level, as well as a selection of Nordic conferences on personalised medicine.

Common Nordic Initiatives

Listed below is a selection of recent strategic initiatives related to personalised medicine.

Nordic Society for Human Genetics and Precision Medicine

Cohorts and scientists from the Nordic countries have been at the forefront of the major discoveries made in the genomics of common diseases for more than a decade. Harnessing this Nordic power-hub and exploiting its full potential requires the unification of resources, infrastructures and expertise. To this end, the Nordic Task-Force for Precision Medicine was formed in 2016. This Task-Force was the precursor of the current Nordic Society for Human Genetics and Precision Medicine (NSHG-PM), which was launched at the Society's inaugural meeting in Reykjavik in June 2018, following a series of previous meetings on Nordic precision medicine. Members of the NSHG-PM include the five Nordic countries as well as Estonia. The vision of NSHG-PM is to advance precision medicine and health care in the Nordic region. Specific goals include establishing a Nordic framework for research into the genetics of human diseases, accelerating discovery of disease susceptibility genes and genes protecting from disease through integrated analyses using multiple large-scale datasets and a range of experimental designs, and translating these findings so that they can be used for precision medicine to improve public health. Through meetings and interactions, the NSHG-PM has formalised the Nordic Precision Medicine Initiative (NPMI), which represents a large-scale research program germane to the interests of the Society. The NPMI has developed a road map aiming to help the Nordic countries achieve their potential to become world leaders in precision medicine research (Njolstad et al. Nat Genet. 2019). The NPMI has been granted initial support from NordForsk.

¹⁷ Reinforced Nordic collaboration on data resources – Challenges from six perspectives. TemaNord 2012:514. ISBN 978-92-893-2342-0

Nordic Trial Alliance

The Nordic Trial Alliance (NTA)¹⁸ was a three-year pilot project originally running from 2013 to 2016, funded by the Nordic Council of Ministers and NordForsk. The NTA was launched to meet the negative trend of decreasing number of clinical trials in the Nordic countries, mainly as a consequence of clinical research moving out from the region. Unless better conditions for Nordic trials are put in place, more multinational trials will be moved to other areas of the world. This will in turn mean that the Nordic population will have less and delayed access to new treatment methods and products, industry will move its activities to other countries and it will be harder for SMEs to develop products.¹⁹

The purpose of the NTA was to enhance Nordic cooperation on clinical multi-centre trials. Increased Nordic cooperation on clinical research will lead to a rise in the number of joint clinical trials and thus boost the attractiveness of the Nordic countries as partners in research. Such activities will also promote knowledge transfer as well as increased efficiency and research output. The NTA was based on established national networks for clinical research, and designed to lay the foundation for increased collaboration between national and Nordic stakeholders.

The NTA focused on funding strategic activities, mostly networks and workshops, aiming to support and facilitate clinical trials in the Nordic countries. A call for Nordic clinical trial projects was announced in 2014. The NTA also arranged annual thematic workshops to create a platform for its stakeholders. In January 2017, an NTA Stakeholder Meeting focused entirely on personalised medicine was held in Oslo. The meeting was entitled *NTA 2.0: "Towards personalised medicine in Nordic clinical trials cooperation"*.

The Nordic Trial Alliance 2.0 - towards personalised medicine was funded as a priority project under the programme for the Norwegian presidency of the Nordic Council of Ministers in 2017. The project is funded from 2017 to 2019. In 2018 the NTA issued a call for Nordic clinical trial projects on paediatric cancer treatment that aims to fund projects focusing on personalised medicine for children with cancer (see below). In 2018 and 2019 the NTA also issued calls for strategic activities to promote Nordic cooperation within clinical research. Example of anticipated activities include strategic workshops or networking activities with a vision to move Nordic collaboration in a specific area forward, and a concrete outcome that will enhance Nordic clinical research cooperation.

Nordic Health Research and Innovation Networks

Nordic Health Research and Innovation Networks (NRI)²⁰ is an independent, non-profit organisation working to promote health research and innovation in the Nordic region. The NRI is based on partnership where the partners are university hospitals, universities and other research organisations, the pharmaceutical industry, the medical technical industry, governmental bodies and patient organisations. With support from the Nordic Trial Alliance, the NRI organised a conference on personalised medicine called "Nordic Model for Personalized Medicine" in May 2017.²¹

Nordic Alliance for Clinical Genomics

The Nordic Alliance for Clinical Genomics is an independent, non-governmental, not-for-profit, Nordic association that has received initial funding from NordForsk.²² The overall mission is to share trustworthy genomics data and technology competence for improved diagnosis and treatment, and as a resource for research. To this end a Nordic alliance of key national research infrastructures in genomics is being built, as well as key clinical environments for implementing genomic medicine in the Nordic countries. The alliance acknowledges that the Nordic countries, with their high trust in government, transparent societies and similar health care systems based upon the ideal of equal access to care for all members of society, have the potential to become leading countries in the sustainable implementation of personalised medicine. Following three informal workshops, an inaugural meeting was held in Høvik, Norway on 15–16 November 2017, bringing together key stakeholders in the Nordic countries to identify specific action points for the future of the alliance.

18 <https://nta.nordforsk.org/>

19 <http://nta.nordforsk.org/files/NLSInterviewLafolie.pdf>

20 <http://nordicnetworks.org/>

21 <https://nta.nordforsk.org/events/nri-conference-2017-nordic-model-for-personalized-medicine>

22 <http://dsmg.dk/wp-content/uploads/2017/10/15.-16.-November-2017.pdf>

Specific goals of the alliance include:

- Facilitating the responsible sharing of genomic data, bioinformatics tools, sequencing methods and best practices for interpretation of genomic data.
- Enhancing quality of genomic data and processes, and exploring methodologies to provide assurance.
- Understanding legal barriers to the implementation of personalised medicine and engaging with key stakeholders that influence these barriers.
- Developing demonstration projects that challenge perceived legal barriers that limit responsible and ethical sharing of genomic and health data.
- Building bridges between research and clinical communities, technologies and practices to foster innovation.

Nordic Biobank Network

The Nordic initiative Nordic Biobank Network²³ is a collaborative network between national biobanking infrastructures in the Nordic countries. The network also wishes to contribute Nordic expertise to developing the European biobank cooperation under BBMRI-ERIC. The infrastructure of the Nordic countries is similar enough that biobank-based research can be implemented not only nationally, but at a large-scale Nordic level as well. The network has received funding from NordForsk for a pilot project on colon cancer. The aim is to create a common Nordic database of standardised biobank information that will be compared with the national cancer registers and material from questionnaires in order to try to zero in on the environmental and genetic factors that lead to colorectal cancer.

Nordic Collaboration for Sensitive Data (Tryggve)

Tryggve²⁴ is the name for the Nordic collaboration for sensitive data funded by NeIC and ELIXIR nodes of participating countries. The Tryggve project develops and facilitates access to secure e-infrastructure for sensitive data, suitable for hosting large-scale cross-border biomedical research studies. The aim is to develop state-of-the-art scalable infrastructure for safe, efficient, ethical, and legal storage, analysis and sharing of sensitive personal data for biomedical research between countries. The project supports open and transparent data access processes by engaging with the key stakeholders from each of the Nordic countries. Tryggve contributes to facilitating automated cross-border sample and data movements complying with the Nordic legal framework, with an ambition to scale to Europe and beyond. The outcomes of the project will enable researchers to conduct their research utilising sensitive data in secure settings and facilitate Nordic collaboration in biomedical research.

NORIA-net on Registries

NORIA-net is a coordination activity for national and Nordic research funding agencies and policy makers, funded by NordForsk. The results of a NORIA-net will either be directed towards the development of a common research policy for a given area - with possible joint Nordic initiatives in research policy and research funding - or the preparation of specific programmes and calls for proposals. The *NORIA-net on Registries* was initiated in 2011 with the aim to increase use of the unique data registries and biobanks in and between the Nordic countries, thereby strengthening Nordic cooperation on registry-based research.²⁵ A report by the Nordic Council in 2012²⁶ mapping the most significant challenges and obstacles for a reinforced Nordic cooperation on data resources served as important background material for the NORIA-net group. Activities within the NORIA-net were intended to increase coordination and accessibility of registries to the different research communities, map national workplans, as well as to investigate potential limitations (legal, ethical, political etc.) impeding cooperation and propose ways to overcome these. Coordination activities targeting statistical authorities, data inspection boards and ethical

23 <https://www.ntnu.no/biobanknorge/nordic-biobank-network>

24 <https://neic.no/tryggve/>.

25 <https://www.nordforsk.org/en/programmes-and-projects/projects/noria-net-on-registries>

26 Reinforced Nordic collaboration on registers and databases: challenges from six perspectives. TemaNord 2012:514. ISBN 978-92-893-2342-0.

committees were foreseen. The project resulted in a policy paper in 2014.²⁷ Based on a recommendation from this group, the NordForsk board funded a cooperation project between the Nordic Statistical Institutes, called NordMAN, aimed at facilitating research on Nordic data.²⁸

Common Nordic Calls

Listed below is a selection of common Nordic calls for funding of projects related to personalised medicine.

NordForsk Call on Innovations in Personalised Medicine

The Icelandic Centre for Research (Rannís), Innovaatorahoituskeskus Business Finland, Innovation Fund Denmark, the Research Council of Norway and Sweden's innovation agency (Vinnova), in collaboration with NordForsk, launched a call for proposals in 2018 with the aim of funding Nordic projects that contribute to implementation of personalised medicine in health care.²⁹ The call builds on strengths and synergies in the Nordic countries. The total funding budget was EUR 15 million. The overall goals of NordicPermed include promoting implementation of new personalised medicine approaches for more effective and sustainable health care; improving the Nordic position in personalised medicine by creating a platform for research, innovation and business that will build on Nordic strengths; increasing collaboration between companies, research-performing organisations and public organisations and civil society. The initiative is expected to significantly advance personalised medicine activities related to the following three topics:

- Data: Knowledge generation and value creation in relation to the use of existing omics and health-related data at the Nordic level for personalised medicine purposes, and support for the development of data management practices.
- Clinical/regulatory: Development and implementation of solutions to overcome clinical and regulatory challenges related to personalised medicine.
- Health economics: Research and development of health economics models that are useful in a personalised medicine setting.

Funding decisions were announced in December 2018.³⁰ Over 40 applications were received, and of these, seven were selected for funding.

NordForsk Call on Clinical Trial Projects on Paediatric Cancer Treatment

A call for personalised paediatric cancer treatment was announced in 2018.³¹ The call – a collaboration between NordForsk, the Norwegian Cancer Society and the Research Council of Norway – had a total budget of EUR 4 million and was announced as a Nordic Trial Alliance activity under the Nordic Programme on Health and Welfare.³² The aim of the call was to support Nordic research projects in cancer medicine or the expansion of ongoing national projects into Nordic ones. The projects are to focus on personalised treatment and utilise Nordic health data; a study at the Nordic level should lead to benefits beyond those of a single country study. Funding decisions were announced in December 2018.³³ Three Nordic projects on personalised cancer treatment for children were funded. The projects focus on Nordic cooperation on clinical studies, to help giving children diagnosed with cancer access to the very latest treatment methods.

27 Joint Nordic Registers and Biobanks - A goldmine for health and welfare research. ISSN 1504-8640

28 <https://www.nordforsk.org/en/programmes-and-projects/projects/nordic-microdata-access-network-nordman>.

29 <https://www.nordforsk.org/en/funding/innovations-in-personalised-medicine-towards-implementation-of-personalised-medicine-in-health-care>

30 <https://www.nordforsk.org/en/news/nordic-nok-165-million-initiative-to-boost-research-and-innovation-in-personalised-medicine>

31 <https://www.nordforsk.org/en/news/nok-38-million-towards-research-on-personalised-paediatric-cancer-treatment>

32 <https://www.nordforsk.org/en/programmes-and-projects/programmes/nordisk-program-om-helse-og-velferd>

33 <https://www.nordforsk.org/en/news/historic-investment-in-nordic-paediatric-cancer-research>

Nordic Conferences on Personalised Medicine

Listed below is a selection of Nordic conferences related to personalised medicine.

Nordic Precision Medicine Forum

The first annual Nordic Precision Medicine Forum was held in Copenhagen in April 2017 and had over 170 attendees. The common goal was to bring better outcomes to patients faster. The second meeting took place in Copenhagen in March 2018 and brought together representatives from academia, industry, health care, government and patient groups. A third meeting took place in Stockholm in March 2019.

Nordic Conference on Personalised Medicine 2018

The first Nordic Conference on Personalised Medicine (NorPM2018) took place 30 May–1 June 2018 in Nyborg, Denmark.³⁴ The conference focused on both basic and clinical aspects of research regarding personalised medicine. The programme consisted of talks and workshops within pharmacogenetics, drug interactions, epigenetics and other factors that may cause variation in drug response among individuals.

Genomic Medicine Nordic Conferences

The fifth annual Genomic Medicine 2018 Nordic Conference took place at South Denmark University (SDU) in Odense on 2–3 October and was preceded by a clinical NGS Data Analysis Workshop on 1 October. The conference itself focused on the use of genomics and next generation sequencing (NGS) technologies and tools to look at human disease both in research as well as in a clinical setting. The sixth annual Genomic Medicine 2019 Nordic Conference will take place at the Kennedy Centre at Rigshospitalet in Copenhagen on 13–14 November. The conference will be preceded by a clinical NGS Data Analysis Workshop on 12 November.

³⁴ <https://www.ncbi.nlm.nih.gov/pubmed/29878592>

CURRENT STRATEGIES AND INITIATIVES IN THE NORDIC COUNTRIES

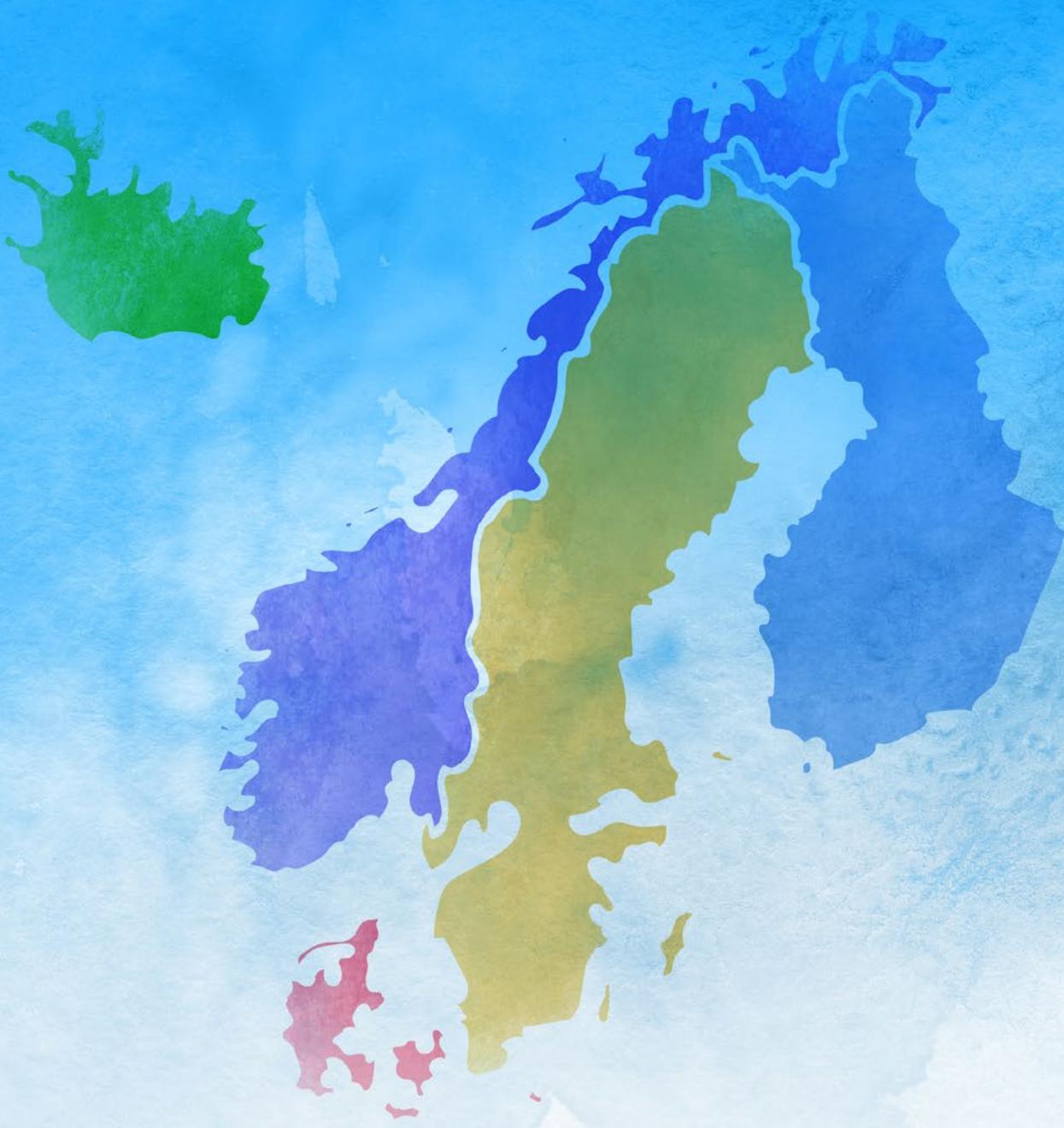


Illustration: Tanach/shutterstock.com

CURRENT STRATEGIES AND INITIATIVES IN THE NORDIC COUNTRIES

NOS-M decided in September 2017 to carry out a study to map out personalised medicine in the Nordic region. A questionnaire was sent to the administrative representatives of the Nordic countries and the answers form the basis of the country specific reports below. Estonia, although formally not a Nordic country, has been included in the survey as the country is in many ways at the forefront when it comes to personalised medicine. The information was updated by NOS-M early 2019.

Denmark

A lot of activities have recently been undertaken in the field of personalised medicine in Denmark. Recent political initiatives include a number of pre-analyses of the state of personalised medicine in Denmark and internationally.^{35,36,37} The National Strategy for Personalised Medicine lays the foundation for the continued development of personalised medicine in Denmark.

National roadmaps/strategic agendas for personalised medicine

National Danish Strategy for Personalised Medicine

The Danish Government and the Danish Regions published a new national strategy for personalised medicine³⁸ in December 2016, designed to lead to more effective treatments and less adverse effects in the future. The Danish Government will spend EUR 13.4 million over 2017–2020 to finance the personalised medicine effort. An important aim of the strategy is to build and manage an infrastructure for genome data generation, storage and interpretation, and to strengthen collaboration between the Danish health care system and research community to ensure that the Danish people can benefit fully from the new technologies and other advances. To this end, diagnosis, treatment, research, infrastructure, ethics and safety must be developed hand in hand.

In the strategy, the Government and Danish Regions agree on six principles that are intended to guide the activities relating to personalised medicine:

- The Danish efforts within personalised medicine are to focus on the patients. Genome sequencing is to be used for treatment purposes and in research projects.
- Confidentiality, the individual's right to self-determination, protection of information and research ethics approval are paramount.

35 Danskernes tanker om og holdninger til Personlig Medicin og gentest. Ministry of Health and Danish Regions, September 2016.

36 Kortlægning af internationale erfaringer med personlig medicin. Ministry of Health. June 2016.

37 Afrapportering fra referencegruppen vedr. foranalysen for personlig medicin. October 2016.

38 Personalised Medicine for the Benefit of Patients. National Strategy for Personalised Medicine 2017-2020. Ministry of Health and Danish Regions, December 2016

- The use of personalised medicine as a standard offer in the health care system must be evidence-based and economically sustainable.
- Genome sequencing and data processing must be based in the public sector.
- The national infrastructure and adopted standards must be used, and data must be shared securely for the benefit of future research and treatment.
- The distribution of research funds as part of the strategy must take place in competition – and research projects should in principle be nationwide.

The development and implementation of personalised medicine in the health care system require that many initiatives are initiated and evolve in parallel. Many areas have to come together; the Government and Danish Regions have therefore agreed on seven strategic action areas that will guide the work in the coming years:

- Transparent, nationwide governance structure.
- Clear legal framework, ethical principles and security.
- Patient and citizen involvement.
- Technological infrastructure with secure, efficient and equal access.
- Genomics research – international and deeply integrated in the health care system.
- Tools and competencies to use genomic data.
- Denmark must have an attractive development environment.

The Danish National Genome Initiative

The consortium *GenomeDenmark* consisting of four Danish universities, two hospitals and two private firms, has recently established a Danish Reference genome.³⁹ Triplets of mother, father and child were sequenced from a total of 50 Danish families. The reference genome, which is of very high quality in an international perspective, reveals detailed knowledge about genetic variations and deviations specific to the Danish population. Due to the world-class Danish health registers and longitudinal studies, the country is uniquely positioned to couple genomics and other types of health data on a large scale in Denmark.⁴⁰

Other strategies/initiatives that may be of relevance to the field

The Danish National Genome Centre

The Danish Ministry of Health has established a national genome centre in Copenhagen, closely linked with Aarhus. The cooperation between the regions is expected to help introduce and implement the Danish Regions' strategy on personalised medicine on a national level. The national genome centre will serve as a hub for integrating genomic data that can be used for more personalised medical care for Danish citizens. In addition the centre will also undertake a national coordinative role in regards to education and competency development of health professionals. Lastly the national genome centre will aim at including citizens and patients in the development of personal medicine, which includes the ethical and juridical aspects, are clarified. The government finances the cost of running the national genome centre and has set aside EUR 13.5 million (USD 14.2 million) for the period 2017–2020.⁴¹

39 Marett L et al. (2017). Sequencing and de novo assembly of 150 genomes from Denmark as a population reference. *Nature* 548: 87–91.

40 <http://www.dtu.dk/english/news/2017/07/danish-reference-genome-now-mapped>

41 <http://healthcaredenmark.dk/news/new-danish-genome-centre-for-research-on-personalized-medicine.aspx>

New Life Science Strategy

Recently the Danish Government has published a new growth strategy for life science in Denmark.⁴² The strategy seeks to support growth and development in the Danish life science sector and incorporates 36 initiatives. Though none of them directly touches upon personalised medicine, several of the initiatives are indirectly related to the topic. Examples are initiative 2 – more resources allocated to life science from the Research Reserves, and initiative 11 – more dialogue with the life science industry. Thus, the strategy will support efforts related to personalised medicine.

RESEARCH2025

RESEARCH2025⁴³ is a catalogue which identifies and presents the most important research areas of the future as seen from the perspectives of businesses, organisations, ministries, Danish knowledge institutions as well as a wide variety of other stakeholders. The catalogue is to serve as a source of inspiration and knowledge and as a basis for prioritising research investments in various contexts such as political negotiations of the distribution of the research reserve, strategic considerations at Danish knowledge institutions and in relation to Danish participation in international research cooperation. The catalogue has 19 themes in total, one of them being "Better health with personal medicine". The report concludes that Denmark has some unique strengths within biomedical basic research and disease biology, in addition to register and bioinformatics research. Denmark has a strong tradition of fundamental research in disease mechanisms and has become an international leader in several fields, which means that Danish researchers can contribute significant breakthroughs in the treatment of disease to the benefit of patients and the Danish economy alike. The following research needs are identified as being the most important for the progression of personalised medicine in the next few years: fundamental research in disease biology/molecular pathophysiology research; measurement methods, biomarkers and testing systems; management and interpretation of data; ethical, legal and societal aspects related to personal data.

Biopeople – Denmark's Life Science cluster

Biopeople is Denmark's Life Science Cluster located at the University of Copenhagen. It is part of the Danish infrastructure for innovation - established and co-funded by the Ministry of Higher Education and Science. Biopeople integrates all relevant Danish stakeholders, including several companies, and aims to act as a neutral catalyst for collaboration between companies and public research. The vision of Biopeople is to facilitate the growth of Danish life science through innovation and collaboration. The strategic priority is to support the paradigm shift in the health care sector, implying a strengthened focus on biomarkers, companion diagnostics, precision / personalised medicine, regulatory science, and stakeholder involvement, including patient and investor communities.⁴⁴

⁴² <https://em.dk/english/news/2018/03-06-life-science>

⁴³ RESEARCH 2025 – Promising future research areas. Danish Agency for Science and Higher Education. ISBN 978-87-93468-65-8.

⁴⁴ <https://biopeople.eu/about/>

Funding initiatives related to personalised medicine

In Denmark, both private (e.g. Novo Nordisk Foundation, Lundbeck Foundation,⁴⁵ etc.) and public (e.g. Innovation Fund Denmark) funding initiatives allocate significant funding to research within personalised medicine. The research area is further emphasised in RESEARCH2025.

Innovation Fund Denmark (IFD)

The IFD is a governmental agency under the Ministry of Higher Education and Science. The IFD invests in innovative ideas, from young start-ups to solutions that resolve societal challenges. In 2018, the IFD programme invested EUR 23.4 million in the health area⁴⁶ with the aim of supporting the continuous improvement of the health system. Focus areas include both treatment and prevention, in light of current and future challenges such as demographic changes in the population. As part of the investments in the health area, the IFD also invests in order to strengthen the industrial health sector in Denmark. In 2018, the IFD invested EUR 32.2 million in new technologies, some of which pertain to bio- and life science.

Having realised that personalised medicine is an interdisciplinary field that will drive the health research and innovation agenda for years to come, the IFD has formulated an investment strategy within personalised medicine⁴⁷ as part of its overall health strategy. Through its investments the IFD wants to contribute to resolving the main bottlenecks in developing and implementing personalised medicine to the benefit of patients and society. The investments support strategic research as well as more specific and innovative solutions within personalised medicine. As of today, the IFD has funded a number of ongoing projects relating to various aspects of personalised medicine. In addition, the IFD engages in international personalised medicine initiatives, participating in the ERA PerMed first joint transnational call for proposals, and the Nordic Call on Personalised Medicine (NordicPerMed).

Participation in international consortia related to personalised medicine or other -initiatives/calls

Denmark participates in a number of international collaborations on personalised medicine, including ICPeMed. Innovation Fund Denmark is also participating in the ERA PerMed first joint transnational call for proposals, and the Nordic Call on Personalised Medicine (NordicPerMed).

Challenges, including legal, related to the above

It is estimated that the costs for hospital drugs in Denmark has increased at an annual rate of 8.5 % in the past seven years.⁴⁸

45 <https://www.lundbeckfonden.com/wp-content/uploads/Personalised-Medicine.pdf>

46 <https://innovationsfonden.dk/da/publikationer>

47 <https://innovationsfonden.dk/da/publikationer>

48 AMGROS (2015). Sygehusmedicin 2015.

Estonia

Estonia stands out as one of the first countries to set up population biobanks for the use of biomarkers in combination with information from health records and lifestyle habits. The Estonian Genome Project is a population-based biological database and biobank which was established in 2000 to improve public health in Estonia. It contains health records and biological specimens from a large percentage of the Estonian population.

National roadmaps/strategic agendas for personalised medicine

Implementation of personalised medicine in Estonia is being carried out within the framework of the personalised medicine programme 2016–2020 managed by the Ministry of Social Affairs.⁴⁹ The launch of the programme was preceded by a thorough preliminary study carried out in 2015, resulting in four comprehensive reports.^{50,51,52,53} As the personalised medicine programme was not officially approved, Estonia uses the approved eHealth strategy 2020 alongside the personalised medicine programme to plan and implement activities. There is also a general roadmap for personalised medicine in Estonia.

Other strategies/initiatives that may be of relevance to the field

Estonian Genome Project

The Estonian Government allocated EUR 5 million in 2018 to a joint development project of the Ministry of Social Affairs, the National Institute for Health Development and the Estonian Genome Center of the University of Tartu. The project aims to collect the genetic data of 100 000 people and integrate it into everyday medical practice by giving people feedback regarding their personal genetic risks. The general purpose of the project is to boost the development of personalised medicine in Estonia.⁵⁴ While there are several biobanks available worldwide, the majority of them focus on genomic research rather than personalised medicine⁵⁵. Iceland, for instance, is similar to Estonia in having a rather small and homogenous population, and a very ambitious genome sequencing programme. However, the biobanks of Iceland are privately owned, making it more difficult to integrate the information into personal health on a national scale. The Estonian biobanking system, in contrast, is built on a law that fundamentally protects gene donors' privacy and establishes their rights.⁵⁶ The following six key elements were identified to implement genomic medicine on a national scale:⁵⁷

- Research to generate solid knowledge of the principal risk factors.
- Electronic Health Record.
- Automated systems to support decision making. The reports on disease risk and drug response will be included in the HER.
- Key professionals with specific training to use the data in daily practice and if the pilot phase is successful, it will be replicated for the rest of the population.
- Powerful biobanks: Together with Iceland, Estonia was one of the first countries to design population biobanks for the use of biomarkers in combination with information from health records and lifestyle habits to study the most common diseases and to develop treatments.

49 <https://www.sm.ee/en/personalised-medicine>

50 Feasibility Study for Personalised Medicine in Estonia: Clinical Approach. Ministry of social affairs report 160164.

51 Description of the current status and future needs of the Information Architecture and Data Management solutions for the national personalised medicine pilot project. Ministry of Social Affairs report 160112.

52 Feasibility study for the development of digital decision support systems for personalised medicine. Ministry of Social Affairs report 160141.

53 Feasibility study for the development of business cooperation, management organisation and evaluation methodology for personalised medicine pilot project. Ministry of Social Affairs report 160149.

54 <https://www.sm.ee/en/news/100-000-estonians-will-be-offered-information-about-their-genetic-risks>

55 <https://www.theatlantic.com/health/archive/2015/10/is-a-biobank-system-the-future-of-personalized-medicine/409558/>

56 <https://www.riigiteataja.ee/en/eli/531102013003/consolide>

57 Proposal of Recommendations for a Personalised Precision Medicine National Strategy: Anticipating the future. Accelerating changes. Fundación Instituto Roche (2017).

- Necessary infrastructure to promote secure exchange of information. Estonia has national infrastructure called the X-Road Platform. Since 2010, the medical information from hospitals, primary care and medical prescriptions has been accessible through this platform.

My e-Health

As a part of e-Estonia, which is a movement by the government of Estonia to facilitate citizen interactions with the state through the use of electronic solutions, the e-Health Record is a nationwide system integrating data from Estonia's different health care providers to create a common record every patient can access online.⁵⁸ My e-Health is a patient's digital health information portal. It was launched in 2009, and since then 17 per cent of the population has visited the portal.⁵⁹

Health Sense project

As a part of the personalised medicine package, this project entails the development of a database which uses health, lifestyle and lifecycle data. The aim of the database is to promote research and development for creating databased solutions that will increase a person's healthy life years. This project is in its planning phase.

Diginest

To further international collaboration and research in the field of personalised medicine, Estonia is in the planning phases of founding an independent legal entity owned by the state, which will serve as a central facilitation point between all of Estonia's health-related projects, databases and collaboration partners. The aim of this initiative is to make it easier to find research participants and beta-testers as well as have access to multiple data sources for the development of more nuanced and comprehensive personalised medicine products and solutions. This initiative is currently under consideration in the Parliament of Estonia.

RITA

Estonia is conducting two clinical trials to validate polygenic risk scores in the Estonian population for breast cancer and cardiovascular disease. The results of these trials will provide input to a clinical decision support system for doctors, where the polygenic risk scores will be combined with individualised lifestyle and environmental data and will form the basis of personalised feedback and recommendations for the patient. Both trials are currently in the data collection phases.

Norway-Estonia collaboration

Estonia and Norway have paired up to invest in personalised medicine start-ups. The programme will be launched on 15 October and start-ups offering personalised medicine-based solutions for patients, clinicians and health data management will be eligible.

Funding initiatives related to personalised medicine

Participation in international consortia related to personalised medicine or other initiatives/calls

Estonia is a partner of ICPeMed and also participates in the ERA PerMed first joint transnational call for proposals through the Ministry of Social Affairs.

⁵⁸ <https://e-estonia.com/solutions/healthcare/e-health-record/>

⁵⁹ <https://estonia.ee/getting-personal-with-personalised-medicine/>

Finland

Finland has a long tradition of internationally strong genetic research and excellent registries and databanks. Recent major initiatives include a health sector growth strategy and the establishment of a National Genome Centre. There is an ongoing major reform of the national social and health system in Finland.⁶⁰

National roadmaps/strategic agendas for personalised medicine

There is no specific national strategy or roadmap for personalised medicine, but the theme is an essential element in several recent national strategies.

The Finnish National eHealth and eSocial Strategy 2020

In 2015 the Ministry of Social Affairs and Health published a Finnish National eHealth and eSocial Strategy 2020⁶¹ emphasising the importance of data management in developing research, innovation, health care and commercial activities. The objective of the strategy is to support the renewal of the social welfare and health care sector and the active role of citizens in maintaining their own well-being by improving information management and increasing the provision of online services.

Health Sector Growth Strategy for Research and Innovation Activities Roadmap for 2016–2018

The national Health Sector Growth Strategy Roadmap for Research and Innovation Activities was published in 2016.⁶² This roadmap gives further details about the implementation of the growth strategy for research and innovation activities published in 2014,⁶³ and is aligned with the Government's key projects and priorities. Personalised medicine is an essential element of the health sector growth strategy. A total of 12 key action areas are presented in the roadmap, four of which explicitly refer to personalised medicine/health care. The importance of personalised medicine was also emphasised by the Minister of Family Affairs and Social Services at the launching of the roadmap, who stated that "Finland is in a good position to become a pioneering country for health care, top-class research and global business using genome data. For private individuals this means that disease prevention and improvement will become more effective. In the future, it will be possible, for example, to determine the most suitable and effective drugs for each individual."⁶⁴ Strong coordination at the national level and common actors are required to fully utilise the unique social welfare and health care data resources, sample resources of the biobanks and genome data. In order to achieve this, the Finnish Government has decided to invest in the necessary infrastructures, to set up the national organisations enabling the utilisation of genome data, and to intensify cooperation between the actors.

The Health Sector Growth Strategy Roadmap was prepared and is being implemented in collaboration between the following: the Ministry of Employment and the Economy, the Ministry of Social Affairs and Health, the Ministry of Education and Culture, research and innovation funding providers (Business Finland,⁶⁵ Academy of Finland) and health sector actors.

⁶⁰ <https://alueuudistus.fi/en/frontpage>

⁶¹ <https://stm.fi/julkaisu?pubid=URN:ISBN:978-952-00-3575-4>

⁶² Innovating together: Health Sector Growth Strategy for Research and Innovation Activities, Roadmap for 2016–2018

⁶³ Health Sector Growth Strategy for Research and Innovation Activities. Ministry of Employment and the Economy report 16/2014.

⁶⁴ <http://www.aka.fi/en/about-us/media/whats-new/2016/government-to-create-conditions-for-competence-based-growth-of-health-sector/>

⁶⁵ As of 1 January 2018, Finpro – the Finnish trade promotion organization – and Tekes – the Finnish Funding Agency for Innovation – united as Business Finland.

Other strategies/initiatives that may be of relevance to the field

The Finnish Biobank Act

The Biobank Act (688/2012),⁶⁶ which took effect on 1 September 2013, aims to specify the practices and principles governing the use of human biological samples in different kinds of medical research projects that are not necessarily known at the time of the donation. There are also several other acts and ethical guidelines that complement and specify the practices and principles governing biobanking activities. From the point of view of the researcher, the most important change set out in the Biobank Law is the authorisation to compile samples for research programmes which are not yet fully formulated. Previously, novel usage of the samples considering any new research was not possible without first obtaining a new consent of the donor.

The Secondary Use Act

An act regulating the secondary use of health and social data is being drawn up in the Ministry for Social Affairs and Health.⁶⁷ The aim is to ensure flexible and secure use of data by establishing a centralised electronic licence service and a licensing authority for the secondary use of health and social data. The act is closely related to the Biobank Act, but it concerns health data instead of biological samples. The new act would streamline the processing of data requests, allow faster access to data and improve data security.

The Finnish Genome Act

The Ministry of Social Affairs and Health is preparing a new Genome Act that is scheduled to enter into force in 2019.⁶⁸ The law will regulate the usage and management of genome data. It also provides for the establishment of a national genome centre that will be a central repository for all national genome data according to high level information security standards. The genome centre, originally proposed in the genome strategy 2015, will promote and facilitate the use of genome data in both research and health care.

Genome Strategy

Finland's National Genome Strategy⁶⁹ was published in 2015. The strategy will establish the conditions that are required for the effective utilisation of genomic data in Finnish health care. The strategy comprises seven main goals with proposed measures: four enabling goals to create the possibility for full utilisation of genome information in health care, in research and business activities, and in people's own lives; and three utilisation goals to produce the actual benefit to the individual, Finnish health care, and society from the use of genome information. The respective goals are specified below:

Enabling goals:

- Ethical principles and legislation exist for the use of genome information.
- Genome research is closely linked with activities of health care.
- Health care personnel are well prepared for the use of genome information.
- Finland has data systems that allow for the effective use of genome information.

66 The biobank law (Law 688/2012), Ministry of Social Affairs and Health, Finland

67 <https://stm.fi/en/secondary-use-of-health-and-social-data>

68 https://stm.fi/documents/1271139/6584841/bedomningspromemoria_av_arbetsgruppen_for_genomcentrum_SV.pdf/e43d0b07-8e66-4bbe-ad39-ee819b0453b1

69 Improving health through the use of genomic data. Finland's Genome Strategy. Working Group Proposal. Ministry of Social Affairs and Health 2015:34. ISBN: 978-952-00-3605-8.

Utilisation goals:

- Genome information is extensively used in health care based on the needs of individuals and the population.
- People are capable of utilising genome information in their own lives.
- Finland has an internationally enticing research and business environment for genomics.

The establishment of a *national genome centre* bringing together all parties within the field of genomics is proposed in the strategy. The centre will have the responsibility for development of a national reference database and for implementing many of the actions included in the genome strategy. The Ministry of Social Affairs and Health appointed a working group to prepare the setting up of a national genome centre⁷⁰ in 2016. Another task of the working group was to draw up a proposal for the structures and processes of the genome centre's other operations that aim to facilitate the efficient use of genome data in health care, research and development and the promotion of health and wellbeing.

Isaacus

The Finnish Innovation Fund, Sitra, has launched a new set of projects to prepare for the establishment of an organisation focused on gathering together and coordinating well-being data. The working title of this is "Isaacus – the Digital Health HUB".⁷¹ From a single access point, this service organisation will provide data that can influence well-being (e.g. patient, demographic and lifestyle data) and open data gathered from various registries and sources. The work is done in extensive collaboration with the public and private sectors and NGOs. The Ministry of Social Affairs and Health, the Ministry of Employment and the Economy, the National Institute for Health and Welfare, the Association of Finnish Local and Regional Authorities, Statistics Finland and CSC are among the organisations involved. Examples of ongoing projects include the development of a solution for creating and managing common metadata descriptions, the design of a data-secure environment for the use of well-being data, and the creation of a common process and tools for all biobanks for the formulation of research data.⁷²

FinnGen

The FinnGen study was launched in the autumn of 2017 and combines genome information with digital health care data from national registries to make new breakthroughs in disease prevention, diagnosis and treatment. FinnGen is a global research project representing one of the largest studies of this type.⁷³ The project aims to improve human health through genetic research, and ultimately identify new therapeutic targets and diagnostics for treating numerous diseases. The FinnGen study plans to analyse up to 500 000 unique blood samples collected by a nationwide network of Finnish biobanks, with the aim of deepening the understanding of the origins of diseases and their treatment. The project is expected to continue for six years, with a current budget of EUR 59 million.⁷⁴ The FinnGen study is coordinated by researchers from the University of Helsinki and the Helsinki University Central Hospital. In addition to biobanks and research organisations, the Finnish Funding Agency for Innovation (Business Finland) and seven international pharmaceutical companies are taking part in the study. Two-thirds of the project funding is expected to come from pharmaceutical companies and one-third from Business Finland.

70 http://stm.fi/en/artikkeli/-/asset_publisher/tyoryhma-valmistelemaan-genomikeskuksen-perustamista

71 <https://www.sitra.fi/en/topics/well-being-data/#latest>

72 <https://www.sitra.fi/en/projects/isaacus-pre-production-projects/#what-is-it-about>

73 <https://www.finnngen.fi/en/node/17>

74 https://www.eurekalert.org/pub_releases/2017-12/uoh-fag121917.php

Sequencing Initiative Suomi

The Sequencing Initiative Suomi (The SISu project) is an international collaboration between research groups aiming to build tools for genomic medicine.⁷⁵ These groups are generating whole genome and whole exome sequence data from Finnish samples and provide data resources for the research community. The SISu search engine⁷⁶ offers a way to search for data on sequence variants in Finns. It provides summary data for researchers and clinicians as well as other people having an interest in genetics in Finland. The SISu project is an international collaboration between multiple research groups aiming to build tools for genomic medicine. The first version of the SISu search engine was released in 2014. The project is coordinated in the Institute for Molecular Medicine Finland (FIMM) at the University of Helsinki.

Funding initiatives related to personalised medicine

Personalised Health – From Genes to Society

The Personalised Health Research Programme (pHealth) is a four-year research programme (2015–2019) funded and coordinated by the Academy of Finland with a total budget of EUR 10 million. The programme explores the application of genome and other personal health data to maintain and promote an individual's health and to prevent and treat diseases. In addition, the programme will look into the technological, judicial, ethical, social and societal issues and impacts with regard to the collection, storing and use of such data. Funded consortia are to be genuinely multidisciplinary, and the funded projects will make good use of Finland's unique genetic population, its favourable societal conditions and the country's highly advanced databases and registries.⁷⁷ The first and foremost theme of the programme is to produce data and tools to contribute to the understanding of individual characteristics at molecular level, and to using these data and tools for health promotion.

Health from Cohorts and Biobanks

Finnish health promotion research has achieved a very high international standard in the last decade. A crucial asset has been the access to high-quality research datasets, including cohort data collected from different population groups, which have provided important evidence on the health effects of lifestyle factors. The emergence of biobanks has opened the possibility to analyse detailed genetic and biological data at population level.

Health from Cohorts and Biobanks (COHORT)⁷⁸ is a new type of Academy programme that provides funding to new types of investigator-driven research projects that fall outside the scope of current Academy of Finland funding schemes. The programme runs for three years (2017–2019) with a total budget of EUR 5 million. The pilot programme provides funding for projects that have both concrete short-term goals for research integration and longer-term goals that require commitment on the part of the host organisation and that will facilitate the continuity of integration. Funding is awarded for integration between projects that already have basic research funding in place. The aim is to increase cooperation between different research partners and especially different levels of research, which through scientific renewal will contribute to enhancing the impact of research in this thematic area. The programme is closely connected to pHealth and the two programmes are governed by the same steering group.

Business Finland programme on Personalised Health

In 2018 Business Finland launched a new programme in the area of personalised health.⁷⁹ The aim is for Finland to become a global pioneer in the provision of personalised health by 2025. The programme will provide innovation funding amounting to EUR 80 million to start-ups, SMEs and large companies, universities and research organisations as well as hospital districts and other health care organisations.

75 <https://www.fimm.fi/en/research/grand-challenge-programmes/finnish-genome-sequencing-preventive-health-care/sisu-project>

76 <http://sisuproject.fi/>

77 <http://www.aka.fi/globalassets/32akatemiaohjelmat/phealth/personalised-health-programme-memorandum.pdf>

78 http://www.aka.fi/globalassets/32akatemiaohjelmat/laboratoriosuomi/cohort_programmememorandum_en.pdf

79 <https://www.businessfinland.fi/en/for-finnish-customers/services/build-your-network/health-and-wellbeing/personalized-health/>

The focus is on the use of data for the promotion of health and well-being. The programme offers tools for building business ecosystems, as well as increasing exports, innovations and foreign investments in Finland. The programme also helps growth companies to raise venture capital and R&D funding, grow new know-how and attract international venture capital, R&D and business units to Finland.

Participation in international consortia related to personalised medicine or other initiatives/calls

Finland is a partner of ICPeMed and also participates in the ERA PerMed first and second joint transnational call for proposals through the Academy of Finland programme pHealth. Finland also participates in the NordForsk initiative Nordic PerMed through Business Finland.

Challenges, including legal, related to the above

A major reform of the social and health care system in Finland is planned to enter into force in 2021.⁸⁰ The first priority of the reform is to ensure that high-quality health care and social services are available to everyone on an equal basis, regardless of where they live. The reform is planned to open up business prospects for private players in the health care system and moves responsibility for the provision of services to 18 new health care regions, starting from 2021, from more than 300 local governments at present.⁸¹ In the current scene, the new health care regions will be the major responsible parties in the new system. However, the position of research/R&D and education has not yet been definitively determined. An ongoing effort is under way to determine how to best realise the administration of R&D and education in the new system to avoid negative effects on medical research in general, and especially on the development and implementation of personalised medicine.

Iceland

There is currently no national roadmap/strategic agenda specifically for personalised medicine. However, there are number of ongoing initiatives related to personalised medicine being undertaken by e.g. deCODE genetics, Icelandic Cancer Registry, The Icelandic Heart Association and University of Iceland.

National roadmaps/strategic agendas for personalised medicine

The Ministry of Education, Science and Culture is developing a roadmap for research infrastructures in line with the policy of the Science and Technology Council for the years 2017–2019. According to the policy, international participation in research infrastructure will also be strengthened and a policy will be developed on open access to data.⁸² The Directorate of Health is in charge of all national eHealth projects in Iceland (Regulation No. 550/2015). This involves promoting the use of eHealth applications within health care to enhance patient safety and quality of care and to support better health for the citizens. The present strategy outlines future visions of eHealth implementation toward the year 2020.⁸³ The main focus is on improving access to information and health services, patient safety, and quality of care with efficient use of financial resources.

80 <http://alueuudistus.fi/en/frontpage>

81 <https://www.reuters.com/article/us-finland-government-healthcare/finnish-government-agrees-on-health-care-reform-plan-idUSKBN14A2A0>

82 [https://www.government.is/library/01-Ministries/Ministry-of-Education/Policy and action plan 2017-2019.pdf](https://www.government.is/library/01-Ministries/Ministry-of-Education/Policy%20and%20action%20plan%202017-2019.pdf)

83 https://www.landlaeknir.is/servlet/file/store93/item28955/National_eHealth_Strategies_January_2016_final.pdf

Health care policy

The Ministry of Health is now working on health care policy for the next decade.

Other strategies/initiatives that may be of relevance to the field

deCODE genetics

The Icelandic population is the most genotyped in the world, mainly due to the pioneering work of deCODE genetics, starting already in the 1990s. Currently, over half of the adult population has been genotyped and 25 000 whole genomes have been sequenced. Together with detailed genealogy data this enables imputation of the genotypes of the whole population to a varying degree of accuracy. Whether the health care system needs to proactively intervene in these cases is currently being discussed by the Ministry of Health.

Biobanks

There are several Biobanks⁸⁴ that operate under the act (110/2000).⁸⁵ The biobanks provide access to samples for scientific research in accordance with the law and the regulations.

Funding initiatives related to personalised medicine

Participation in international consortia related to personalised medicine or other -initiatives/calls

Iceland is a partner of the Nordic Call on Personalised Medicine (NordicPerMed) through Rannís.

Challenges, including legal, related to the above

Iceland follows the EU legislation as part of the EEA cooperation. In addition to the EU, other supranational legislation may affect the legal landscape as well.

Icelandic laws that may be of relevance:

- Analysis of personal health data applies to the Act on the Protection of Privacy as regards the Processing of Personal Data, No. 77/2000.
- Act on Scientific Research in the Health Sector No 44/2014.
- Act 110/2000 on Biobanks and health-data banks, as amended by Act No 45/2014, and Regulation No 1146/2010, on the storage and utilisation of biological samples in biobanks.

84 <https://www.landlaeknir.is/um-embattid/greinar/grein/item32062/lifsynasofn>

85 <https://www.althingi.is/lagas/nuna/2000110.html>

Norway

A national strategy for personalised medicine and an associated action plan for research and innovation were recently published. In addition, Norway has a number of large projects, infrastructure and initiatives relevant for personalised medicine.

National roadmaps/strategic agendas for personalised medicine

Norwegian Strategy for Personalised Medicine in Healthcare 2017–2021

The Norwegian Strategy for Personalised Medicine in Healthcare 2017–2021,⁸⁶ developed by the Norwegian Directorate of Health, is meant to support and form a basis for health care services in the development and implementation of personalised medicine. The strategy is to be viewed as an initial step, which will be followed up with concrete action plans. There is no specific funding for the strategy.

The key recommendations of the strategy include development of expertise, a coordinated national development of the field, development of ICT systems and registries. The Norwegian Directorate of Health is responsible for coordinating follow-up activities from the national strategy. Health care providers, patient organisations, industry and commerce will play important roles in the follow-up of the strategy. The strategy prioritises cancer, rare hereditary diseases and infections for increased personalised medicine focus and attention. As a follow-up to the strategy, the Ministry of Health and Care Services has asked the Regional Health Authorities to establish a national network for regional centres of competence on personalised medicine and a national anonymous registry of frequency of hereditary humane gene variants.

Action plan for research and innovation in the field of personalised medicine 2018-2021

Based on the strategy, a Norwegian action plan for research and innovation in the field of personalised medicine 2018-2021⁸⁷ was compiled by the Research Council of Norway. The action plan is intended to contribute to optimum utilisation of existing research and innovation funding schemes and to facilitate good knowledge development in the field of personalised medicine in Norway through cooperation between relevant funding bodies.

The action plan proposes a long list of measures to

- Stimulate joint initiatives and improve collaboration.
- Stimulate international research and innovation cooperation.
- Make use of national advantages and opportunities.
- Raise the field's profile, increase interdisciplinary activity and improve coordination.
- Identify barriers to collaboration.
- Maintain an ongoing role as a driving force.
- Promote responsible research and innovation.

86 Summary of The Norwegian Strategy for Personalised Medicine in Healthcare 2017–2021. Helsedirektoratet. Publication number: IS-2146 E.

87 https://www.forskningsradet.no/prognostikk-behandling/Nyheter/Lanserer_ny_handlingsplan_for_personaltilpasset_medisin/1254036039692&lang=no

Other strategies/initiatives that may be of relevance to the field

The Health Data Programme

The Norwegian Health Data Programme⁸⁸ was established by the Norwegian Directorate of eHealth (NDE) in 2017 and is planned to be concluded ultimo 2020. All main actors within eHealth in Norway take part in the large programme organisation. The aim of the programme is to improve the utilisation and quality of health data, simplify reporting to the national health records and make data management safer. The programme will provide better accessibility and utilisation of health data by

- Establishing national technical community solutions that will help better utilise health data, including faster and more secure access to personal data.
- Examining and introducing standards that lead to higher quality and harmonised health data.
- Contributing to regulatory development to provide better conditions for researchers and other secondary use of the data and for stronger privacy for the population.
- Establishing the Norwegian Health Analysis Platform for availability and analysis of health data that can be used directly by researchers or in conjunction with other research infrastructures.

The health platform in mid-Norway

A new regional health platform⁸⁹ is under development. This platform will acquire and impose new joint patient records at hospitals and municipalities throughout mid-Norway. The aim of the health platform is to provide increased quality in patient care, improved patient safety and more user-friendly systems, thereby enabling health professionals to carry out their tasks better and more efficiently. The journal puts the patient at the centre of every level in the health service.

Other national research infrastructures

Over decades, public funding in Norway has been dedicated to infrastructures important for different aspects of personalised medicine, e.g. high-throughput omics methodology, making health data and biobanks available for secondary use, and platforms for storage and analysis of sensitive data. The main research infrastructures relevant for development of personalised medicine is the Norwegian Health Analysis Platform and the following:

Biobank Norway

Biobank Norway⁹⁰ is the Norwegian BBMRI-ERIC node. Biobank Norway is to

- Sustain and strengthen its role as a highly advanced and comprehensive national research infrastructure for health sciences.
- Enhance the use of biobanks as a basis for excellent research and innovation, and reinforce Norway's ability to participate in international research.
- Provide internationally competitive biobanking services for basic, clinical and epidemiological medical research.

Relevant environment and biomarker data are available for all major population based biobanks in Norway. This framework generalised to epigenetic data specifically enhances the importance of the infrastructure to studies within personalised medicine. The national infrastructure is coordinated by the Norwegian University of Science and Technology. Collaborators are the University of Tromsø, the University of Bergen, the University of Oslo, the Norwegian Institute of Public Health as well as the Regional Health Authorities in Norway.

88 <https://ehelse.no/helsedataprogrammet>

89 <https://helse-midt.no/vart-oppdrag/prosjekter/ehelse/helseplattformen>

90 <https://www.ntnu.no/biobanknorge>

Health Registries for Research

Health Registries for Research (HRR)⁹¹ is a national research infrastructure addressing the need to establish a research documentation service that offers improved documentation (metadata) of the health registries, to develop statistical methods specifically for health registries, and to provide statistical support service. The project enhances data security by facilitating the use of secure servers for storage and analysis of research data. The project is coordinated by the University of Bergen. Collaborators are the University of Tromsø, the Norwegian University of Science and Technology, the University of Oslo, the Norwegian Institute of Public Health, the Norwegian Directorate of Health as well as the Regional Health Authorities in Norway.

Analysis platforms for sensitive data

In Norway, three technical platforms in particular are dedicated to storage and analysis of sensitive health data. Services for sensitive data (TSD)⁹² is owned by the University of Oslo. It is used to collect, store and analyse sensitive research data in a secure environment for researchers working in public research institutions. SAFE (Sikker Adgang til Forskningsdata og E-infrastruktur [Safe Access to Research Data and E-Infrastructure])⁹³ was developed at the University of Bergen. SAFE ensures sound information security with respect to confidentiality, integrity and accessibility in processing sensitive personal data within research. The HUNT Cloud⁹⁴ at the Norwegian University of Science and Technology delivers digital infrastructure that enables data controllers and researchers to store, access and analyse sensitive data in controlled environments.

Norwegian Genomics Consortium

The Norwegian Genomics Consortium (NGC)⁹⁵ is a national platform for high-throughput genomics. The three nodes are located in Oslo, Bergen and Trondheim. It provides the Norwegian and international scientific community with state-of-the-art high-throughput genomic analysis services. Since its foundation year 2000, initially as the Norwegian Microarray Consortium, the consortium has been the leading provider of high-throughput genomic analyses in Norway.

The Norwegian Primary Care Research Network

The Norwegian Primary Care Research Network (PraksisNett)⁹⁶ was initiated by the University of Bergen in 2018. When finalised, the PraksisNett will be an infrastructure that helps researchers to conduct reliable, quality-assured clinical studies on patients in Norwegian general practice. At the same time, PraksisNett gives GPs an opportunity to participate in research in a predictable and secure manner

91 <https://hrr.w.uib.no/>

92 <https://www.uio.no/tjenester/it/forskning/sensitiv/>

93 <https://it.uib.no/SAFE>

94 <https://www.ntnu.edu/huntgenes/hunt-cloud>

95 <http://www.genomics.no/>

96 <https://www.uib.no/praksisnett>

Large research and innovation projects

Several large research and innovation projects within personalised medicine are established in Norway. Some examples are:

Norwegian Cancer Genomics Consortium

The Norwegian Cancer Genomics Consortium (NCGC) runs the largest research project in Norway within cancer genomics.⁹⁷ The consortium consists of clinicians and specialised cancer research groups situated at the Norwegian university hospitals. The NCGC is working to establish new clinical practices for cancer treatment. Other areas of focus are ethics, law and health economics.

Actionable Targets in Cancer Metastasis

"Actionable Targets in Cancer Metastasis (MetAction) - from Bed to Bench to Byte to Bedside"⁹⁸ is a large collaborative research project primarily between the university hospitals in Oslo and Akershus focusing on intratumoral heterogeneity and personal-adapted treatment of metastatic cancers. The MetAction hypothesis is that personal-adapted therapy will only work if targeted to actionable regulatory proteins present in the life-threatening metastatic lesion(s). The project has established the necessary infrastructure and multidisciplinary teams to gain experience and carry out personal-adapted clinical trials. MetAction successfully conducted the first N-of-1 study in Norway. Molecular and clinical data are integrated in a systems biology approach to identify the optimal drug target combination.

ICT lighthouses for health

In 2016, the Research Council funded three large ICT projects with relevance for personalised medicine. The idea of the ICT lighthouse projects was to bring together commercial actors, public actors and users to solve health challenges through innovative ICT solutions for the future.

- **BigMed** (Big data Medical solution)⁹⁹ aims to identify and address the barriers to precision medicine in Norway. The project focuses on four clinical areas: colorectal cancer, monogenic diseases, sudden cardiac death and frost bite, and will build a platform for further advancement and to help nourish an expanding ecosystem of partners from the clinical, academic and commercial worlds.
- The **DoMore**¹⁰⁰ project aims to improve cancer diagnosis by utilising big data and software-driven automation of pathology.
- The **INTROMAT**¹⁰¹ project aims to improve public mental health with innovative technologies and psychological treatments.

97 <http://kreftgenomikk.no/en/>

98 <https://kliniskestudier.helsenorge.no/spredning-av-kreft-genforandringer-i-spredningssvulsten>

99 <https://bigmed.no/>

100 <http://domore.no/>

101 <http://intromat.no/>

Funding initiatives related to personalised medicine

In Norway, there are several sources of public, private, national and international funding that may support projects relevant to personalised medicine, even if their funds are not earmarked for a specific initiative.

A priority within the clinical health programme in the Research Council of Norway

The Research Council of Norway established a health research programme on High-quality and Reliable Diagnostics, Treatment and Rehabilitation in 2016¹⁰². Personalised medicine is one of several priorities set out in the work programme. The main call for proposals with application deadline in April 2018 specifically sought projects using existing health data (in e.g. registries and analysed from biobank materials) in clinical studies. In the main call for proposals for the April 2019 deadline, the priorities reflect the personalised medicine action plan for research and innovation. Approximately EUR 10 million is made available for each of the main calls for proposals under the programme.

New step towards personalised paediatric cancer treatment

NordForsk, the Norwegian Cancer Society and the Research Council of Norway are collaborating to fund research in the area of personalised cancer treatment for children. The call for proposals is issued under the Nordic Programme on Health and Welfare. The application deadline was October 2018. Approximately EUR 4 million was made available, and three projects received funding. All of these had at least one Norwegian partner.

Participation in international consortia related to personalised medicine or other -initiatives/calls

PerMed

Norway is a partner of ICPerMed through the South-Eastern Norway Regional Health Authority and participates in ERA PerMed joint transnational calls for proposals through the Research Council of Norway. Norway is also a partner of the Nordic Call on Personalised Medicine (NordicPerMed) through the Research Council of Norway. The application deadline was September 2018. A total of close to EUR 14 million was available and seven projects were funded. All of these had at least one Norwegian partner.

Systems medicine

Norway participates in the ERA-NET Co-fund on Systems Medicine (ERACoSysMed) through the Research Council of Norway. ERACoSysMed is relevant for development of methods and tools for personalised medicine.

Challenges, including legal, related to the above

There are challenges associated with the fact that different laws and regulations apply for research and clinical treatment. Additionally, the financial structures for research are different from the structures for clinical practice. The ability to dedicate and coordinate funding initiatives towards personalised medicine is an issue nationally and in international collaborations between research funding organisations. The BIGMed (project described above) has published a position paper that illustrates current challenges for the implementation of personalised medicine within four focus areas.¹⁰³

¹⁰² https://www.forskningradet.no/prognnett-behandling/Home_page/1254012355386

¹⁰³ <https://bigmed.no/news/21-bigmed-position-paper-launched>

Sweden

The Swedish Government has recently published a roadmap for life science in which precision medicine is identified as one of the key priorities. There is no national strategy specifically dedicated to personalised medicine, although there are a number of ongoing initiatives of relevance to the field. Many resources are available for personalised medicine, but they are split between different funders. There is thus a need for national coordination of funding.

National roadmaps/strategic agendas for personalised medicine

Roadmap for life science

The Swedish Government published a roadmap for Life Science¹⁰⁴ in June 2018. Precision medicine is identified as one of three key priority areas. The report concludes that Sweden in many respects fulfils the prerequisites to position itself as an international test market with excellence in attracting new investments for research and development close to the patient. Together with a concerted focus on policy development and openness to effective implementation of innovations, the current efforts to support national infrastructure will help to put Sweden on the map as a leading nation in research, innovation and investments in the precision medicine area. Eight priority areas have been identified for the future collaboration between the government, academia, health care providers, and industry:

- Partnership, coordination, sustainability
- Utilisation of health data for research and innovation
- Policy development and ethics
- Integration of research and innovation in health care
- Implementation of welfare technology
- Research infrastructure
- Capacity building, talent attractions, and lifelong learning
- International attractiveness and competitiveness

Other strategies/initiatives that may be of relevance to the field

Action Plan for Swedish Life Sciences

In May 2018 a common action plan for life science was presented by the Swedish Life Science Industry Organization (SwedenBIO), the Swedish Association of the Pharmaceutical Industry (LIF), and Swedish Medtech (the Association for Medical Technology in Sweden).¹⁰⁵ The action plan highlighted three key areas which need to be strengthened for companies to operate and develop in Sweden: research and development, the introduction of innovative treatment methods, and making Sweden the first choice for investment and establishment.

Precision Medicine – The Swedish Industry Guide 2018

SwedenBIO published the results of a first mapping of the Swedish precision medicine industry landscape¹⁰⁶ in March 2018. It is a guide to 76 companies, all of which are developing innovative products and services with the potential of advancing the field. The report also lists a number of relevant R&D projects as well as launched products.

Swedish Genomes Program

The Swedish Genomes Program¹⁰⁷ is part of the SciLifeLab National Sequencing Projects,¹⁰⁸ and supports Swedish researchers in performing human whole genome sequencing to identify the genetic causes of disease with high health relevance. The projects can include studies of familiar cases of disease as well as case-control studies. There are currently 18 projects ongoing within the Swedish Genomes Program. A reference tool is being constructed for use by the genetics research community and clinical genetics

104 Färdplan life science – vägen till en nationell strategi. Swedish Government Offices.

105 <https://nordiclifescience.org/new-action-plan-for-swedish-life-sciences/>

106 Precision Medicine – The Swedish Industry Guide 2018 (SwedenBIO)

107 <https://www.scilifelab.se/infrastructure/national-projects/swedish-genomes-program/>

108 <https://www.scilifelab.se/news/33-million-to-large-scale-genomic-research/>

laboratories as part of the programme.¹⁰⁹ This high quality genetic variant database for the Swedish population is being established from the genomes of 1000 individuals selected to reflect the genetic structure and geographical distribution of the Swedish population.

Genomic Medicine Sweden

Genomic Medicine Sweden is an initiative that will employ a preparatory study as a basis for building a new type of infrastructure in Swedish health care that implements precision medicine at a national level.¹¹⁰ The primary focus will be patients with rare inherited diseases and cancer, but sequencing will also be performed in other areas such as in complex diseases and the microbiome. The initiative will be organised as a broad-scale collaborative project among different key societal stakeholders, the Swedish health care system, academia and SciLifeLab.

National Genomics Infrastructure Platform

The National Genomics Infrastructure (NGI) platform¹¹¹ comprises two nodes, one in Stockholm and one in Uppsala, and is one of the largest sequencing centres in Europe. The platform offers next generation sequencing (NGS) and genotyping to all academic researchers in Sweden through a comprehensive range of technology platforms. Expertise in computational biology is closely integrated with the National Genomics Infrastructure unit hosted at SciLifeLab in order to optimise throughput, data handling, and basic analysis. The NGI is supported by the Swedish Research Council, host universities (Karolinska Institutet, KTH Royal Institute of Technology, Stockholm University, and Uppsala University), the Knut and Alice Wallenberg Foundation and SciLifeLab.

National platform for Diagnostics Development

The national platform for Diagnostics Development (DD)¹¹² and its clinical genomics facilities have been established in Stockholm, Uppsala, Lund and Gothenburg (together these four regions cover approximately 80 per cent of the Swedish population) to facilitate the translation of new high-throughput techniques, such as next-generation sequencing, into clinical use. The overall aim of the platform is to meet the needs of translational researchers and clinicians in health care and public health systems by providing service and support at the national level in order to promote and adapt the use of high-throughput techniques in routine diagnostics. The platform integrates technological, bioinformatics and clinical expertise to facilitate the application of high-throughput genomics in diagnostics. An important aim of the platform is to disseminate up-to-date information about established assays/protocols and hence serve as a national competence centre for high-throughput analysis in collaboration with hospitals and public health organisations throughout the country. A crucial aspect of this work is also to prepare national guidelines and ethical principles for interpretation of test results using these new technologies.

Regional Cancer Centres

In 2009 the Swedish government launched a national cancer strategy¹¹³ and in 2010 six regional cancer centres were founded working across traditional organisational boundaries. Today these cancer centres with their mainly central government funding constitute six well recognised knowledge hubs for cancer. The centres have developed supportive activities in collaboration with health care providers and the regional health administrations. Because they are not responsible for any funding or provision of services, they cannot directly influence care.

The Register Utiliser Tool

The Swedish Research Council has had a commission to facilitate register-based research in Sweden and set up infrastructures for register-based research since 2013. A web-based system, the Register Utiliser Tool,¹¹⁴ has been developed to help researchers to search, identify and validate metadata from Swedish registers and biobanks. The tool will contain rich metadata from the most frequently used registers in research and will make it easier to identify which data and registers that are suitable for research.

109 <https://swefreq.nbis.se/>

110 <http://ki.se/en/mmk-national-initiative-for-precision-medicine-genomic-medicine-sweden>

111 <https://www.scilifelab.se/platforms/ngi/>

112 <https://www.scilifelab.se/platforms/diagnostics-development/>

113 Wilkens et al. Health Policy 120 (2016) 1378–1382.

114 <http://rut.registerforskning.se/>

Funding initiatives related to personalised medicine

National programme for protein research, method development and biologics production

The Swedish government has given Sweden's innovation agency (Vinnova) and the Swedish Research Council the shared responsibility to establish a national programme for protein research, method development and production of biologics.¹¹⁵ Established in 2016, the research programme aims to make Sweden a leader in the development and production of biologics. The research programme will run for a period of eight years and state funding will total EUR 31.5 million. The research programme is part of the Swedish Government's strategic investment in the life sciences to improve health, meet societal challenges and strengthen Sweden's competitiveness in an international context. In 2016, 11 projects for development and production of biologics were awarded a total of EUR 4.4 million and in 2017 an additional 9 projects were awarded a total of around EUR 4.2 million. In addition, EUR 10.2 million was allocated for the development of three new R&D centres as a step in creating strong research and development environments within biopharmaceuticals. Several of Sweden's largest pharma companies will collaborate in the centres with smaller companies, universities and players in the health care sector to carry out research, development and innovation activities.¹¹⁶

Personalised medicine in Ageing and Health

The Swedish Research Council has a commission from the government to support research on ageing and health. In 2017 a call for applications on research environment grants in ageing and health was issued, where the main objective was to support research in the development of individualised diagnostics, prevention and medication. A total of seven research environment grants were awarded EUR 13.6 million in total for the period 2017–2022. In the 2018 call for research project grants in medicine and health an additional EUR 9.5 million was allocated to a special initiative on ageing and health, where personalised medicine was an essential component.

Sweper

Sweper¹¹⁷ is a project funded by Vinnova. In this project, the health care industry, business community and academy will jointly analyse what needs to be done to ensure that Swedish health data provide the support required to maximise the potential of personalised medicine. The focus of the project is on oncology, but many of the questions are general and can be applied to several diagnoses.

Participation in international consortia related to personalised medicine or other -initiatives/calls

Sweden is a partner of ICPeMed where the country is represented by both the Swedish Research Council and Sweden's Innovation Agency. Sweden also participates in the ERA PerMed joint transnational calls for proposals through the Swedish Research Council. In addition, Sweden agencies participate in the NordForsk initiative Nordic PerMed through Vinnova. The Swedish Research Council and Forte participated in the call for Nordic Register-based Research Projects 2017 in which personalised medicine was a theme.

Challenges, including legal, related to the above

The Swedish Government has not outlined a national ambition to further the implementation of personalised medicine, which may be explained by the fact that decision-making in the Swedish health care sector is regionalised. The resources for general implementation are available in Sweden, but there is a need for national coordination and dedicated funding for clinically oriented proof-of-concept studies. Although Sweden performs at a world-class level in "omics research", it is essential to establish a national framework ensuring optimal utilisation of the current health care system and university-based research facilities in order to succeed in meeting the industry's requirement for fast drug development.¹¹⁸

115 <http://www.government.se/press-releases/2015/12/billion-kronor-investment-in-next-generation-biologics/>

116 <http://nordiclifescience.org/three-new-rd-centres-receives-100-msek/>

117 <http://swelife.se/vi-erbjuder/fornylse/sweper/>

118 <https://www.vinnova.se/globalassets/mikrosajter/strategiska-innovationsprogram/agendor/personaliserad-medicin.pdf>

STATE OF PERSONALISED MEDICINE IN EUROPE





STATE OF PERSONALISED MEDICINE IN EUROPE

The European research environment is fragmented overall, but a number of initiatives have been undertaken to facilitate the realisation of personalised medicine at the European level. The European Commission was an early mover in personalised medicine, and there are a number of ongoing national initiatives in Europe. One central player aiming to align research and funding activities on European and international level is the International Consortium for Personalised Medicine, which brings together the majority of European nations. Listed below are a number of current or recent strategic and funding initiatives.

Common European Initiatives

ESF Position Paper and Forward Look Report

The European Science Foundation published a position paper in May 2011¹¹⁹ that focuses on tissue sample collections and European cohorts as essential elements of particular European strength that may help to ensure a continued leading role for Europe in the area of personalised medicine. The ESF Forward Look report *Personalised Medicine for the European Citizen*¹²⁰ was published in December 2012. This was the result of a foresight exercise – or Forward Look – initiated by the European Science Foundation to gain insight into the shift towards personalised medicine, and into the needs in terms of research programmes, infrastructures, policy and education. The overall aim of the ESF Forward Look was to analyse in a systematic way the complex and constantly moving field of personalised medicine to provide policy advice that will help prepare Europe for the necessary changes. The Forward Look proposed a series of recommendations under four core headings: data handling; models and decision-making processes; interdisciplinarity, participation and translational research; infrastructure and resources.

ICPerMed

The International Consortium for Personalised Medicine, ICPerMed, brings together over 40 European and international partners representing ministries, funding agencies and the European Commission (EC). Together, they work on coordinating and fostering research to develop and evaluate personalised medicine approaches. An important task of ICPerMed is to align research and funding activities on the European and international level. ICPerMed members will develop and agree on future research actions based on knowledge of ongoing efforts. In addition ICPerMed will identify the requirements for a suitable framework in terms of infrastructures, resources and regulatory procedures to foster the development and implementation of personalised medicine. The consortium was preceded by the PerMed project under the European Union's 7th Framework Programme. That project resulted in a strategic research and innovation agenda in 2015, describing challenges and giving recommendations for advancing the field.¹²¹ ICPerMed was initiated during a number of workshops organised by the European Commission throughout 2016.

119 European Biobanks and sample repositories – relevance to Personalised Medicine. ISBN: 978-2-918428-41-1.

120 Personalised Medicine for the European Citizen (iPM) – Towards more precise medicine for the diagnosis, treatment and prevention of disease. ISBN: 978-2-918428-90-9.

121 The PerMed SRIA: "Shaping Europe's Vision for Personalised Medicine" (2015).

The first action of the ICPeMed members was to refine the recommendations of PerMed and define “actionable research items” that can more or less directly be converted to research funding programmes. The result was the publication of the ICPeMed Action Plan.¹²² In this action plan, a European Research Area Network for personalised medicine (ERA-PerMed) was suggested, and a first Joint Transnational Call for Proposals to support translational research projects was launched in 2018 (see below).

European Alliance for Personalised Medicine

The European Alliance for Personalised Medicine was launched in March 2012, bringing together European health care experts and patient advocates involved with major chronic diseases.^{123,124} The aim was to improve patient care by accelerating the development, delivery and uptake of personalised medicine and diagnostics, through consensus. The alliance played a key role in shaping the Council conclusions on personalised medicine.¹²⁵

1 Million Genomes

The European Alliance for Personalised Medicine has proposed a project to link sequencing efforts across the EU, ultimately compiling a database of a million genomes for clinical research purposes. Proponents believe the project, called the Million European Genomes Alliance (MEGA), will spur research, stimulate the life sciences economy, and ultimately improve patient care. They also see it as a response to the Precision Medicine Initiative in the US, which has received initial funding of USD 215 million and similarly aims to build a research cohort of at least a million individuals that will include their genomic data.¹²⁶ MEGA is just as much a vehicle for advancing personalised medicine in Europe as it is for bringing together actors from different European countries to overcome a fragmented research environment. On Digital Day April 2018, 13 European countries signed a declaration for delivering cross-border access to their genomic information. The Signatories of the declaration of cooperation “Towards access to at least 1 million sequenced genomes in the EU by 2022” are setting up a collaboration mechanism with the potential to improve disease prevention, allow for more personalised treatments and provide a sufficient scale for new clinically impactful research. Since its launch on Digital Day 2018, the “1+ Million Genomes” initiative has grown into a real cooperation mechanism involving 20 signatory Member States and Norway. Agencies from several Nordic countries participate in this initiative.

ERA-Net on Personalised Medicine

The ERA-Net on Personalised Medicine, *ERA PerMed*, was initiated by the International Consortium for Personalised Medicine to foster the implementation of the ICPeMed Action Plan by funding transnational research projects in the field of personalised medicine. ERA PerMed is supported by 32 partners from 23 countries and co-funded by the European Commission (EC). The first Joint Transnational Call for Proposals – Research Projects on Personalised Medicine: smart combination of pre-clinical and clinical research with data and ICT solutions – was launched in 2018.¹²⁷ A second transnational call opened in January 2019,¹²⁸ comprising the following three research areas: “Translating Basic to Clinical Research and Beyond”, “Integrating Big Data and ICT Solutions”, and “Research towards Responsible Implementation in Health Care”. The overall objectives of the ERA PerMed calls are (i) to support translational research projects in the field of personalised medicine; (ii) to encourage and enable interdisciplinary collaborations towards implementation of personalised medicine, and; (iii) to encourage collaboration between academia, clinical/public health research and private partners.

122 The ICPeMed Action Plan (2017).

123 <https://www.euapm.eu/>

124 https://www.euapm.eu/pdf/EAPM_governance_document.pdf

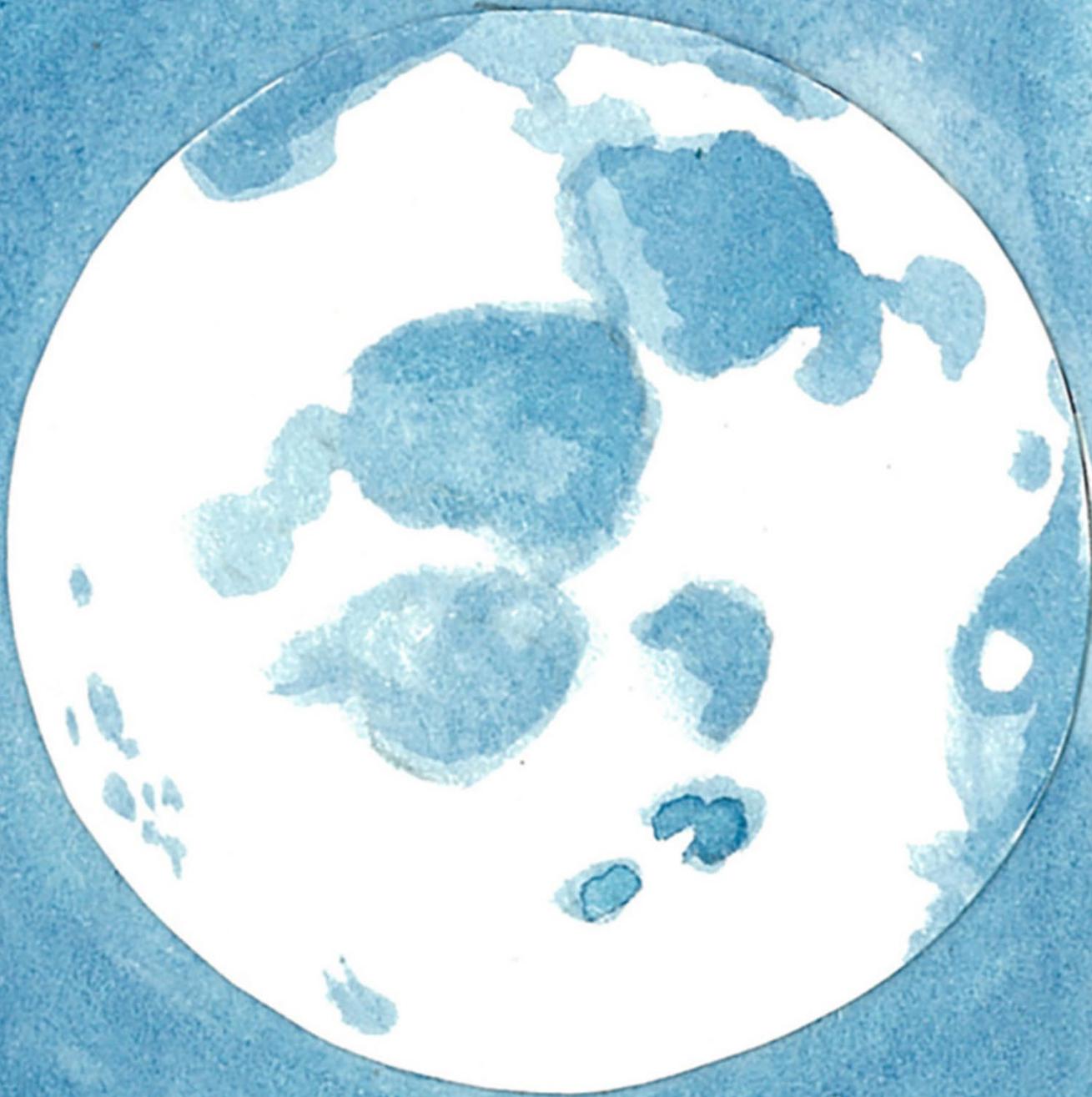
125 Personalised medicine for patients - Council conclusions (7 December 2015). Doc. no. 15054/15.

126 <https://www.genomeweb.com/informatics/million-european-genomes-alliance-proposed-response-obamas-precision-medicine-initiative>

127 http://www.icpermed.eu/media/content/ERA_PerMed_2018_pre-announcement_FV.pdf

128 <http://www.erapermed.eu/joint-transnational-call-2019/>

GLOBAL STATE OF PERSONALISED MEDICINE



GLOBAL STATE OF PERSONALISED MEDICINE

There is global recognition of the potential benefits of personalised medicine. Health systems in several countries, including the US, Germany, France, Canada, Australia, China and India are formulating policy and research programmes to support the adoption of more personalised approaches to health care. There are also several ongoing genome sequencing initiatives across the globe, e.g. in the UK, France, Canada, US, and China. Listed below are a number of current or recent strategic genomics and personalised medicine initiatives.

Genomics Initiatives

Genomics England and the 100,000 Genomes Initiative

The Genomics England project¹²⁹ was launched in July 2013. Genomics England is a company set up and owned by the UK Department of Health to run the 100,000 Genomes Project. This project will sequence 100,000 genomes from around 70,000 people. Participants are National Health Service (NHS) patients with a rare disease, plus their families, and patients with cancer¹³⁰ (the genomic information of an affected individual plus two of the closest relatives is generally sufficient to pinpoint the cause of a genetic condition). The project reached its halfway milestone in February 2018, with sequenced genomes of 8 000 cancer patients and 42 000 patients with rare diseases.¹³¹

Genomic Medicine France 2025

In 2015 the French Prime Minister commissioned the National Alliance for Life Sciences and Health (Aviesan) to examine how to integrate large-scale sequencing into the care pathway. The France Genomic Medicine Plan^{132,133} was developed in 2016 and it specifies three main targets for the year 2025:

- Position France among the countries leading the way in personalised and precision medicine with export of the expertise derived from the French medical and industrial genomic medicine system.
- Prepare for integration of genomic medicine into the care pathway and the management of common diseases. This means setting up a generic care pathway with access for all patients with cancer, a rare disease or a common disease by 2025, with genomic medicine available to all affected patients in the country. By 2020, some 235 000 genomes will be being sequenced each year. Beyond that, the system will be expanded to cover common diseases.
- Set up a national genomic medicine framework capable of driving scientific and technological innovation, industrial capitalisation and economic growth. This plan will create a dynamic in innovation in a number of fields: conservation, the generation and mathematical processing of big data, Web semantics and the Web of Objects, medical devices, dematerialisation, digitisation and e-Health, etc.

129 <https://www.genomicsengland.co.uk/>

130 <https://www.gov.uk/government/news/dna-mapping-to-better-understand-cancer-rare-diseases-and-infectious-diseases>

131 <http://www.cancerresearchuk.org/about-us/cancer-news/news-report/2018-02-21-100000-genomes-project-hits-halfway-milestone>

132 Levy Y. Genomic Medicine 2025: France in the race for precision medicine. *Lancet* 388(10062), p. 2872. 2016 Dec 10.

133 Lethimonnier F, Levy Y. Genomics Medicine France 2025. *Annals of Oncology* 2018 Jan 19.

The US Precision Medicine Initiative

In his 2015 State of the Union address, President Barack Obama announced the launch of the Precision Medicine Initiative.¹³⁴ The overall aim of the initiative is to enable a new era of medicine through research, technology, and policies that empower patients, researchers, and providers to work together toward development of individualised care. The initiative was launched with a USD 215 million investment in the President's 2016 Budget. Key investments include:

- USD 130 million for development of a voluntary national research cohort of a million or more volunteers to expand understanding of health and disease.
- USD 70 million to scale up efforts to identify genomic drivers in cancer and apply that knowledge in the development of more effective approaches to cancer treatment.
- USD 10 million to the Food and Drug Administration to acquire additional expertise and advance the development of high quality, curated databases to support the regulatory structure needed to advance innovation in precision medicine and protect public health.
- USD 5 million to the Office of the National Coordinator for Health Information Technology to support the development of interoperability standards and requirements that address privacy and enable secure exchange of data across systems.

Key objectives of the initiative include:

- More and better treatments for cancer.
- Creation of a voluntary national research cohort.
- Commitment to protecting privacy.
- Regulatory modernisation.
- Public-private partnerships.

Genome Canada

Genome Canada¹³⁵ is a non-profit organisation aiming to use genomics-based technologies to improve the lives of Canadians. It is funded by the Government of Canada and provides large-scale investments that develop new technologies, connect the public sector with private industry, and create solutions to problems of national interest, such as health, sustainable resources, the environment, and energy. Genome Canada also funds research on the ethical, environmental, economic, legal and social aspects of genomics. This includes topics such as genetic privacy and genetic discrimination, as well as public acceptance of genetically modified organisms. Genome Canada researchers generate policy briefs on these and other topics. Currently, there are six regional genome centres in Canada that receive funding from Genome Canada.¹³⁶

GenomeAsia100K

Asian populations represent around 40% of all humans, but the populations are currently underrepresented in genomic studies and reference genome databases. However, a number of initiatives have recently been undertaken to help accelerate Asian population-specific medical advances and precision medicine. Furthermore, the unique genetic diversity prevalent in South, North and East Asia will provide a valuable source of clinical insights that should enhance the understanding of several rare and inherited diseases, as well as chronic diseases such as cancer, diabetes and cardiovascular disease.

The Genome Asia 100K initiative¹³⁷ is led by a consortium of companies, academics, and other major stakeholders in the field of genetics. The plan is to sequence 100,000 individuals from 12 South Asian and at least 7 North and East Asian countries. The first stage aims to sequence 10,000 Asian individuals for

134 FACT SHEET: President Obama's Precision Medicine Initiative. The White House. Office of the Press Secretary. January 30, 2015.

135 <https://www.genomecanada.ca>

136 Genome Canada Strategic Plan 2012-2017

137 <http://www.genomeasia100k.com>

ethnic stratification. This will be followed by sequencing an additional 90,000 individuals combined with clinical and phenotype information (microbiome, clinical, and phenotype information) to allow deeper analysis of diseased and healthy individuals.

Asian Reference Genome

A high-resolution *de novo* diploid genome assembly of an individual from Korea was published in 2016.¹³⁸ From this sequence, scientists will be able to identify the parts that are unique to the Korean population, and to Asian populations in general. A number of structural rearrangements specific for the Asian population have already been discovered from the genomic sequence and the functional significance of the newly-discovered structural rearrangements is to be demonstrated in clinical practice.

China Precision Medicine Initiative

The China Precision Medicine Initiative was announced almost exactly one year after President Barack Obama announced the US Precision Medicine Initiative. The Chinese Government announced precision medicine as part of the five-year plan for 2016–2020, with an expected investment of more than USD 9 billion for research in the next 15 years. The Chinese initiative is much larger than its US counterpart, and the country has excellent capacity in genome sequencing as well as access to millions of patients. There are however concerns that problems with the nation's health-care infrastructure – in particular a dearth of doctors – threaten the effort's ultimate goal of improving patient care.¹³⁹

Personalised Medicine Strategic Initiatives

UK Personalised Medicine Strategy

Through the 100,000 Genomes Project, the NHS is building partnerships with academia and industry to decode the human genome in people with rare diseases and cancer. The Personalised Medicine Strategy¹⁴⁰ intends to integrate personalised and genomic medicine into daily health care. A work programme is to be created consisting of four interdependent elements:

- Building an infrastructure to underpin personalised medicine in the NHS.
- Developing a clinical change model incorporating: high impact commissioning challenges; changes to clinical pathways; pharmacogenomics and synergies between companion diagnostics and medicines optimisation; and links to the 100,000 Genomes Project, its findings and NHS transformation outcomes.
- Embracing technology and innovation and creating the knowledge base. This will include: the scientific and technological advances in all genomics (incorporating the functional genomics pathway in totality) and in other underpinning diagnostics; bringing in the knowledge from NHS England Digital Health Services and the National Information Board; growing artificial intelligence and machine learning applications; and an NHS England solution to the requirement for an integrated genomic and personalised medicine knowledge base with complex analytical solutions to inform both clinical practice and research and development.
- Policy and system alignment.

138 Seo J-S et al. (2016). De novo assembly and phasing of a Korean human genome. *Nature* 538: 243–247.

139 Cyranoski D (2016). China embraces precision medicine on a massive scale. *Nature* 529: 9–10.

140 Paper: PB.24.09.15/05. BOARD PAPER - NHS ENGLAND. Title: Personalised Medicine Strategy. From: Sir Bruce Keogh, National Medical Director.

The UK Stratified Medicine Programme

The Cancer Research UK Stratified Medicine Programme¹⁴¹ is a collaborative initiative to undertake large volume genetic testing within the UK, aiming to test around 9,000 patients across the UK in a 2-year period. The programme is supported by the UK government's Technology Strategy Board, pharmaceutical industry (AstraZenca, Pfizer etc.), and diagnostic and IT companies. The Stratified Medicine Programme was designed to demonstrate how cancer gene testing can be done at a large scale. The programme is operating through 3 technology hubs, 8 clinical hubs and 26 feeder hospitals.¹⁴² A number of key barriers to a national system were identified, including:

- Establishing routine consent of data and samples for research.
- Achieving clinically relevant turnaround times.
- Data issues/challenges.
- Establishing standards for sample handling, preparation and processing.

US Personalized Medicine Coalition

The Personalized Medicine Coalition (PMC),^{143,144} representing innovators, scientists, patients, providers and payers, promotes the understanding and adoption of personalised medicine concepts, services and products to benefit patients and the health system. The PMC was formed as a non-profit umbrella organisation of pharmaceutical, biotechnology, diagnostic, and information technology companies, health care providers and payers, patient advocacy groups, industry policy organisations, major academic institutions, and government agencies. The PMC provides a structure for achieving consensus positions among these stakeholders on crucial public policy issues, a role which will be vital to translating personalised medicine into widespread clinical practice.

California Initiative to Advance Precision Medicine

The California Initiative to Advance Precision Medicine (CIAPM) is a partnership between the state, the University of California, and other entities to help build infrastructure needed to support precision medicine efforts state-wide.¹⁴⁵ The initiative, which was launched in April 2015, supports patient-focused demonstration projects, and builds an inventory of California's precision medicine assets, such as research projects and clinical studies, databases, and analysis platforms. As a centralised information base, the inventory will coordinate the use of precision medicine resources, and stimulate cross-sector collaborations among the state's scientists, clinicians, entrepreneurs and patient participants, enabling them to turn available large data sets and technical innovation into better health outcomes. To lay the groundwork for innovation, CIAPM is pursuing two main goals, (1) to assemble an extensive inventory of precision medicine assets in California, and (2) to support demonstration projects that have the potential for tangible benefit to patients within a short timeframe.

141 <https://www.cuh.nhs.uk/news/cancer-services/stratified-medicine-programme-changing-face-cancer-research>.

142 http://www.jhsf.or.jp/paper/cd_rom/16-3.pdf

143 Abrahams E, Ginsburg GS, Silver M. The Personalized Medicine Coalition: goals and strategies. *Am J Pharmacogenomics*. 2005; 5(6):345-55.

144 <http://www.personalizedmedicinecoalition.org>

145 <http://www.ciapm.org>

