DANISH NATIONAL
GENOME CENTER

Enabling personalised medicine for the benefit of patients

Annual Report 2023

Contents

Introduction

Message from the CEO

Continuous striving for excellence

The vision of the Danish National Genome Center (DNGC) is to support a better future for patients, where treatment is targeted to the individual patient. Within this ambitious vision, DNGC has been given the task to establish a national infrastructure for personalised medicine and to support the implementation of whole genome sequencing (WGS) in healthcare.

BETTINA LUNDGREN

CEO, DNGC

Clinical microbiology specialist and doctor of medical science (DMSc)

A total of 23,897 genomes have already benefitted patients with rare diseases and cancer, thereby contributing to more precise diagnoses and more targeted treatment and prevention. The National Genome Database is growing steadily and constitutes a significant research resource that will contribute to the further development of personalised medicine. We will open up access to the database for research purposes in the first half of 2024.

This annual report gives me an opportunity to reflect on our achievements and progress in Denmark over the last 5 years and how we can continue to create real value for patients today and in the future.

Being included in the "Thought Leadership Series" at the American Society of Human Genetics in 2023 was a significant recognition of the Danish ambition and achievements so far. National and international collaboration as well as continuous striving for excellence are key to our current and future success within personalised medicine.

Based on the solid foundation of national strategies for personalised medicine, legislation, regional and national financing and the grant from the Novo Nordisk Foundation, the major achievements in the 5-year history of DNGC include:

- WGS is now a systematic part of the investigation and diagnostic processes for patients across the country.
- More than 20,000 patients benefit from improved care today from the use of WGS.
- Establishment of strong national collaboration, including national and regional networks within genomics and personalised medicine.
- A uniform national process for the implementation of new technology (i.e. WGS), including the establishment of a professional and administrative governance structure for the development of personalised medicine.
- Establishment of a national IT infrastructure for personalised medicine, including a National Genome Database, and the completion of a proof-of-concept technical solution for sharing healthcare data.
- Technical and administrative structure and implementation of data and information security, including ISO-27701 and -27001 certification.
- Valuable international shared knowledge and formal collaborations with Sweden, France and England as well as participation in 1+ Million Genomes and other international initiatives on personalised medicine.

I am particularly proud of the impact that our national collaboration among clinicians, researchers and experts has had on patient care. A number of very moving examples of the value of WGS for patients are shared by clinical experts in this report.

Based on our established collaboration structures and big-data capabilities, DNGC is actively working to enable the combined use of genome data with data from existing registers, databases and other sources of information in both clinical and research contexts.

DNGC is contributing to the implementation of the national strategies for personalised medicine, the Strategy for Life Science and the Vision for the Better Use of Healthcare Data. These strategies share the common goal of establishing a nationally coordinated data-infrastructure as a foundation for a true learning healthcare system, international collaboration and the effective use of healtcaredata and new technologies, such as artificial intelligence.

The efforts created across healthcare, universities and industry will benefit future patients through more individualised care, the development of new therapies, prevention strategies and the allocation of resources for other tasks within our healthcare system.

Bettina Lundgren
CEO

Milestones

2016

National strategy for personalised medicine for the benefit of the patients

2017

Establishment of a national collaborative structure for personalised medicine

2018

Act on the establishment of the Danish National Genome Center

Novo Nordisk Foundation allocates a framework grant of DKK 990 million to the Danish National Genome Center, of which DKK 102 million is granted up front for investments in HPC-capacity. Another DKK 30 million is granted to develop a roadmap.

2019

Formal establishment of The Danish National Genome Center as an agency under the Ministry of Health

Roadmap for the Danish National Genome Center ready. Novo Nordisk foundation grants the remaining DKK 888 million to the Danish National Genome Center

2020

17 patient groups selected for whole genome sequencing

Implementation of a new national infrastructure for personalised medicine

2021

National strategy for personalised medicine (2021-2022)

Establishment of a new national governance structure for personalised medicine

2022

All 17 patient groups in operation

The Danish National Genome Center ISO-certified (ISO/IEC 27001 and ISO/IEC 27701)

2023

Evaluation of the impact of whole genome sequencing for the 17 patient groups initiated

Key figures

3 International collaboration agreements (MoUs)

The Danish National Genome Center has signed formal collaboration agreements (MoUs) with Sweden, France and England that share the Danish ambitions to develop personalised medicine nationally for the benefit of patients.

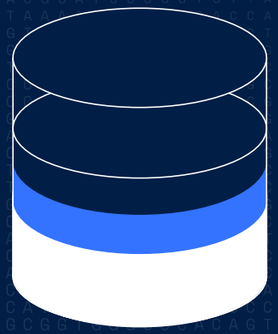
4 Strategic partners

The Danish National Genome Center provides storage of health data for personalised medicine to partners and develops solutions for infrastructure capacity in research services for other Danish authorities. The collaboration with strategic partners supports a future where health and socio-economic data can be used more effectively.

17

Patient groups offered whole genome sequencing

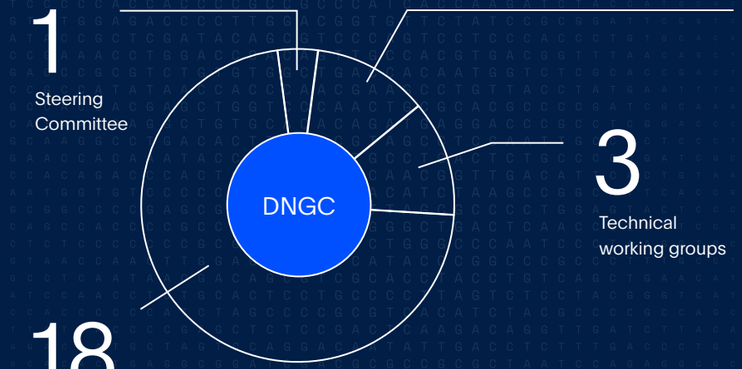
Patients within 17 different disease areas are offered whole genome sequencing as part of their treatment. This allows each patient to potentially receive a more precise diagnosis and a more tailored treatment.



Genomes in the database

23,897

22,889 genomes are from patients that have received whole genome sequencing as part of their treatment, and 1,008 genomes are from research. In 2024, researchers gain access to the database for groundbreaking research within personalised medicine.



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Steering Committee

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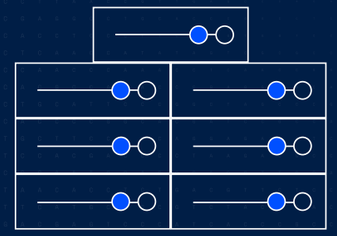
Technical working groups

3
Advisory boards

18
Clinical working groups



1

Supercomputer

Based on users' needs, the National High Performance Computing Center is responsible for making services, tools and data available, aimed at providing better support for the doctors' treatment of individual patients in hospitals and for research in personalised medicine.

8

Research projects

Researchers can use the Danish National Genome Center's supercomputer for personalised medicine research via a tailored Cloud, accessing its storage and computing power.

27001 & 27701 ISO/ IEC-certification

Storing the genomes of Danish patients and making them available to doctors, researchers and patients requires the highest level of security. The Danish National Genome Center is certified according to the most known and recognised international security and privacy standards.

557

Individual users of DNGC infrastructure

Most clinical departments with genetic interpretation functions in Denmark are users of the national infrastructure. More specifically, users of the infrastructure include 317 clinicians, 177 researchers and 63 individuals from strategic partners.

Whole genome sequencing

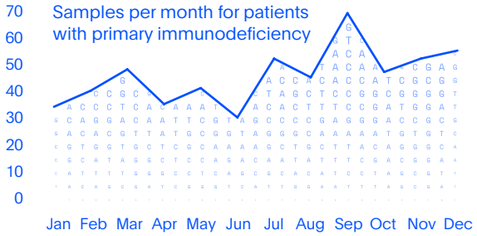
- Distribution of whole genome sequencing across patient groups
- Monthly production of genome equivalents
- Effect of the implementation of whole genome sequencing

BEFORE

AFTER

INFO

NAME:	BARBARA VIDEBAEK
ILLNESS:	PRIMARY IMMUNODEFICIENCY



"The availability of genomic analyses will reduce morbidity, mortality and the long-term consequences associated with primary immunodeficiency."

Trine Hyrup Mogensen

CASE REPORT FROM WHOLE GENOME SEQUENCING IN DENMARK

Barbara received individualised treatment

Barbara Videbaek struggled with fungal infections in her mouth and on her skin for many years. She frequently developed abscesses on her skin and experienced pain in her feet. Barbara was bothered on a daily basis by her pain, needed to use custom-made shoes and felt socially limited.

Barbara Videbaek was in and out of hospitals. After several examinations, Barbara Videbaek was offered a genomic analysis, where doctors discovered that she had a rare genetic disease and that was the cause of her illness. She was diagnosed with 'primary immunodeficiency.'

Subsequently, Barbara Videbaek received targeted treatment, which she has to continue for the rest of her life. With this, she no longer experienced infections or pain in her feet, and she was cured.

The genetic mutation was subsequently identified in some of Barbara Videbaek's close relatives with similar symptoms. They were informed and may benefit from the same preventative treatment.

Professor Trine Hyrup Morgensen studies and investigates primary immunodeficiency and the genetic mechanisms underlying increased susceptibility to serious infectious diseases caused by viruses and bacteria. According to Trine Hyrup Mogensen, patients suffering from primary immunodeficiencies can greatly benefit from a genomic analysis.

"I am convinced that it will enable precise diagnosis in a much larger proportion of our patients than it is presently. Based on this, we can implement targeted, preventive and immunomodulatory treatment, which will reduce the risk of infections and/or inflammation as well as autoimmunity in this patient group."

The long-term goal is to gain a deeper understanding of the disease mechanisms behind primary immunodeficiency. This knowledge will serve as the foundation for developing and testing new treatment modalities and vaccines.

"Overall, the availability of genomic analyses will enable individualised treatment and thereby reduce morbidity, mortality and the long-term consequences associated with primary immunodeficiency, including severe infections and conditions involving a dysregulated immune system."

TRINE HYRUP MOGENSEN

VICE CHAIRMAN, NATIONAL SPECIALIST NETWORK PATIENTS WITH PRIMARY IMMUNE DEFICIENCY

Professor, Department of Biomedicine, senior physician, Department of Infectious Diseases, Aarhus University Hospital

"With the right medicine, I became normal. It was like a miracle!"

Barbara Videbaek
Patient with primary immunodeficiency

The whole genome sequencing may have been carried out in a regional setting

Distribution of whole genome sequencing across patient groups

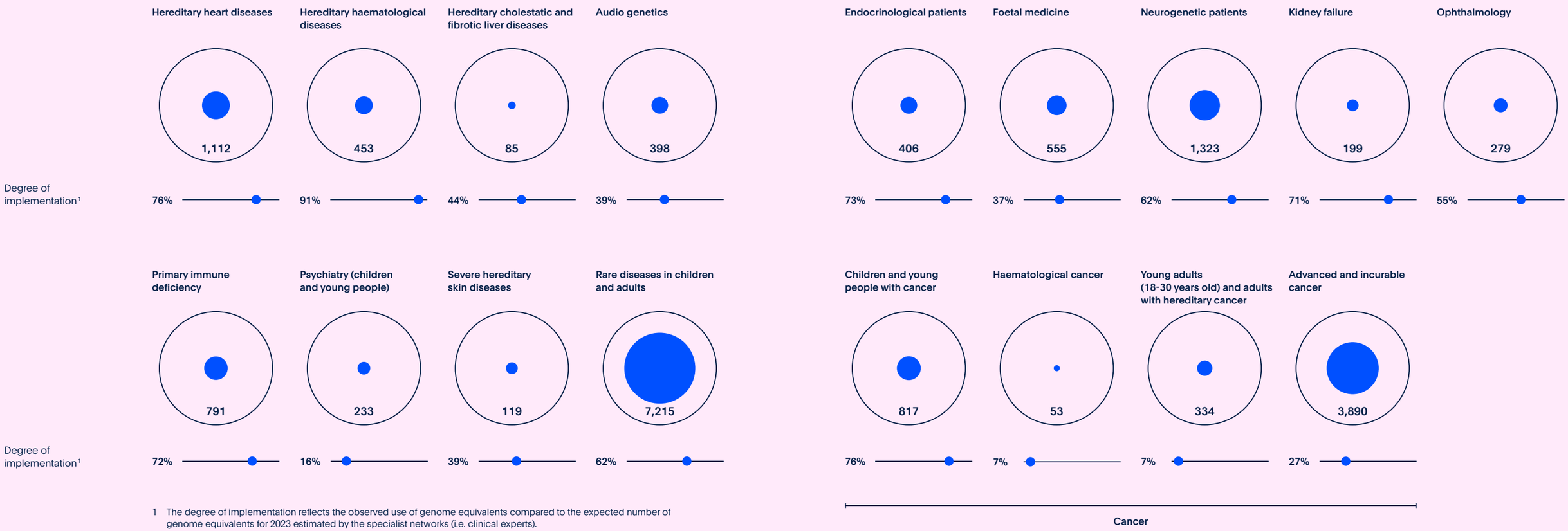
Number of genomes and RNA samples performed by DNGC's facilities per patient group

Total number of genome and RNA samples across all patient groups

Since 2019, more than 20,000 patients have benefitted from a whole genome sequencing (WGS) as part of their treatment. Consequently, the National Genome Database is growing steadily month by month. The genome data can, with the right permissions, be reused for patient treatment and for research in personalised medicine.

More specifically, the total number of genome and RNA samples in the National Genome Database has grown from 9,778 in 2022 to 23,897 in 2023 (144% increase), of which 18,449 have been performed by the Danish National Genome Center's two facilities.

Implementation speed varies across patient groups due to different times of approval for the implementation of the individual patient group as well as different levels of organisational and clinical readiness for implementation across regions and clinical departments. Moreover, different patient groups follow different procedures for diagnostics and follow-up, and there is also a time-dimension introduced in terms of when WGS is applied as a diagnostic tool in the course of the disease for the individual patient.



1 The degree of implementation reflects the observed use of genome equivalents compared to the expected number of genome equivalents for 2023 estimated by the specialist networks (i.e. clinical experts).

Monthly production of genome equivalents

While implementation speed varies across patient groups, there has been a very positive and consistent total monthly development in the use of genome equivalents in 2023.

The Danish National Genome Center expects to have performed 60,000 genome equivalents by January 2026. The prognosis is depicted in Figure 1.

The prognosis assumes 1,500 genome equivalents sequenced per month and 1,500 equivalents used for the Genome of Europe Project (spread over 2024).

Overall, the facilitation of increased uses of whole genome sequencing (WGS) have proved more challenging than assumed in the original roadmap (Playbook). This can be attributed to many factors, including but not limited to extended process for patient selection, extended process for data processing agreements (GDPR), COVID-19 pandemic, challenges related to implementing a national pipeline and regional implementation of WGS.

Figure 1. Cummulative development from July 2022 to January 2026 in genome equivalents[2]

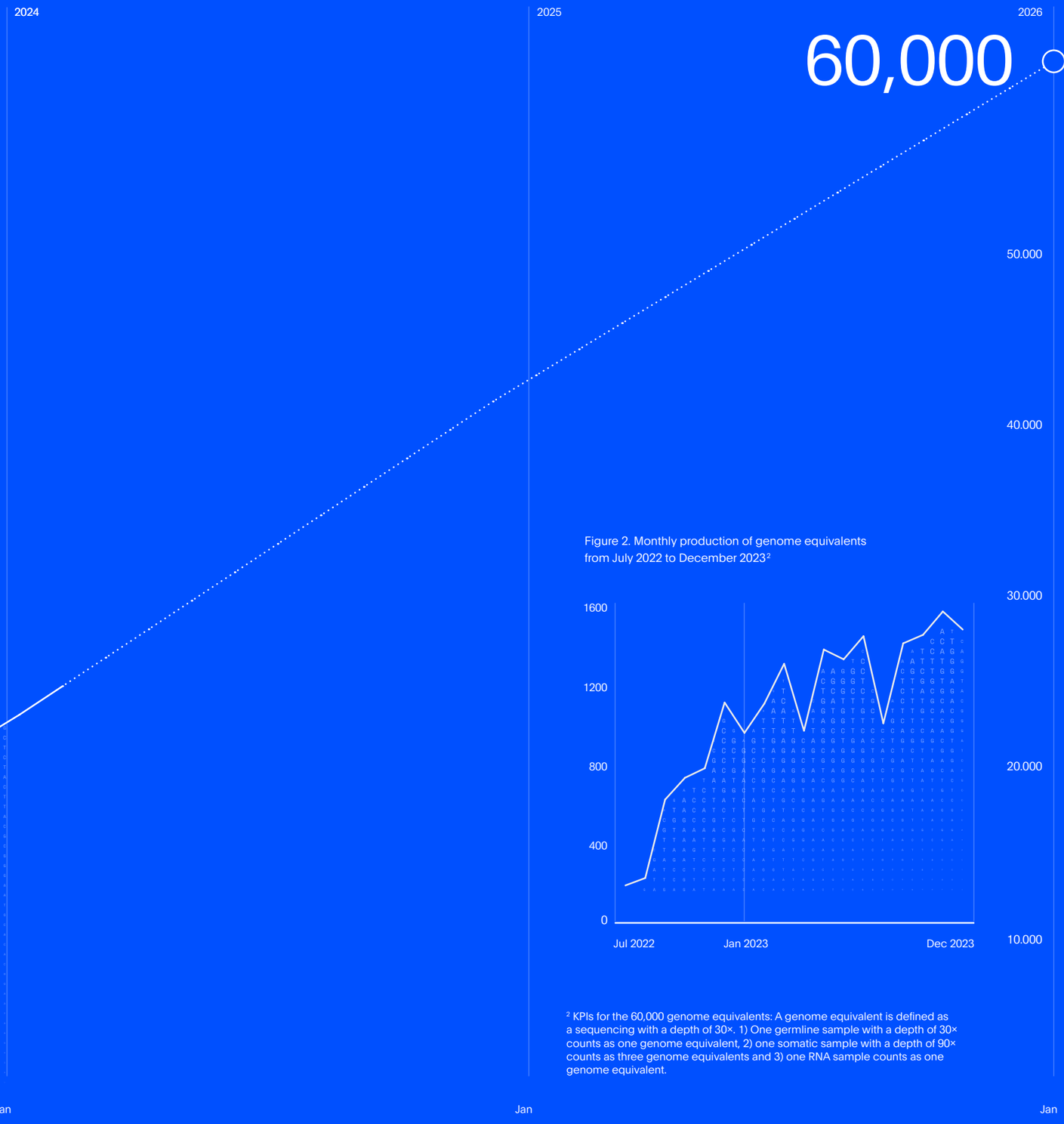


Figure 2. Monthly production of genome equivalents from July 2022 to December 2023[2]

[2] KPIs for the 60,000 genome equivalents: A genome equivalent is defined as a sequencing with a depth of 30×. 1) One germline sample with a depth of 30× counts as one genome equivalent, 2) one somatic sample with a depth of 90× counts as three genome equivalents and 3) one RNA sample counts as one genome equivalent.

Effect of the implementation of whole genome sequencing

The Danish National Genome Center (DNGC) has collected experiences from networks of specialists and patient representatives over the past year to gain insight into the value of offering whole genome sequencing (WGS) for various patient groups.

Based on clinicians' experience, DNGC has compiled a report for each patient group, in which the experiences with the national implementation of WGS is described. The reports of implementation are based on the following elements:

- The number of sequencings for the patient group.
- The process time from receiving the patient sample at the WGS facilities to data being ready for interpretation.
- International experience with WGS, for example whether similar patient groups and indications are offered WGS in similar countries, including Sweden, France and England.
- Systematic literature review.
- Interviews with clinicians.
- Patient cases describing the added value of offering WGS.

The evaluation model does not contain clinical data as it has been evaluated, on the basis of a pilot test, that the resources required up-front would not yield the necessary gain. It is expected that the use of WGS for all patient groups will instigate research projects to further elaborate on the diagnostic yield and clinical effect.

The importance of WGS for many of the patient groups is highlighted in the systematic literature reviews, exemplified by international recommendations, for example by 'The American college of Medical Genetics and Genomics' and several European reference networks for rare diseases. Within the literature, the clinical effect of WGS described is consistent with the clinical effect described by clinicians in Denmark.

"It has been a very fruitful process engaging with the networks of specialists to describe experiences with implementing whole genome sequencing (WGS) nationally."

Peter Johansen
Team lead in the healthcare team, DNGC

Implementation for clinical use

There is a nearly identical national clinical utilisation of WGS in Denmark compared to similar countries like England, France and Sweden, where WGS is offered to equivalent patient groups. There are many similarities in the clinical use of WGS between the countries, yet the method of updating existing and adding new patient groups is slightly different:

- In Sweden, WGS is implemented by updating clinical guidelines with recommendations on WGS use.
- England has implemented a national governance around applications and approval of updates to genetic diagnostic practice where new investigations are evaluated by a 'test evaluation working group' and the National Health Service (NHS) in England before implementation in clinical practice.
- In France, new disease indications for WGS are evaluated and recommended by Genomic Medicine France and subsequently by the national health authorities.

Literature

A major international study demonstrates:

- There is a 1.2 times higher chance of making an accurate diagnosis for rare diseases when using WGS compared to exome sequencing, and 77% of patients achieve a clinical effect.

For more than three-quarters of the patients, sequencing resulted in altered clinical management such as a referral for a follow-up or monitoring, indication or contraindication for tests as well as surgery or medication compared to a clinical effect of 44% with exome sequencing[1].

According to two major studies from the US:

- Extensive genetic diagnostics in patients with congenital anomalies or intellectual disability led to a change in clinical management of the patient in 6.3% to 8% of all those examined.

6.3% of all examined individuals experienced a short-term clinical effect. Among the patients who received a genetic diagnosis, 16.7% experienced a short-term clinical effect. Extensive genetic diagnostics further resulted in changed longterm clinical management for 10% to 17.5% of all the individuals examined, where 17.5% corresponds to 46.4% of all those who received a genetic diagnosis. The changed clinical management could, for example, involve altered monitoring or follow-up of the patient[2].

A large study from England demonstrates:

- For 25% of patients with rare diseases who received a genetic diagnosis, the diagnosis impacted the clinical management of the patient.

The genetic diagnosis was assessed to have no benefit in only 0.2% of cases in a large study from England. Overall, they found that the offering of WGS benefitted the patients in the form of a more precise diagnosis or altered treatment[3].

National experiences

In the first 12 status reports published for 12 patient groups, clinicians highlight the following benefits of the national implementation of WGS:

- WGS is now a systematic part of the diagnostic process for patients nationally, leading to more patients being evaluated and diagnosed genetically.

- A genetic diagnosis holds significant importance for patients. It can help reduce uncertainty and enables individualised follow-up and treatment.
- There has been an increased focus on genetics in several medical specialties and a greater emphasis on genetic evaluation.
- The project has accelerated the formation and use of both formal and informal collaboration forums. New collaborations and multidisciplinary teams have especially been formed between clinicians, geneticists and interpreters nationally and across hospitals.
- Strong collaboration of the Danish National Molecular Tumor Board.
- Storing genomes in a national database allows for reanalysis of patients' genomic data.
- WGS offers a technological advantage, as it is increasingly possible to identify both structural and rare gene variants through whole genome sequencing compared to other types of genetic analyses.

Clinicians point out the following challenges:

- Shortage of interpreters, physicians and bioinformaticians to process WGS data.
- Increased turnaround times due to a rising number of samples and a lack of resources for interpretation are observed.
- The absence of national clinical and variant databases.
- It is time consuming to obtain written consent.
- Logistical challenges associated with the requisition of WGS.

Furthermore, there are now more national networks organised by the regions and medical societies. These include GenNets, which are formalised forums organised under the Danish Society for Medical Genetics that work on describing which genes should, as a minimum, be analysed for specific diagnostic workup.

[1] This is demonstrated by a major international study titled "Meta-analysis of the diagnostic and clinical utility of exome and genome sequencing in pediatric and adult patients with rare diseases across diverse populations".

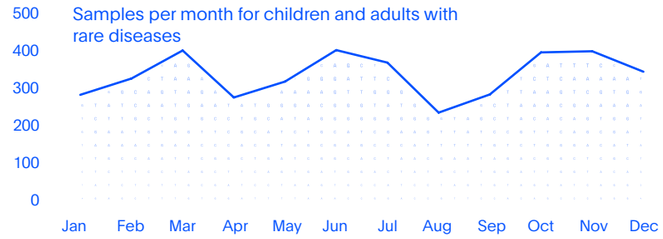
[2] Two major studies from the US, "Exome and genome sequencing for pediatric patients with congenital anomalies or intellectual disability: an evidence-based clinical guideline of the American College of Medical Genetics and Genomics (ACMG)" and Canada, "Genome-Wide Sequencing for Unexplained Developmental Disabilities or Multiple Congenital Anomalies: A Health Technology Assessment" evaluate clinical effects in the short and long term.

[3] A large study from England "100,000 Genomes Pilot on Rare-Disease Diagnosis in Health Care - Preliminary Report"

CASE

INFO

NAME:	ANONYMOUS
ILLNESS:	DELAYED IN HIS NATURAL DEVELOPMENT AND HAS HEARING IMPAIRMENT



CASE REPORT FROM WHOLE GENOME SEQUENCING IN DENMARK

Patient with a rare disease gets clarity

A 6 year old boy is being followed in a paediatric department as he is delayed in his natural development and has hearing impairment and is enrolled in a school for children with special needs. His mother has a history of learning difficulties.

The boy and his parents undergo a triowhole genome analysis, comparing his genetic material with that of his parents. Doctors identify a genetic mutation on the X chromosome (the female sex chromosome). The mutation is the cause of his X-linked intellectual disability.

The intellectual disability cannot be treated, but the parents are relieved to have clarity. The assistance the boy receives in daycare, school and at the hospital can now be better tailored to his needs.

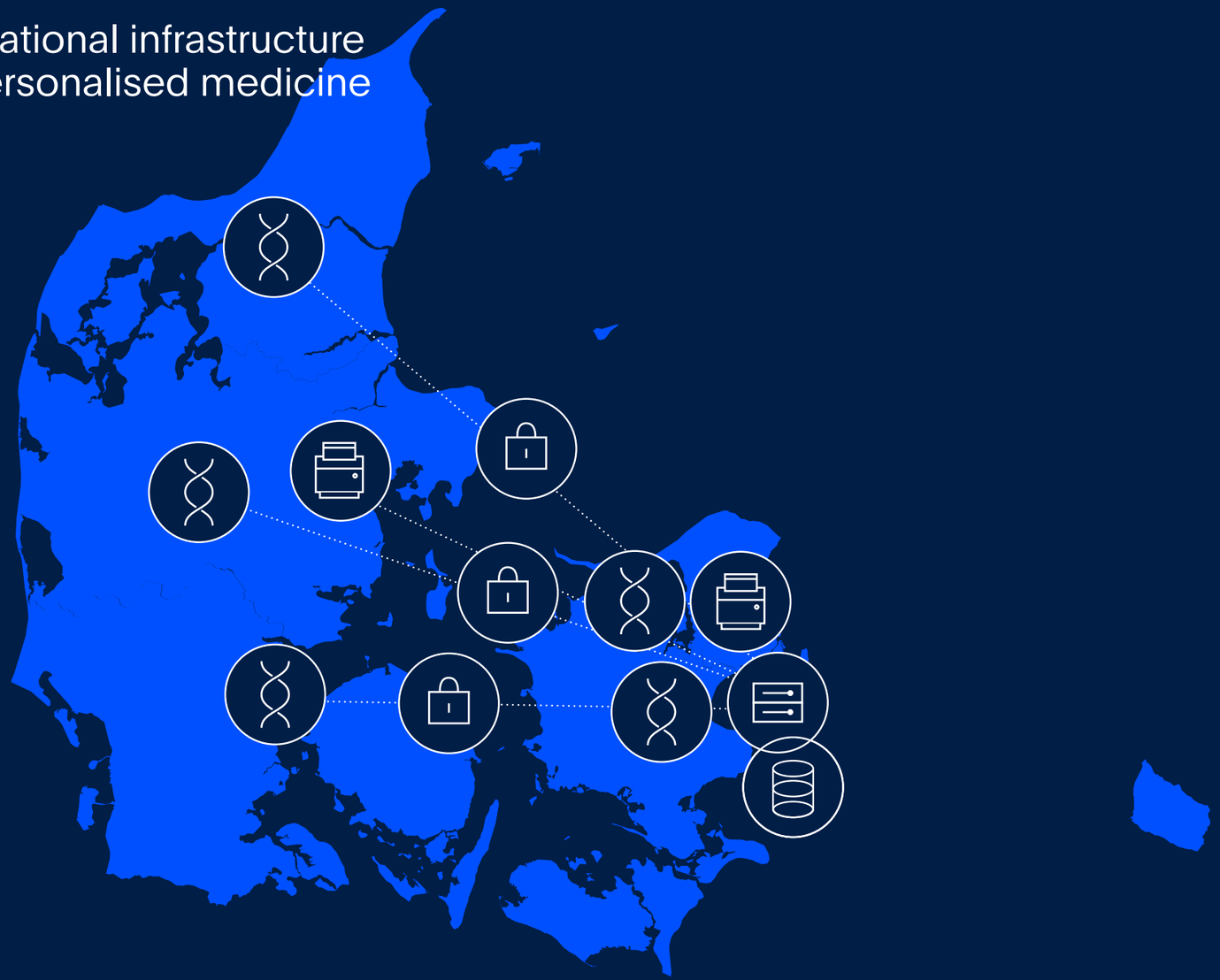
The whole genome sequencing may have been carried out in a regional setting.

Anonymous patient, stock photo from Unsplash archives.

The national infrastructure for personalised medicine

- The national infrastructure for personalised medicine
- National Whole Genome Sequencing Center
- National High Performance Computing Center
- Security is part of our DNA
- Research projects on the supercomputer
- The potential of Artificial Intelligence and Machine Learning
- Strategic partners on the supercomputer

The national infrastructure for personalised medicine



The Danish National Genome Center develops and operates Denmark's national infrastructure for personalised medicine, consisting of a National Whole Genome Sequencing Center and a National High Performance Computing Center, including a National Genome Database.

Infrastructure highlights

To accommodate for the increasing volumes of users and data, the focus in 2023 has been on further fine-tuning the infrastructure, including optimisation of performance and capacity management as well as further enhancing user support processes, customer journey management processes and compliance processes.

Highlights in 2023 include:

- New bioinformatic tools and pipelines to support the clinical users in the patient treatment.
- Standardisation of metadata stored in the National Genome Database according to the international standard Global Alliance for Genomics and Health (GA4GH).
- Expansion of the 'General Report Process' to support new clinical use-cases (e.g. trio and foetal samples).
- Expansion of the National Interpretation platform in order to optimise the clinical user's interpretation work.
- Introduction of transcriptomic data in order to support interpretation of somatic variants.
- Continuous improvement in data security framework, e.g. implementation of a new vulnerability detection and control framework as well as increased capacity on the AI-based threat detection and response platform.

Sequencing

Access to whole genome sequencing through the National Whole Genome Sequencing Center (East and West). Standardised high-quality data for clinical diagnostics. Fast and cost-effective.

Processing

Access to data processing on a supercomputer (computing power and validated pipelines) that reduces the turnaround time for analyses. When all departments in Denmark use the same national pipelines, it becomes easier to compare/integrate data in the long run.

Secure connections

High-speed connections to all regions. Traffic is always encrypted, and the connection to the Danish National Genome Center infrastructure ensures secure and highly fast data transfer and services. High-Performance Computing (HPC is available 24/7).

Interpretation

Access to certified disease-specific interpretation tools and general interpretation support tools, along with access to a variant database. Simple user interface that does not require coding experience. Compliant with the national standards and consistent across all regions.

Storage

Access to a future-proof environment with ample storage capacity that can be infinitely scaled. Data never leaves Denmark and is stored in a highly secure facility. Genome data is automatically reported to the National Genome Database.

National Whole Genome Sequencing Center

The National Whole Genome Sequencing Center (National WGS Center) provides access to standardised, high quality and cost-effective whole genome sequencing (WGS) for clinical diagnostics. The National WGS Center serves clinical departments across the country, covering the entire Danish population of 5.9 million. The National WGS Center is integrated into highly specialised laboratory facilities: The Department of molecular medicine (MOMA) at Aarhus University Hospital in the Central jutland (WGS West) and Genomic Medicine (GM) at Rigshospitalet in the Capital Region (WGS East). Both laboratories are accredited according to the international laboratory standard ISO15189. The collaboration for the national implementation of WGS in patient care draws on the facilities' extensive experience in sequencing.

During the period from 2020 to 2023, approximately DKK 251 million of the Novo Nordisk Foundation (NNF) grant money has been invested in personnel, machines and reagent kits for WGS East and WGS West. This includes the purchase in 2023 of Illumina's new NovaSeq™ X Plus machines.

The facilities are expected to process a total of 1,625 equivalents per month in 2024. In 2024, 125 equivalents per month are sequenced for the Genome of Europe (GoE) project. In 2025, the facilities are, therefore, expected to process a total of 1,500 equivalents per month. The expected number of genomes is a forecast, based on what the facilities have reported so far. The number of sequencing depends on the number of patients referred for whole genome sequencing, as well as the regional capacity for interpreting data from whole genome sequencing. The equipment capacity in the two laboratories is between 30,000-40,000 WGS samples per year. The laboratories also perform whole genome sequencing for patients that are not covered by the Danish National Genome Center (DNGC), and they perform other sequencing besides whole genome, such as exome sequencing.

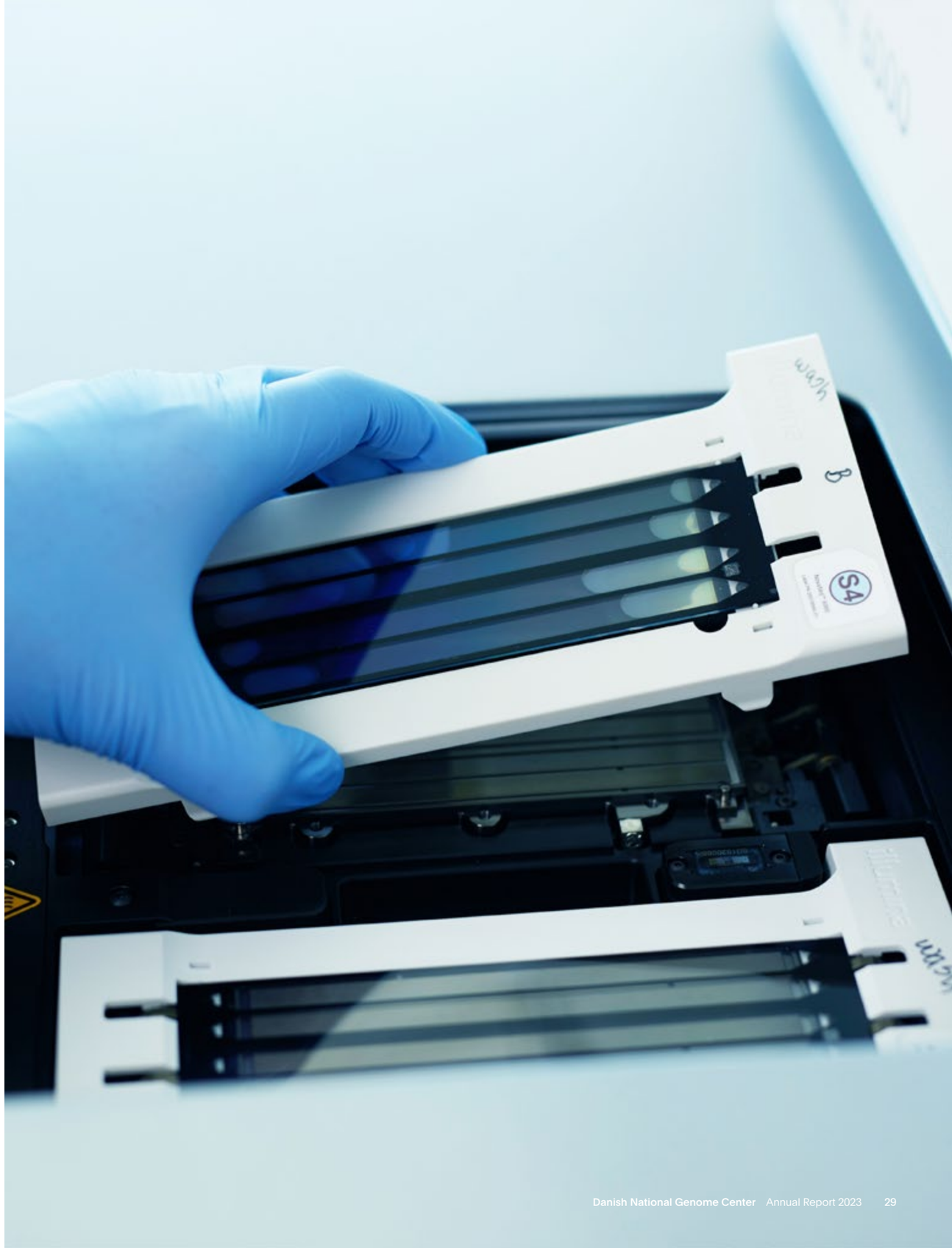
As initially agreed, the operations, financing and further development of the National WGS Center will become a regional responsibility from mid-2024. Together, the DNGC and the regions will fulfil the plan for the 17 patient groups and the 60,000 genomes.

"The national setup is unique, as it provides our patients and clinical colleagues with an up-front causal diagnosis, based on state-of-the-art sequencing technologies. The national infrastructure is essential for efficient targeted treatment for Danish patient. The clinical turn-around-time from sample receipt to the release of data for interpretation is around 2 weeks (1 week for urgent samples) for 90% of the samples. In the current workflow, we carry out around 1,500 whole genomes per month, but the overall machine capacity of the Danish sequencing facilities is 40,000 sequencings per year. We are excited for the future and we are looking forward to the continuous collaborations with the Danish National Genome Center."

Maria Rossing
Head of WGS East, Chief Physician, Clinical Research Associate Professor, MD, PhD, Center for Genomic Medicine (GM), Rigshospitalet

"The national initiative has made a significant difference for the ambitions of personalised medicine on behalf of the patients. The national anchoring has contributed to uniform standards for whole genome sequencing, analysis and treatment of the patients. This means that patients receive the same high quality across the country owing to quick and consistent operations, making each test more cost-effective overall."

Ole Halfdan Larsen
Head of WGS West, Chief Physician, Associate professor, PhD., Department of Molecular Medicine (MOMA), Aarhus University Hospital



National High Performance Computing Center

Based on users' needs, the National High Performance Computing Center (National HPC Center) is responsible for making services, tools and data available, and it is aimed at providing better support for doctors' treatment of individual patients in hospitals and for research in personalised medicine.

More specifically, the National HPC Center provides equal access to the following services and tools for clinicians, researchers and strategic partners across the country:

- High Performance Computing power and validated pipelines for the processing of genome data, including further processing capabilities via Nextflow tower and Sentieon.
- Interpretation tools and databases for interpretation support: VarSeq, Alamut, HGMD and QCI.
- National Genome Database

In the first half of 2024, Danish National Genome Center (DNGC) will open up for access to the National Genome Database for research purposes.

The development and operation of the National HPC Center is based on a collaboration agreement between DNGC and The Technical University of Denmark (DTU) and University of Copenhagen. By the end of 2023, a total of approximately DKK 182 million of the NNF-grant have been invested at DTU, providing access to HPC-hardware.

ALI SYED
CTO, DNGC

Ali Syed is the Danish National Genome Center's Chief Technology Officer

Ali Syed was appointed as new Chief Technology Officer (CTO) at the Danish National Genome Center (DNGC) on 1 January 2024.

For the last 10 years, he has worked at the intersection of health research and computer science. He was the chief architect behind Denmark's first Life Science supercomputer, developed in collaboration with the Technical University of Denmark, the University of Copenhagen and the Danish e-Infrastructure Consortium, specifically designed for handling sensitive health data.

Since January 2019, he has been a crucial part of building DNGC's technical setup as an external strategic adviser on the development and operation of DNGC's supercomputer.

"We have already come a long way at Danish National Genome Center, and I can clearly see the path forward regarding the further development of the infrastructure which is necessary to support the vision of personalised medicine."

Ali Syed
CTO at DNGC

Facts about the supercomputer

- The supercomputer is environmentally friendly. 70% of the computer's servers are cooled with water at 40 degrees Celsius, and the heat generated is used to heat the surrounding buildings.
- The supercomputer has approx. 17,000 CPU cores.
- The supercomputer's performance is approx. 1,300 teraflops.
- The supercomputer is based on "security by design".
- The supercomputer takes up the space of two 18.5 metre containers.
- The supercomputer is specifically designed for Life Science purposes and can handle large amounts of data safely, flexibly and accurately.

Long-term benefits of using the services and tools, provided by the National HPC Center:

- Use of the common national infrastructure, including standardisation of data, will facilitate and enable sharing of national and international information and knowledge, e.g. in relation to the national Vision for the Better Use of Healthcare Data, as well as to the European 1+ Million Genomes Project, Genomic Data Infrastructure Project and European Health Data Space.
- Use of the national interpretation tools will enable the build-up of variant- and frequency databases, which in turn may lead to an increase in interpretation – and diagnostic speed.
- The physical collection of genome data in one place, i.e. in the National Genome Database, will improve the conditions for combining genome data with other types of data.
- The use of machine learning and artificial intelligence requires large quantities of data and computing power, thereby underlining the need for common solutions.
- It is expected that a national infrastructure will lead to better use of resources and capacity, and thus reduce costs and the environmental impact compared to several, decentralised infrastructure solutions.

With more than 23,000 genomes at the end of 2023, the National Genome Database already constitutes a significant research resource that can contribute to the further development of personalised medicine in Denmark and beyond.

Short-term benefits of using the services and tools provided by the National HPC Center:

- Equal access to computing power, data processing tools, interpretation tools and secure storage of data across regions.
- National licences that may be used by an unlimited number of users.
- The mandatory general-purpose reporting of genome data to the National Genome Database enables regions to delete local copies of genome data, which is also required by the data minimisation principle (GDPR).
- Supports the national standardisation of data, data interpretation and data storage.

Security is part of our DNA

The approach at the Danish National Genome Center (DNGC) is to have risk and crisis management anchored in top management and supported by key roles, technical controls, defined processes and documentation. The security system is continually improved and tested through internal and external audits carried out by auditors and accredited institutions in connection with e.g. ISAE3000 declaration and DNGC's ISO 27001 and ISO 27701 certifications.

In 2023, DNGC updated its data protection impact assessment (DPIA) to include data access for clinicians and researchers. The DPIA was sent to the Data Supervising Authority and is expected with their feedback in March 2024. DNGC also prepared the management system to be audited against the new ISO 27001:2022 standard for the periodic audit 2024.

Jacob Drasbeck is head of compliance and security and responsible for cyber-, information security and data protection. Jacob Drasbeck and his team engages with peers within the ministry and the healthcare sector to develop new best practices for cyber-, information security and data protection.

"It is part of our mission to ensure best possible information security and personal data protection. Information security and privacy has been an integral part of the Danish National Genome Center from the start."

Jacob Drasbeck
CISO, DNGC

Research projects on the supercomputer

Researchers can utilise the supercomputer for conducting research in the field of personalised medicine. Through a customised cloud, researchers can leverage the supercomputer's storage capacity and computing power. The supercomputer can accommodate large amounts of data and perform advanced analyses, which researchers can use to gain a better understanding of diseases and develop new treatment methods.

So far, researchers have been able to use their own data from whole genome sequencing (WGS), and in the first half of 2024, researchers working within the field of personalised medicine will be able to apply for access to the National Genome Database and utilise WGS data in their research.

In 2023, another three pilot projects PREDICT, ICOPE/STAGING and BIOSKIN transitioned to a permanent agreement with the Danish National Genome Center's (DNGC) cloud. In the same year, an additional three research projects gained access to DNGC's supercomputer, bringing the total number of research projects utilising the supercomputer for personalised medicine research to eight.

For more information about the research projects, go to 'Research and international collaboration' at eng.ngc.dk

On the Danish National Genome Center's supercomputer at the end of 2023

8

Research projects

8 research projects utilise the Danish National Genome Center's supercomputer to conduct research in personalised medicine.

177

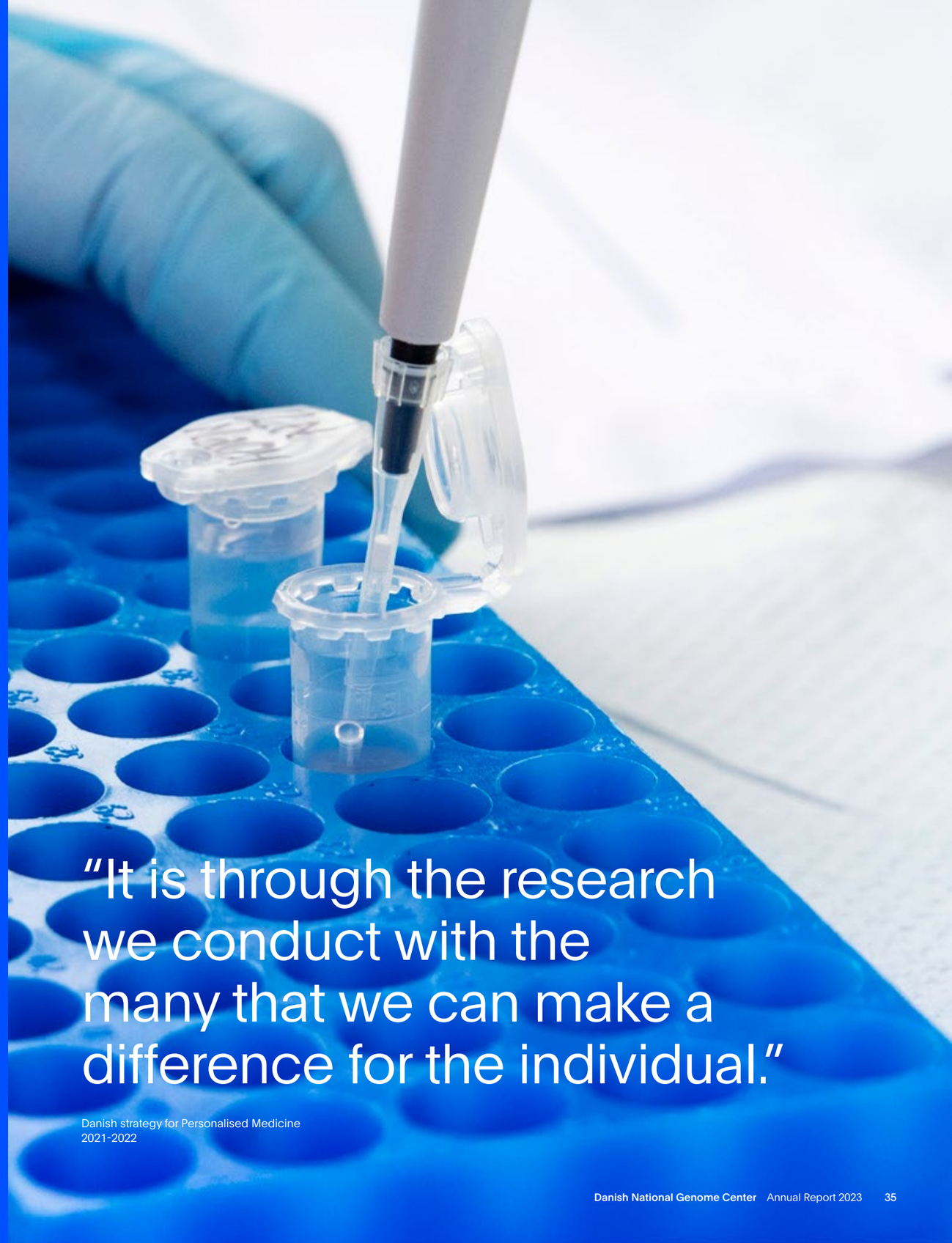
Research users

177 out of 557 users on the supercomputer are researchers.

1,008

Genomes generated from research

Out of the total 23,897 genomes stored in the National Genome Database, 1,008 have been generated from research.



"It is through the research we conduct with the many that we can make a difference for the individual."

Danish strategy for Personalised Medicine 2021-2022

TRANSLATE
A research collaboration

TORBEN HANSEN
PRINCIPAL INVESTIGATOR
MD, PHD, EXPERT IN DIABETES AND GENETICS, PROFESSOR AT NOVO NORDISK FOUNDATION CENTER FOR BASIC METABOLIC RESEARCH, UNIVERSITY OF COPENHAGEN.

TRANSLATE seeks to improve the diagnosis and treatment of non-autoimmune diabetes by implementing a comprehensive workflow that also addresses the challenges involved in gene-based personalised medicine. The vision is to develop pipelines that obviate the need to manually handle genetic information in diabetes and subsequently other diseases. The purpose is, therefore, to introduce cost-effective sequencing technology, which enables the use of Whole Genome Sequencing (WGS) as a standard diagnostic method and will capitalise on already generated Danish reference data on selected diabetes genes. TRANSLATE processes WGS data from diabetes patients in collaboration with the Danish National Genome Center (DNGC) using an accelerated nf-core/Sarek nextflow workflow. The workflow is designed to detect variants on WGS data. DNGC is actively participating in the development of key elements of Sarek. This collaborative effort underscores the shared vision to enhance the utility and efficiency of tools, ensuring they are robust, user-friendly and accessible.

802 clinical responses have been sent to patients, of which 25% where positive, and 1,008 genomes are generated from the TRANSLATE project.

DALYCA
Danish Lymphoprolierative Cancer reaserch center

The purpose of the research project is to improve and personalise the treatment of patients with lymphoproliferative cancers. The researchers combine clinical data, disease characteristics, molecular and genetic data to find the optimal treatment. They have gathered electronic health records from over 60,000 patients, including more than 3,000 different routine data points covering biochemistry, microbiology, pathology, prescription medication, in-hospital medication, antineoplastic treatment, vital parameters and free-text notes. They use Danish National Genome Center's supercomputer to develop datadriven algorithms that can assist doctors in making treatment decisions based on the data.

CARSTEN UTOFT NIEMANN
PRINCIPAL INVESTIGATOR
CONSULTANT, CLINICAL LECTURER

BIOSKIN
The Copenhagen Translational Skin Immunology Biobank and Research Program

The research focuses on inflammatory skin diseases such as psoriasis, atopic dermatitis and contact eczema. The purpose is to gather knowledge about how skin diseases develop over time so that, in the future, the patients can receive more individualised treatment. The researchers collect clinical data and skin and blood samples from 3,000 patients over a period of a minimum of five years. They use Danish National Genome Center's supercomputer to store data, analyse patients and explore connections between clinical data and molecular signatures, such as genetics.

LONE SKOV
PRINCIPAL INVESTIGATOR
PROFESSOR, CHIEF PHYSICIAN

Patient trajectories from heterogeneous data types across healthcare and other domains

The purpose of the research is to estimate how a patient's disease trajectory will develop and use that knowledge to possibly treat patients differently. Genetics, previous medical history, medication and other exposures influence which diseases we develop later in life and how fast they progress. The researchers use healthcare data from registries and electronic patient records, socioeconomic data and genetics to feed machine learning algorithms that can predict new events. Using the Danish National Genome Center's supercomputer, they group patients, identify patterns and define various significant trajectories that can contribute to predicting and possibly prevent future diseases of individual patients. A focus area is patients with diabetes, where the researchers investigate how certain mental disorders and cancer co-occur in connection with diabetes. The approach addresses in a population-wide manner, complex patients with many multimorbidities, which, due to the general ageing of the population, is now a significant societal problem.

SØREN BRUNAK
PRINCIPAL INVESTIGATOR
RESEARCH DIRECTOR, PROFESSOR

BKFMS
The Biology behind New Clinical Phenotypes of Multiple Sclerosis

The purpose of the research is to develop tailored treatments for patients with multiple sclerosis. Using artificial intelligence, researchers identify how patients experience different disease trajectories. The researchers utilise clinical and demographic data from the Danish Multiple Sclerosis Registry, which has been collecting data from all Danish multiple sclerosis patients since 1956. This data is combined with genetic information to enhance precision. By employing the computational power of the Danish National Genome Center's supercomputer, researchers analyse the data in statistical models that account for relevant clinical information and lifestyle factors.

MELINDA MAGYARI
PRINCIPAL INVESTIGATOR
CHIEF PHYSICIAN

PREDICT
Center for Molecular Prediction of Inflammatory Bowel Disease

Center for Molecular Prediction of Inflammatory Bowel Disease (PREDICT) is a national research centre where researchers develop strategies for personalised medicine for patients with inflammatory bowel diseases.

Inflammatory bowel diseases (IBD), including Crohn's disease and ulcerative colitis, are serious chronic conditions. The causes of these diseases are only partially understood, and they can manifest very differently in different individuals. Some experience mild symptoms, while others face severe inflammation, repeated surgeries and the risk of other health problems such as liver and bile issues and even cancer.

In PREDICT, led by Professor and Centre Director Tine Jess as the principal investigator, Danish National Genome Center's (DNGC) infrastructure is utilised for studies involving extensive datasets related to inflammatory bowel diseases.

Researchers use DNGC's supercomputer to store and analyse extensive datasets, including genetic data, obtained by linking biological information from samples from Denmark's National Biobank and regional biobanks with data from Danish health registries as well as nationally and regionally collected cohorts.

"It is essential that the country's most important initiatives, such as the development and especially the implementation of personalised medicine, are centralised. Despite Denmark being a relatively small country, we tend to work in a disorganised manner in many silos, which is not beneficial for progress in any area." - Tine Jess

By comparing data with information on how patients' diseases have evolved over time, PREDICT hopes to discover new insights into what causes IBD, why it progresses differently in different individuals and why people respond differently to treatment.

"In Denmark alone, approximately 50,000 young people have been diagnosed with chronic intestinal inflammation, surpassing the number of people living with type 1 diabetes. Unfortunately, there is significant taboo surrounding chronic bowel diseases, and awareness of these conditions is limited. Inflammatory bowel diseases often affect young individuals, and there is still no cure for these diseases, which can be associated with pain, diarrhea, weight loss, bleeding and the need for surgical interventions."

Tine Jess

TINE JESS
PRINCIPAL INVESTIGATOR
CENTER DIRECTOR, PROFESSOR, MD, DMSC, PREDICT, AALBORG UNIVERSITY, COPENHAGEN

NGS KMA RegH
The research project NGS for Infection and Outbreak Surveillance as well as Microbiome

The departments of clinical microbiology at Amager and Hvidovre Hospital and Herlev and Gentofte Hospital perform whole genome sequencing on pathogenic microorganisms. These data are used in the daily clinical work for infection control and outbreak surveillance. The data are also utilised in several research projects to obtain insight into e.g. antibiotic resistance of microorganisms and to develop new microbiome-based medicine. Researchers use the Danish National Genome Center's (DNGC) supercomputer to store data and conduct complex analyses of bacterial genomic and microbiome data.

"The Danish National Genome Center's supercomputer is enabling us to run complex analyses on both bacterial genomic and microbiome data. Analysis of omics data requires large computational resources, which DNGC's supercomputer provides us with. In addition, data security is a priority for us, and by using the supercomputer, our data is always stored in a secure way and backed-up to prevent unintentional loss of data." — Mette Damkjær Bartles

METTE DAMKJÆR BARTELS
PRINCIPAL INVESTIGATOR
CHIEF PHYSICIAN

ICOPE/STAGING
Interregional Childhood Oncology Precision medicine Exploration and Sequencing Tumor and Germline DNA Implications for National Guidelines

The purpose of the research is to improve the treatment of children with cancer and reduce the number of deaths. Over the years, researchers have collected data from 1,200 children with cancer, including family tree information and details about late complications. Using the Danish National Genome Center's (DNGC) supercomputer, researchers are examining the patients' genetics and DNA changes that may increase the risk of developing cancer.

"The goal is that, in a few years, we will know much more than today about why children get cancer. This knowledge will enable us to diagnose the condition earlier and determine the most effective treatment. We envision that each child will be treated differently due to various genetic predispositions or mutations in cancer cells. This understanding will help us identify the most suitable medication for each patient." — Kjeld Schmiegelow

KJELD SCHMIEGELOW
PRINCIPAL INVESTIGATOR
PROFESSOR IN PAEDIATRICS

GATE
Genetic Causes of Epilepsy

The purpose of the research is to provide genetic counselling and develop personalised treatment approaches for epilepsy, ultimately aiming to tailor patients' epilepsy medication to their genetic profile. The researchers achieve this by examining the genetic material in patients with presumed genetically based epilepsy and their families using the computational capacity of the Danish National Genome Center's supercomputer to perform advanced statistical analyses on sequence data collected through wholegenome, exome and nanopore sequencing.

RIKKE STEENSBJERRE MØLLER
PRINCIPAL INVESTIGATOR
PROFESSOR

The potential of Artificial Intelligence and Machine Learning

How artificial intelligence is used on the Danish National Genome Center's supercomputer

We have already seen the early steps in using Artificial Intelligence (AI) and Machine Learning (ML) in the healthcare sector for patient treatment. AI has proved to be effective in analysing medical images such as X-rays, MRIs and CT scans. It can assist in faster and more accurate disease diagnosis and identification of abnormal conditions. AI and ML have also created new opportunities for healthcare professionals who can use tools for clinical data-driven decision support, providing them with data to make informed decisions regarding individual patient treatment.

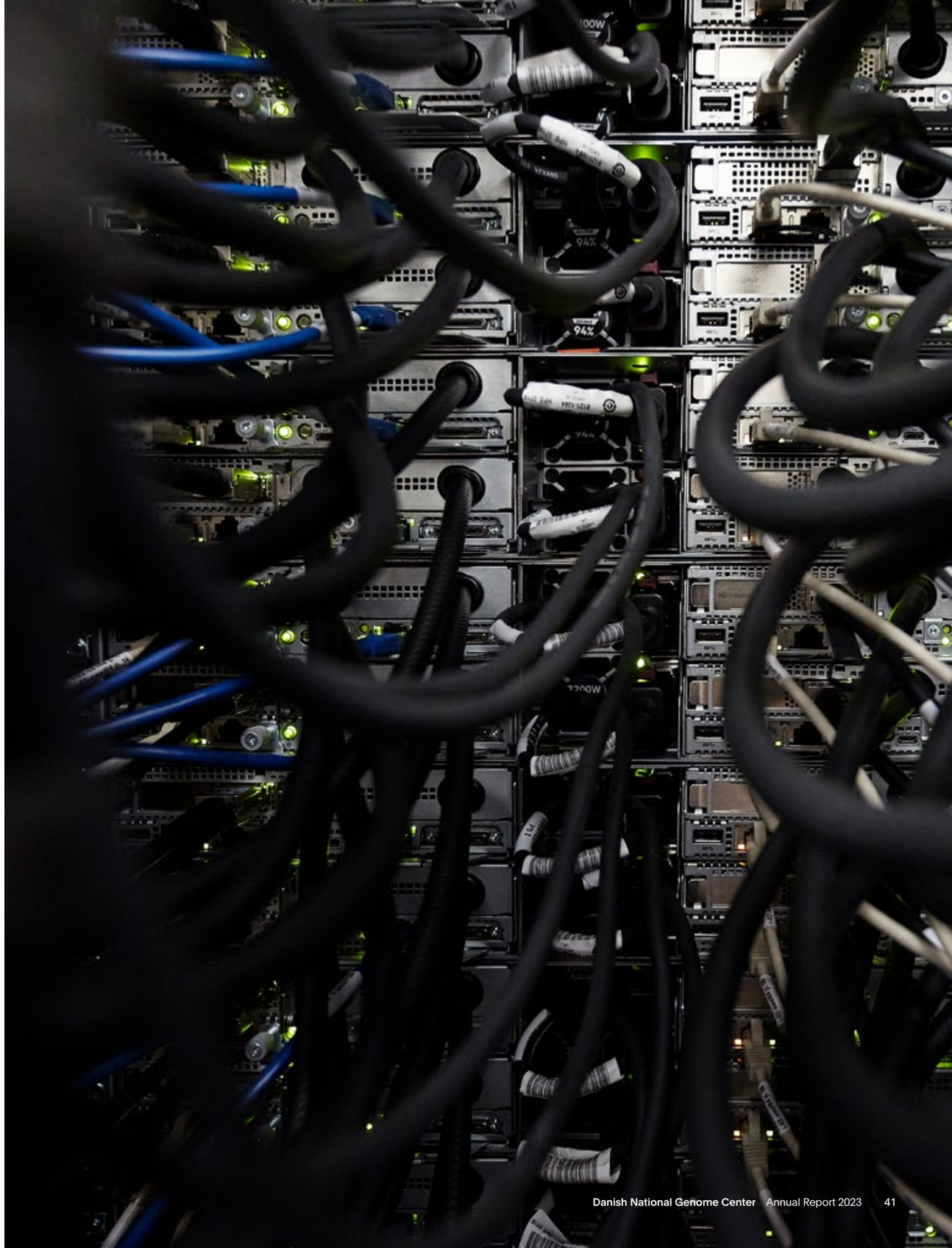
AI and ML have the potential to revolutionise diagnostics and treatment, making our healthcare system truly data-driven. There are already several research projects where researchers use AI and ML on various data sources to find patterns in diseases and treatments. The use of AI and ML enables the complex analysis of large and heterogeneous datasets. AI allows for the identification of complex patterns, relationships and trends in large and heterogeneous datasets much faster and more accurately than traditional methods thus accelerating the generation of new insights and groundbreaking research results.

"An overarching task within health data science is to integrate different data modalities and to take advantage of their complementarities – often in projects that handle millions of patient records. The data types include diagnoses, procedures, medication, laboratory values, results from physical examinations by medical devices, clinical narratives, image and sound files, wearable data, in addition to basic genetic data and sometimes more deep omics data. Machine learning algorithms are the preferred tool that is trained to differentiate between different outcomes and temporal events or, alternatively, identify subgroups in an unsupervised manner.

At the Danish National Genome Center (DNGC), we use graphics processing unit resources to construct predictors of new cardiac events, time to diagnosis (e.g. pancreatic cancer) or prediction of complication trajectories rather than one specific outcome. We make predictors using DNGC's security infrastructure that can be implemented in electronic patient record systems, for example the Health Data Platform in Eastern Denmark. We have a specific focus on polypharmacy where patients are receiving many drugs simultaneously. It is an area where DNGC's genomic data, along with other health data over time, can be used in pharmacogenomic screenings that can be fed back to the clinic and guide medication selection and tweaking of dosages."
— Søren Brunak

The implementation of AI and ML in healthcare improves the accuracy and efficiency of healthcare, resulting in better outcomes for patients and a more sustainable healthcare sector. To reach the potential, it is crucial to ensure high data security, transparency and that technological development aligns with healthcare standards and regulations so that citizens and patients can trust that their health data is used safely and responsibly. It is also essential for researchers and healthcare professionals to have a seamless and easy access to data, enabling advanced data analyses across various data sources. This requires sufficient storage and computing capacity to facilitate advanced data analyses and the integration of large and diverse datasets.

SØREN BRUNAK
PRINCIPAL INVESTIGATOR
RESEARCH DIRECTOR, PROFESSOR
RESEARCH PROJECT:
PATIENT TRAJECTORIES



Strategic partners on the supercomputer

In 2023, the Danish National Genome Center (DNGC) has taken important steps towards a future where health data and relevant socio-economic data can be used better across infrastructures and borders. DNGC has strengthened collaboration with strategic partners nationally and engaged in international discussions on federated infrastructures. Currently, DNGC offers storage of health data relevant to personalised medicine for strategic partners and develops and tests solutions for providing available capacity in the infrastructure to research services related to personalised medicine in other Danish agencies.

STATENS SERUM INSTITUT

Statens Serum Institute, COVID-19 detection, modelling, and research for the benefit of newborns
Statens Serum Institute (SSI) performs a wide range of model calculations used in the authorities' management of, among other things, the monitoring of infection spread. For instance, SSI utilised a cloud on Danish National Genome Center's (DNGC) infrastructure for monitoring COVID-19. SSI sequenced and analysed samples that tested positive for COVID-19 for the purpose of mapping virus variants and contact tracing. Furthermore, DNGC's infrastructure is also utilised by the SSI-based research group Metabolomics, which develops population-based mass spectrometric metabolomics methods used for predictive, personalised and preventive diagnostics of newborns.

STATISTICS DENMARK

Statistics Denmark, Research at the Danish National Genome Center's supercomputer in combination
Researchers using data from Statistics Denmark (SD) for research related to personalised medicine, and whose projects have a significant societal impact, are given the opportunity to use Danish National Genome Center's supercomputer with data from SD in combination with their own data to support their research.

Lægemiddelstyrelsen
Danish Medicines Agency

Danish Medicines Agency, Advancing new medicines at the Data Analytics Centre
The Data Analytics Centre (DAC) is the Danish Medicines Agency's data analysis centre. The experts work on developing new drugs, including medications for patients with rare diseases. DAC translates information and data about medicines and medical devices into knowledge that can benefit citizens, collaborating with various stakeholders, including Danish National Genome Center's. DAC utilises DNGC's supercomputer for analysing aspects such as drug side effects and identifying relevant risk factors for different patient groups.

SUNDHEDSDATA-STYRELSEN

The Danish Health Data Authority, The Health Data Platform
Danish National Genome Center's (DNGC) has, since June 2022, hosted the Health Data Platform on behalf of the Danish Health Data Authority (DHDA). The platform ensures visibility and transparency of healthcare outcomes by providing health data on quality, activity and finances to citizens, healthcare decision-makers and personnel. In 2023, DNGC initiated a proof-of-concept development project with the objective to allow users within the DHDA Research Service to utilise DNGC's supercomputer capacity to support their work in personalised medicine with data from the relevant regional registers.

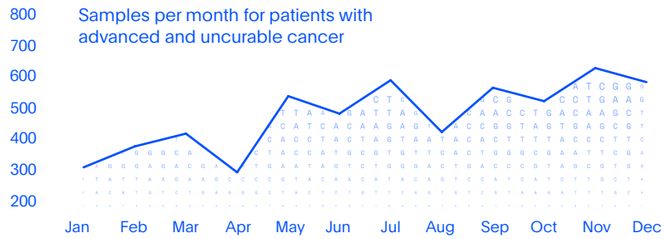
CASE

INFO

NAME:	TONNY BENDIX BRANTLOV
ILLNESS:	CANCER

"In 20 years, at least 47,000 Danes will be affected by cancer each year. This represents a 34% increase from today. At the same time, 70% more people will be living with the disease."

Ulrik Lassen



CASE REPORT FROM WHOLE GENOME SEQUENCING IN DENMARK

Cancer patient receives targeted treatment

Tonny Bendix Brantlov was 72 years old when he was diagnosed with cancer. He is admitted to Aarhus University Hospital and began treatment with chemotherapy and immunotherapy. When the treatment ceased to be effective and no other treatment options were available, Tonny Brantlov is offered a whole genome sequencing (WGS) at the phase 1 unit at Rigshospitalet.

The genetic examination enabled the doctors to provide Tonny Brantlov with medication that targeted the specific cancer gene.

Tonny Brantlov was not cured, but the targeted treatment reduced his cancer. He died in March 2023 at the age of 76. Tonny was on targeted therapy for more than a year and a half with good quality of life, which would not have been possible without genetic analysis.

The whole genome sequencing may have been carried out in a regional setting

"In 20 years, at least 47,000 Danes will be affected by cancer each year. This represents a 34% increase from today. At the same time, 70% more people will be living with the disease. In order for the healthcare system to handle this burden and the challenges posed by other major disease groups, resources need to be utilised more efficiently. If we don't do that, we will be overwhelmed by patients and experience an overloaded system. We need to become better at tailoring treatment to the individual so that we do not provide unnecessary or ineffective treatment.

Personalised medicine based on genetic analyses is now a crucial part of cancer treatment in Denmark, where most cancer tumours are routinely examined for selected genes. Much of the new cancer medication is targeted at specific genetic changes.

The infrastructure established at the Danish National Genome Center has had a significant impact on cancer patients. With whole genome sequencing (WGS), we can provide patients with the best possible treatment, but we can also gain insights into why some treatments are effective while others are not, or why some experience side effects while others do not. I believe that, within the next 5 years, WGS of patients will become the standard in the field of cancer." — Ulrik Lassen

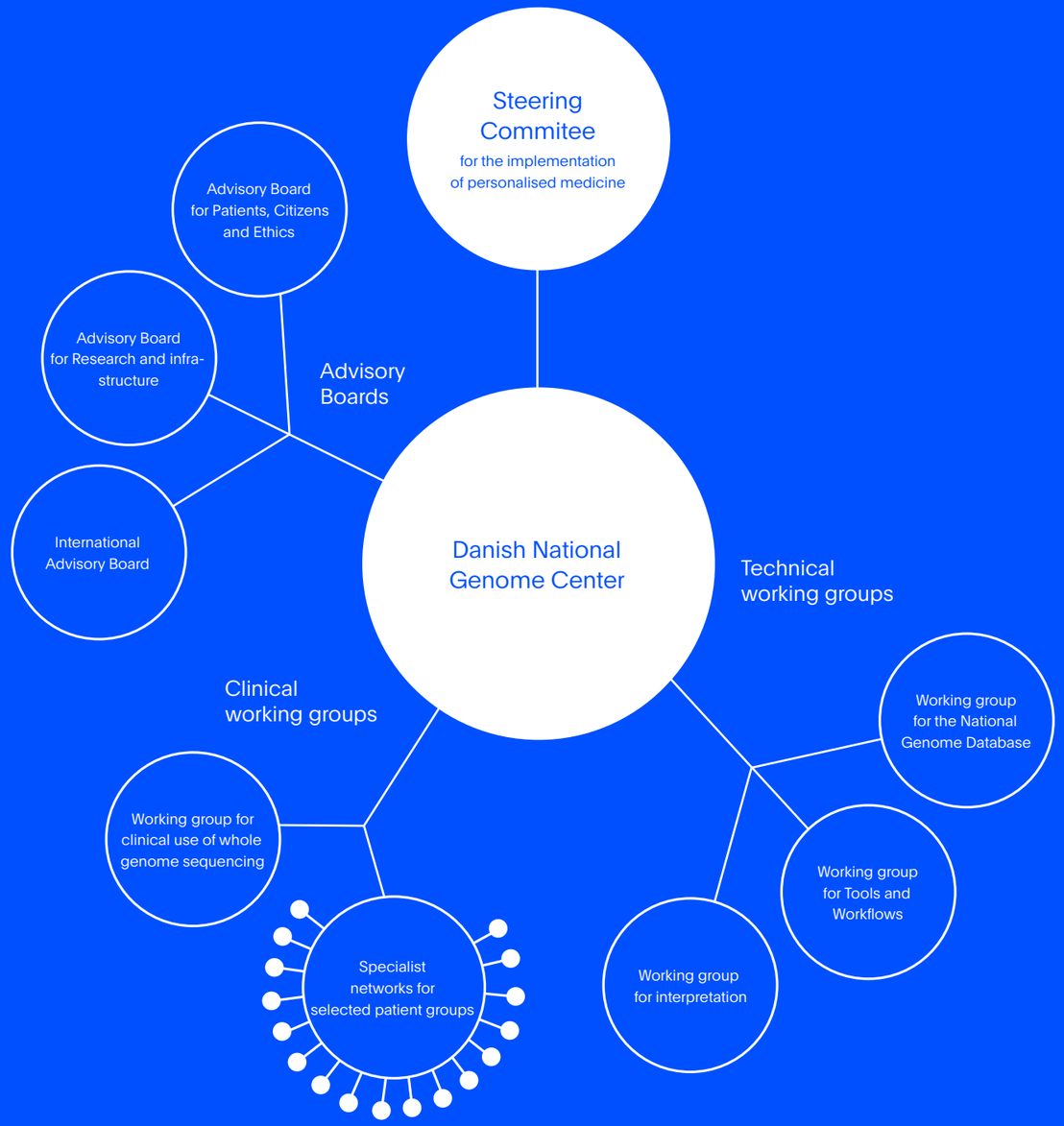
ULRIK LASSEN

VICE CHAIRMAN FOR NATIONAL SPECIALIST NETWORK FOR ADVANCED AND UNCURABLE CANCER

Professor of Clinical Oncology and Personalised Medicine, Chief Physician, Department of Cancer Treatment, Center for Cancer and Organ Diseases, Rigshospitalet, and University of Copenhagen

Collaborations

- National collaboration
- International collaboration



National collaboration

The Danish National Genome Center (DNGC) facilitates the national collaboration on personalised medicine in Denmark. Accordingly, DNGC drives and supports an extensive governance structure, including a steering committee, three advisory boards, four working groups and 17 specialist networks.

See eng.ngc.dk for information on members in each of the 25 national collaboration forums.

DNGC hosts an annual national conference on personalised medicine, and it presents at national and international meetings and conferences, both as participants and as invited speakers. Moreover, DNGC is engaged in relevant national forums concerned with healthcare data and infrastructure, such as the National partnership for health data.

DNGC works actively with the Ministry of Interior and Health regarding the development of personalised medicine, e.g. advising on infrastructure and new technologies, international collaboration and drafting proposals for improving legislative frameworks.

1 Steering committee

The Steering committee for the implementation of personalised medicine ensures a joint public responsibility for the implementation and use of the national infrastructure for personalised medicine. Central tasks include the prioritisation of resources and patient groups, following the implementation of the chosen patient groups and ensuring coordination with other relevant data infrastructures.

DORTE BECH VIZARD
CHAIRMAN OF THE STEERING COMMITTEE
Deputy Permanent Secretary, Ministry of the Interior and Health

KURT ESPERSEN
VICE CHAIRMAN OF THE STEERING COMMITTEE
Chief Operating Officer, Region of Southern Denmark

BETTINA LUNDGREN
VICE CHAIRMAN OF THE STEERING COMMITTEE
CEO, Danish National Genome Center

3 Advisory boards

ADVISORY BOARD
International

The international advisory board's task is to advise the Danish National Genome Center (DNGC) and to be a critical collaborative partner. It provides guidance on strategic issues and the future of DNGC, offering insights into international trends in personalised medicine and genomics. The board also supports assessments of reporting, implementation and development opportunities. It advises on technological infrastructure and facilitates interaction with clinics, patients and research. The board shares experiences from national and international initiatives with DNGC.

ADVISORY BOARD
Research and infrastructure

The Advisory board for Research and Infrastructure advises on relevant trends, experiences and knowledge within research and infrastructure related to personalised medicine. The board consists of 10 members and a representative from the Steering committee for the implementation of personalised medicine. They have expertise in various areas relevant to research and infrastructure, representing Denmark broadly.

ADVISORY BOARD
Patients, citizens and ethics

The Advisory Board for Patients, Citizen and Ethics advises on patient and citizen involvement, communication and ethical considerations in personalised medicine development. With 9 members and a representative from Danish Patients, the board includes patient representatives and experts in personalised medicine, ethics, patient involvement, clinical genetics, oncology and social science, broadly representing Denmark.

International Advisory Board

TIM HUBBARD

CHAIRMAN OF THE INTERNATIONAL ADVISORY BOARD

Professor of Bioinformatics at King's College London; Senior Adviser at Genomics England; Associate Director at Health Data Research UK and the incoming Director of ELIXIR. He is also Head of Genome Analysis at Genomics England

"The constant development within personalised medicine has led to the global development of targeted therapies, especially in areas such as cancer and rare diseases, improving patients' prospects for a life with more healthy years. The key to better interpretation of the individual genome lies in effective information exchange across national borders. It is through this information sharing as well as the exchange of expertise and experience that we can create and enhance treatments for individuals. This need not conflict with robust privacy protection of an individual's genome or associated health data as the use of Trusted Research Environments and federated analytics can enable summary information to be extracted and shared without distribution of individual level data. As the chairman of the international advisory board, it is my conviction that we should take advantage of these approaches to mutual information exchange to advance the development of personalised medicine both clinically and in research contexts."

RICHARD ROSENQUIST

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Director of Genomic Medicine Sweden, Professor of Clinical Genetics Department of Molecular Medicine and Surgery, Karolinska Institutet and Senior Physician in Clinical Genetics at Karolinska University Hospital

RUBEN KOK

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Board member and Chief Strategic Alliances, Health-RI

VALTTERI WIRTA

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Director, Clinical Genomics facility, SciLifeLab at Karolinska Institutet and KTH Royal Institute of Technology

HEIDI L. REHM

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Co-Director of the Program in Medical and Population Genetics, Broad Institute of MIT and Harvard and Director of the Genomic Medicine Unit in the Center for Genomic Medicine, Massachusetts General Hospital

KYM BOYCOTT

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Medical Geneticist, Children's Hospital of Eastern Ontario (CHEO), Senior Scientist, CHEO Research Institute and Professor of Paediatrics, University of Ottawa

DAG UNDLIEN

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Professor; MD, PhD, head of the Department of Medical Genetics

AARNO PALOTIE

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Faculty member, Center for Human Genome Research, Massachusetts General Hospital in Boston, associate member, Broad Institute of MIT and Harvard and research director of the Human Genomics Program, Institute for Molecular Medicine Finland

RUSS B. ALTMAN

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Professor of Bioengineering, Genetics, Medicine, Biomedical Data Science, and (by courtesy) of Computer Science, and Senior Fellow, Stanford Institute for Human-Centered Artificial Intelligence

JEAN-FRANÇOIS DELEUZE

MEMBER OF THE INTERNATIONAL ADVISORY BOARD

Director of the Centre National de Recherche en Génomique Humaine (CNRGH-DRF-CEA). Scientific Director of the Fondation Jean Dausset-CEPH. Director of the Centre de Référence, d'Innovation et d'Expertise (CReflX) of the French genomic medicine plan (PFMG2025)

Advisory Board for Research and Infrastructure

LONE KJELD PETERSEN

VICE CHAIRMAN OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Research Leader, Professor, Chief Physician, MD, Department of Gynaecology and Obstetrics, Odense University Hospital and the Clinical Institute, University of Southern Denmark.

"

Research and development in personalised medicine, including genomics, is an area in constant evolution. There are significant developments both in Denmark and internationally.

The advisory board advises the Danish National Genome Center on relevant trends, experiences, knowledge, and needs within research and infrastructure related to personalised medicine.

This ensures that the latest knowledge in the field is incorporated and addressed in the development of the national infrastructure and services for the Danish research landscape."

SØREN BRUNAK

CHAIRMAN OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Professor of Disease Systems Biology, University of Copenhagen, Bioinformatics Consultant

ISMAIL GOGENUR

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Professor and Consultant, Center for Surgical Science, Department of Surgery, Zealand University Hospital and University of Copenhagen

THOMAS WERGE

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Director, Institute of Biological Psychiatry, Copenhagen University Hospital and professor, department of Clinical Medicine, University of Copenhagen

MARTIN BØGSTED

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Professor in Bioinformatics and Statistics, Head of Center for Clinical Data Science (CLINDA) and Partner in Center for Molecular Prediction of Inflammatory Bowel Disease (PREDICT), Aalborg University

ANDERS D. BØRGLUM

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

MD, PhD, Professor, Center Director, Department of Biomedicine, iPSYCH, Lundbeck Foundation Initiative for Integrative Psychiatric Research iSEQ, Center for Integrative Sequencing, Center for Genomics and Personalised Medicine

CLAUDIO PICA

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Center Director, University of Southern Denmark eScience and CEO DeIC National HPC Center, University of Southern Denmark

KAREN DYBKÆR SØRENSEN

MEMBER OF THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Professor, Department of Clinical Medicine, Aalborg University and Department of Haematology, Aalborg University Hospital

OLE SKØTT

REPRESENTATIVE OF THE STEERING COMMITTEE IN THE ADVISORY BOARD FOR RESEARCH AND INFRASTRUCTURE

Professor and Dean, University of Southern Denmark

Advisory Board for Patients, Citizens and Ethics

KIRSTEN KYVIK

CHAIRMAN OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Head of Department, Department of Clinical Research, University of Southern Denmark, Professor, medical doctor, PhD., MPM and Committee Membership at Danish professional committees.

"

The development of personalised medicine relies on the information provided by Danish patients and citizens for treatment and research.

Transparency and dialogue with the population are, therefore, crucial. Patients and the public should be involved, and the effort must be based on a solid ethical, legal and data security foundation to ensure a balanced development of personalised medicine in Denmark.

This is why the Advisory Board for Patients, Citizens and ethics and its collaboration with the staff of the Danish National Genome Center is so important!"

JAN RISHAVE

VICE CHAIRMAN AND PATIENT REPRESENTATIVE IN THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Chairman, Kidney Association's Donor Committee and Former Chairman, Kidney Association

ANITA KRUSE

MEMBER AND PATIENT REPRESENTATIVE IN THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Cand.psych., authorised clinical psychologist, specialist in psychotherapy and health psychology, member of the Board of Representatives, Muscular Dystrophy Foundation and Vice Chairman of the Board of the Danish Rehabilitation Centre for Neuromuscular Diseases

CAMILLA NOELLE RATHCKE

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Chairman of the Danish Medical Association, Consultant, PhD, Herlev and Gentofte Hospital, Vice Chairman of the Danish Society for Patient Safety

JACOB GIEHM MIKKELSEN

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Professor, PhD., Department of Biomedicine, HEALTH, Aarhus University, and member of The Danish Council on Ethics

IRENE KIBÆK NIELSEN

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Chief Physician, Department of Clinical Genetics, Aalborg University Hospital

LARS HENRIK JENSEN

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Head of Department, Department of Oncology, University Hospital of Southern Denmark, Lillebaelt Hospital, Vejle, Associate professor, University of Southern Denmark

METTE NORDAHL SVENDSEN

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

Professor, Centre for Medical Science and Technology Studies, Department of Public Health, The University of Copenhagen

MORTEN FREIL

MEMBER OF THE ADVISORY BOARD FOR PATIENTS, CITIZENS, AND ETHICS

CEO, Danish Patients, Cand.oecon, Health economics Sociology

18 Clinical working groups

Working group for clinical use of whole genome sequencing
The Working Group for the Clinical Use of Whole Genome Sequencing has been established in collaboration with the regions and the Organization of Danish Medical Societies (LVS). The Working Group ensures a coordinated effort for the clinical development of whole genome sequencing (WGS) in the healthcare system. Comprising 13 members across Denmark, the group contributes to a national overview of the clinical need for WGS, aiming to improve patient diagnosis and treatment. It serves in an advisory capacity, providing professional input based on expert knowledge, clinical practice and research insights to inform decision-making.

Specialist networks for selected patient groups
For each patient group, a network of specialists in the field has been established, appointed from, among others, the five regions and Organization of Danish Medical Societies (LVS). The national specialist networks are intended to provide healthcare expertise and advice regarding the specific patient group to the Danish National Genome Center. The specialist networks have contributed by developing professional recommendations describing clinical criteria for the patients that would benefit the most from access to whole genome sequencing (WGS) within each selected. Overall, their role is to contribute to realising the clinical potential for patient access to WGS in the best possible manner. Furthermore, they are also tasked with advising on the clinical impact follow-up of the intervention and generate follow-up research.

3 Technical working groups

The Danish National Genome Center receives guidance from three technical working groups focused on the National Genome Database, interpretation and tools & workflows. The interpretation group, consisting of 10 members and 2 additional experts, advises on interpreting whole genome sequencing and aligning the national infrastructure with clinical needs. The National Genome Database group, with 12 members, advises on standardization and quality assurance of reportable data. The Tools & Workflows group, with 13 members and one alternative, advises on analysis tools for clinical diagnostics and research, emphasising comparison and validation methods. All groups include members from various expertise areas across Denmark.

Clinical and technical working groups

JESPER GYLLENBORG
CHAIRMAN OF THE WORKING GROUP FOR CLINICAL USE OF WHOLE GENOME SEQUENCING
Chief Medical Officer in the Region of Zealand specialist in neurology

"The working group supports the clinical application of whole genome sequencing in healthcare through an evidence-based approach aimed at improving the diagnosis and treatment of patients. The specialists contribute with their expertise and insights from clinical practice and research nationwide. It is crucial for the development of personalised medicine that it occurs through a coordinated national effort."

CLAUS HØJBJERG GRAVHOLT
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR ENDOCRINOLOGICAL PATIENTS
Clinical professor and chief physician, Department of Clinical Medicine, Hormone and Bone Diseases, Molecular Medicine Department, Aarhus University

"The implementation of whole-genome sequencing has increased awareness about genetics and sequencing among professionals. We now have a greater understanding of how genetic conditions manifest and where in the genes to look for them. This has led to more individuals being involved in genetic diagnostics within specialties such as endocrinology. Additionally, it has contributed to increased knowledge sharing and a common genetic language across specialties and professional groups."

ALLAN THOMAS HØJLAND
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR AUDIO GENETICS
Clinical associate professor, Faculty of Health Sciences, Aalborg University and consultant, Clinical Genetics Department, Aalborg University Hospital

KJELD SCHMIEGELOW
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR CANCER IN CHILDREN AND YOUNG PEOPLE
Professor, MD. DrMedSci, Department of Paediatrics and Adolescent Medicine, The Juliane Marie Centre and the Institute for Clinical Medicine, Faculty of Medicine, University of Copenhagen

CHARLOTTE KVIST LAUTRUP
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR CANCER FOR YOUNG ADULTS (18-30 YEARS) AND ADULTS WITH HEREDITARY CANCER
Chief Physician, Department of Clinical Medicine, Clinical Genetics Section and the Department of Clinical Medicine, Molecular Medical Section, as well as Clinical Associate Professor, Department of Clinical Medicine, Clinical Genetics Section, Aarhus University.

OLAV BJØRN PETERSEN
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR FOETAL MEDICINE
Clinical professor in Foetal Medicine, Department of Clinical Medicine, Copenhagen University Hospital, Rigshospitalet and senior consultant, Foetal Medicine Center, Department of Gynaecology, Fertility and Obstetrics, Rigshospitalet

CHRISTINA FAGERBERG
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR RARE DISEASES IN CHILDREN AND ADULTS
Clinical geneticist and associate professor, Odense University Hospital and University of Southern Denmark

HENNING BUNDGAARD
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK HEREDITARY HEART DISEASES
Professor and Chief Physician, Department of Cardiology, Heart Center and University of Copenhagen

EVA LEINØE
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR HEREDITARY HAEMATOLOGICAL DISEASE
Consultant PhD in the Departments of Haematology and Center for Genomic Medicine, Rigshospitalet

THOMAS DALSGAARD SANDAHL
VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR HEREDITARY CHOLESTATIC AND FIBROTIC LIVER DISEASES
Consultant hepatologist, Associate professor, Department of Hepatology and Gastroenterology, Aarhus University Hospital

MARLENE BRICIET LAURITSEN

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR PSYCHIATRY (CHILDREN AND YOUNG PEOPLE)

Clinical Professor, Clinical Institute, Faculty of Health Sciences, Aalborg University and chief physician in child and adolescent psychiatry, Psychiatry, Aalborg University Hospital

ULRIKKE LEI

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR SEVERE HEREDITARY SKIN DISEASES

Chief Physician, Herlev and Gentofte Hospital, Allergy, Dermatology and Venereology

ANNE STIDSHOLT ROUG

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR HAEMATOLOGICAL CANCER

MD. and external associate professor, Department of Clinical Medicine, Haematology, Aarhus University

ULRIK LASSEN

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR ADVANCED AND INCURABLE CANCER

Professor of Clinical Oncology and Personalised Medicine, Chief Physician, Department of Cancer Treatment, Center for Cancer and Organ Diseases, Rigshospitalet and University of Copenhagen

TRINE HYRUP MOGENSEN

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR PATIENTS WITH PRIMARY IMMUNE DEFICIENCY

Professor, Department of Biomedicine and senior physician, Department of Infectious Diseases, Aarhus University Hospital

UFFE BIRK JENSEN

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR NEUROGENETIC PATIENTS

MD, PhD and Clinical Professor and Chair, Consultant, Department of Clinical Genetics, Aarhus University Hospital

BIRGITTE BANG PEDERSEN

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR KIDNEY FAILURE

Chief Physician, Nephrology Department, Aalborg University

LINE KESSEL

VICE CHAIRMAN OF THE NATIONAL SPECIALIST NETWORK FOR OPHTHALMOLOGY

Professor of Paediatric Ophthalmology and Chief Physician, Department of Ophthalmology, Head-Ortho-Center, Rigshospitalet and University of Copenhagen

CHARLES VESTEGHEM

VICE CHAIRMAN OF THE WORKING GROUP FOR THE NATIONAL GENOME DATABASE

Program Manager - Data Infrastructure and AI-Based Decision Support Tools, Group Leader and Assistant Professor in Digital Health, Center for Clinical Data Science, Aalborg University Hospital and Aalborg University

"

Understanding the underlying drivers of diseases is fundamental to be able to better treat patients. This requires having access to always larger quantity of high-quality data. The mission of the working group is to ensure that the Danish National Genome Center can become an essential part of the solution."

KLAUS BRUSGAARD

VICE CHAIRMAN OF THE WORKING GROUP FOR INTERPRETATION

Associate professor, Senior Researcher, Molecular Biologist, PhD, Department of Clinical Genetics, Odense University Hospital, External Professor Near East University, Founder Amplexa Genetics

MARTIN JAKOB LARSEN

VICE CHAIRMAN OF THE WORKING GROUP FOR TOOLS AND WORKFLOWS

Associate professor, Department of Clinical Research, Clinical Genome Center, Faculty of Health Sciences, University of Southern Denmark. PhD, Clinical Laboratory Geneticist, Bioinformatician, Department of Clinical Genetics, Center for Prenatal Genetics, Odense University Hospital

Annual Conference on Personalised Medicine

On 13 September 2023, the Danish National Genome Center (DNGC) hosted the Annual Conference on Personalised Medicine for the third consecutive year.

With more than 300 participants, including our Minister for Interior and Health of Denmark, Sophie Løhde, as well as prominent national and international speakers, the conference was a great success. And there was also great interest from the international audience, with online participation from several countries.

Takeaways:

- A new national strategy for personalised medicine must build on the massive investments that have been made in DNGC and in the area of personalised medicine, from which Denmark has only just begun to reap the benefits.
- A next step in the development of personalised medicine will be to link genome data more broadly to other relevant data, and to develop automated analysis tools so as to ensure maximum benefit for the patients.
- Focus on developing data access that ensures patients' data security and, at the same time, ensures that researchers get better access to health data.
- Citizen involvement and strong public ownership are central, along with increased opportunities for public-private collaboration.

For more information, see Annual conference on Personalised Medicine 2023 at eng.ngc.dk

International collaboration

Many countries around the world share the Danish ambition of implementing personalised medicine in healthcare. The ambition comes in different shapes and with divergent focuses – but each country chooses individual trajectories according to the structure of national healthcare systems, available resources, legal framework, etc. Every country and every initiative build up valuable experiences. Therefore, the Danish National Genome Center (DNGC) is dedicated to collaborate with other countries and genome-initiatives to ensure continuous knowledge-sharing on everything from how to build a genome database to sustainable storage strategies as well as to gain important insights into new tendencies within personalised medicine.

DNGC also actively participates in EU-initiatives because it gives us access to influence the European agenda within personalised medicine and because a strong European collaboration can benefit Danish patients.

"There is no need for reinventing the wheel in Denmark if we can learn from other personalised medicine initiatives or we can co-develop wheels together with other European actors."

Lene Cividanes
Head of Research and International Relations, DNGC

Lene Cividanes represents Denmark in the 1+ Million Genomes Special Group. Lene and her team are deeply involved in a number of activities related to 1+ Million Genomes, such as the 1+ MG coordination group, the development of a genomic data infrastructure, the Genome of Europe initiative and coordination of a European working group on health economics and outcomes research, among others. Lene also represents DNGC in Global Alliance for Genomics and Health (GA4GH), National Forum Initiatives and is responsible for the bilateral collaboration with key genome initiatives in Europe.

The European 1+ Million Genomes Initiative (1+ MG)

Danish National Genome Center (DNGC) represents Denmark in the European 1+ MG initiative. The initiative aims to enable secure access to genomics and the corresponding clinical data across Europe for better research, personalised healthcare and health policy making.

In 2021, the Danish Minister of Health signed the Member States' declaration on stepping up efforts towards creating a European data infrastructure for genomic data and implementing common national rules enabling federated data access. The initiative forms part of the EU's agenda for the Digital Transformation of Health and Care and is aligned with the goals of the European Health Data Space.

The project aims at ensuring that appropriate technical infrastructure is available across the EU, allowing for secure, federated access to genomic data; making sure that ethical and legal implications of genomics are clear and taken into account. Last but not least, ensuring that the general public and policy makers in the participating countries are well informed about genomics in order to ensure its uptake by healthcare systems and integration into personalised healthcare.

Denmark participates in the project because collaboration and knowledge-sharing within genomics has the potential to revolutionise healthcare in many ways. It could lead to the development of more targeted personalised medicines, therapies and interventions. It could also enable better diagnostics, boost prevention and make more efficient use of scarce resources. From cancer to rare diseases and prevention, genomics can greatly improve health conditions of citizens in Denmark and all over the EU.

Genomic data infrastructure project (GDI)

Together with other European countries, DNGC is currently working on the development of a federated genomic data infrastructure for secure access to data across borders in a legal and ethically justifiable way. The GDI is derived from the 1+MG initiative.

The project aims at ensuring the establishment of a secure and sustainable infrastructure where metadata is exhibited on a common European platform, and where data can be accessed and analysed across borders but without leaving the country. The project involves genomic data and clinical data from databases across Europe, focusing mainly on cancer, infectious diseases and rare diseases.

The project is funded by EU and the participating countries. DNGC has set up a national reference group to ensure future integration with the Danish genome landscape. In the long run, the infrastructure can improve conditions for patient treatment as well as research within personalised medicine.

Genome of Europe (GoE)

Together with the Statens Serum Institute DNGC represents Denmark in the GoE project. The project is a multi-country project bringing together European countries to build a high-quality European network of national genomic reference cohorts, representative of the European population.

All countries involved will generate via whole genome sequencing a national genomic reference dataset based on their own national population, all according to jointly established '1+MG-proof' guidelines. Each country's dataset will form a unique national reference collection in its own right.

Collectively, cross-linked via the 1+MG initiative, the national collections will establish a world-class European reference data resource (The Genome of Europe) for research and innovation of healthcare. The collection will benefit national personalised healthcare and prevention strategies.

Formal bilateral collaborations

The Danish National Genome Center has established a formal collaboration and signed a memorandum of understanding (MoU) with three key-initiatives that share the ambition to develop personalised medicine nationally for the benefit of patients. These initiatives have developed and operate infrastructures within advanced genomic medicine to be used in national healthcare systems and research in personalised medicine.

England

Genomics England (GE) is a company owned and funded by the Department of Health & Social Care collaborating with the English healthcare system to provide diagnostics based on whole genome sequencing. In addition, they offer researchers access to data and a range of tools to identify the causes of diseases with the intention of developing new treatments.

"It is truly valuable for both England and Denmark to enter into a partnership. We can share our experiences and our research data, e.g. by providing access to the National Genomics Research Library data. There is also much within clinical implementation in rare diseases, cancer, newborn sequencing, pharmacogenomics and so on that we should be able to share with each other."

Matt Brown
CSO at Genomics England

The MoU was signed on 14 September, 2023, by Bettina Lundgren, CEO at DNGC, and Matt Brown, CSO at GE

The MoU was signed on 29 April, 2022, by Bettina Lundgren, CEO at DNGC, and Richard Rosenquist Brandell, CEO at GMS

Sweden

Genomic Medicine Sweden (GMS) operates the national infrastructure for genomic-based precision medicine in Sweden, striving to ensure equal access to cost-effective genetic analysis with the aim of enhancing diagnostics and personalised treatment.

The collaboration contributes to faster and more successful progress in establishing common approaches to the implementation of personalised medicine within the healthcare system. This includes solutions and models for data processing and sharing, ethical considerations and health economics.

"The Danish National Genome Center equivalent to Genomic Medicine Sweden will be a crucial partner in the development and exchange of experiences and expertise on how we can continue to advance and implement precision medicine for the benefit of our patients and society."

Richard Rosenquist Brandell
CEO Genomic Medicine Sweden.

France

The French National Alliance for Life Sciences and Health (Inserm) is an umbrella organisation in France that leads and implements the French Genomic Medicine Initiative 2025 (PFMG 2025), integrating genome analysis into national patient care.

As both the French and Danish genomic initiatives aim to implement genome analysis in clinical practice, they must address similar challenges.

"The signing of this MoU provides the opportunity to share experiences and build common approaches with our Danish colleagues to swiftly progress in various areas such as clinical outcomes of genome sequencing, health economic evaluation and data sharing."

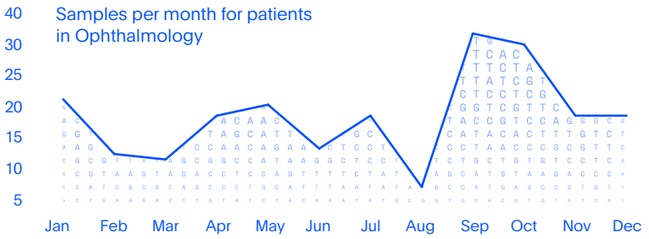
Thomas Lombès
Vice CEO for strategy at Inserm

The MoU was signed on 9 March 2023, by Bettina Lundgren, CEO at DNGC, and Thomas Lombès, Vice CEO for Strategy at Inserm

CASE

INFO

NAME:	ANONYMOUS
ILLNESS:	HEREDITARY RETINAL DISEASE



CASE REPORT FROM WHOLE GENOME SEQUENCING IN DENMARK

It was as if the light was turned on

"It was as if the light was turned on" is how a patient with hereditary retinal disease describes it after receiving gene therapy for the hereditary eye disease Leber's congenital amaurosis (LCA). This highly specialised treatment is carried out at the Department of Ophthalmology at Rigshospitalet.

LCA is caused by an inherited genetic defect where the patient does not produce the protein RPE65, which keeps the light-sensitive cells in the eye functioning. This means that darkness literally slowly descends upon the patient.

Initially, the patient experiences a progressive – and, later on, massive – visual impairment, and total blindness typically occurs when the patient is in their late 20s or early 30s.

The treatment involves gene therapy, classified under Advanced Therapy Medicinal Products (ATMP), where ophthalmologists inject a solution containing a normal copy of the RPE65 gene into the eye. This enables the eye to produce the RPE65 protein on its own, restoring vision for the patients.

To target a genetic treatment, it is necessary to know which gene is affected. Currently, about half of the patients with hereditary retinal diseases receive a genetic diagnosis. Doctors anticipate that whole genome sequencing will result in about 10-20% more patients with hereditary eye diseases receiving a diagnosis.

The whole genome sequencing may have been carried out in a regional setting
The photo is AI-generated

Selected conferences and meetings

The Danish National Genome Center is represented at a wide range of national and international events to share knowledge.

The Festival of Genomics and Biodata 2023.
National Health Service (NHS) East Genomics.
London, 25-26 January, 2023

Summit – A clear direction for health research.
Danish Regions.
Copenhagen, 9 February, 2023

Nordic PMF 2023. Nordic Precision Medicine Forum.
Stockholm, 27-28 April, 2023

2023 Annual conference – ASHG.
American Society of Human Genetics.
Washington, 1-5 May, 2023

National conference on the implementation of personalised medicine in Estonia.
Estonian National Institute for Health Development.
Talin, 25 May, 2023

Folkemøde 2023
Allinge, 15-17June, 2023

Precision Oncology Forum 2023.
Nordic Oncology Forum.
Stockholm, 26-27 June, 2023

Life Sciences. The Era of Personalised Medicine
Stockholm, 26-27 June, 2023

Second GenomDE Symposium 2023 'Of Humans and Molecules: Perspectives of Genomic Medicine'.
Genome DE.
Berlin, 6 July, 2023

Annual conference of Personalised Medicine 2023.
Danish National Genome Center.
Copenhagen, 14 September, 2023

11th Plenary meeting, Global Alliance for Genomics & Health (GAFHG).
San Francisco, 19-22 September, 2023

Nobel Symposium 175.
Precision Medicine Transforms Healthcare:
A New Trajectory for Research and Innovation.
Stockholm, 20-22 September, 2023

Global Alliance for Genomics and Health (GA4GH) National Initiatives Forum 2023.
San Fransisco, 23 September 2023

Nordic conference for rare diseases.
The Swedish National Board of Health and Welfare on behalf of the Nordic Network for Rare Diseases.
Stockholm, 2-3 October, 2023

7th International Congress of the European Society for Pharmacogenomics and Personalised Therapy.
European Society for Pharmacogenomics and Personalised Therapy.
Copenhagen, 25-28 October, 2023

Symposium of the Master's Degree in Personalised Medicine.
Faculty of Health and Medical Sciences, University of Copenhagen.
Copenhagen, 30 October, 2023

Seminar on Health Data.
Danish Industry and The Regions' Clinical Quality Development Programme (RKKP).
Copenhagen, 1 November, 2023

Meeting in the Faculty of Health Sciences' Advisory Board.
University of Copenhagen.
Copenhagen, 15 November, 2023

Round table meeting on the vision for new advanced therapies (ATMP).
The Danish Association of the Pharmaceutical Industry.
Copenhagen, 21 November, 2023

2 days for health 2023. Dagens Medicin.
Copenhagen, 21-22 November, 2023

DSPM annual meeting.
Danish Society for Personalised Medicine.
Copenhagen, 29 November, 2023

Conference on life science strategy for health and growth.
Danish Industry Life Science.
Copenhagen, 30 November, 2023

Expert meeting on Personalised Medicine. Health Committee, the Danish parliament.
Copenhagen, 30 November, 2023

Perspectives

Perspectives

In 2024, the Danish National Genome Center (DNGC) will continue working towards providing a state-of-the-art national infrastructure for personalised medicine.

The main goals for 2024 are:

- Continued expansion of the National Genome Database, with a minimum of 18,000 genomes during 2024, resulting in a total of approximately 42,000 genomes in the National Genome Database at the end of 2024.
- At least 5 research projects have been given access to genome data.
- The long-term governance and financing of the national infrastructure for personalised medicine, including the role of DNGC, has been agreed.
- DNGC has developed a solution that enables the combination of genome data with other external data sources.

More specifically, the Danish National Genome Center (DNGC) will continue to operate and develop the National High Performance Computing Center and provide services to clinicians, researchers and strategic partners. By mid-2024, the financing and operations of the National Whole Genome Sequencing Center will become a regional responsibility, as initially agreed when establishing the national infrastructure for personalised medicine. Together, DNGC and the regions will fulfil the plan for the 17 patient groups and the 60,000 genomes.

DNGC envisions a near future, where an increasing number of patients will be offered whole genome sequencing, and where an increasing number of research projects within personalised medicine will be initiated. As a result, the National Genome Database is expected to grow significantly beyond the initial 60,000 genomes target over the years. The development of further national clinical databases, such as a national variant database and pharmacogenetic databases, will support interpretation and clinical decision-making, and thereby accelerate the clinical impact of personalised genomic medicine in Denmark.

Strategic context and future perspectives

The Danish National Genome Center (DNGC) is a central part of a national eco-system for healthcare data as described in the Danish strategies for personalised medicine, Strategy for life science and Vision for better use of healthcare data. A common goal of the strategies is to improve the access to and use of healthcare data, including the development of a national analysis platform.

Leveraging our expertise in big data and our robust security model, DNGC is actively working on technical solutions that facilitate the integration of genomic data with other relevant data sources. This enables advanced data analysis, including the potential application of AI capabilities, ultimately supporting the strategic ambitions within the area of personalised medicine.

Reporting

- Key Performance Indicators and main goals
- Staff overview
- Financial reporting

Key Performance Indicators and main goals

The number of genomes in the National Genome Database is a significant "impact marker" for measuring the overall progress of Danish National Genome Center (DNGC). The KPIs for 2020, 2021, 2022 and 2023 are listed in Table 1.

In addition to the KPIs, DNGC formulated a number of goals for 2023 in the DNGC 2022 report on activities to the Novo Nordisk Foundation. The status for the 2023 goals can be found in Table 2.

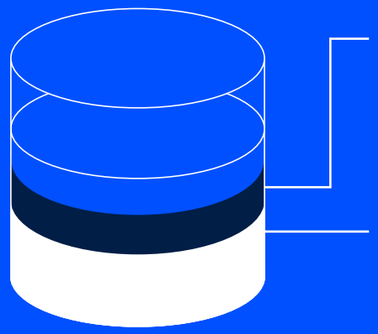
Highlights for 2023 include:

557 ↑100

Users of the national infrastructure

Genomes in the national database

23,897 ↑14,119



5,448

Genomes reported to the Danish National Genome Center and have contributed to patient treatment or research in personalised medicine

18,449

Genomes funded by the Novo Nordisk Foundation have contributed to patient care

Table 1. KPIs for the Danish National Genome Center – December 2023

	2023	2022	2021	2020
Patients				
Number of patient groups included in WGS in DNGC [6]	17	17	1	1
Number of patient groups approved for WGS in DNGC	-	12	5	-
Number of patient groups pending approval for WGS in DNGC	-	0	12	-
National High-Performance Computing				
Number of users of DNGC infrastructure (clinicians and researchers)	557 [7]	457	280	121
Number of DNGC-managed clouds*	65	47	5	5
Number of self-managed clouds*	18	11	7	17
In production externally (strategic partners)	5	4	4	1
Internal pipeline test clouds (development environment)	22	18	1	5
Clouds ready for users	27	57	2	11
Clouds used for testing	2700	817	666	244
Uptime	99.2% [8]	98.7% [9]	99.92%	99.95%
Number of pipelines	13	4	2	1
National Genome Database				
Genomes in the database	23,897	9,778	2,805	748
Genome and RNA samples performed by DNGC	18,449	5,338	1,175	612
General purpose reporting	4,440 [10]	4,440	1,630	136
Genomes reported by researchers	1,008	0	0	0
Tools for interpretation	3	4	3	3
Varseq	X	X	X	X
Alamut Visual	-	X	X	X
HGMD (Human Genome Mutation Database)	X	X	X	X
QCI	X	X	-	-
Research community				
Number of research groups actively using the DNGC research infrastructure	8	7	7	0

* DNGC-managed clouds are managed by DNGC and are used for clinicians, researchers or strategic partners. Self-managed clouds are private clouds used for researchers and strategic partners. Cloud services are paid for by users according to a price model.

[6] The patient group "Rare diseases in children and adults" includes "Rare diseases in children and young people under 18 years" and "Rare diseases in adults". Thus, the total number of patient groups is 17 (as compared to 18 in 2021).
[7] 177 of these users are related to research.
[8] As a result of unexpected power cut at the Risø site due to construction outside of Risø (the episode did not compromise data), and the down-time due to maintenance activities.
[9] Due to DNGC consolidating and moved out of a data centre, which caused downtime.
[10] In 2023, the regions have primarily carried out WGSs within the 17 patient groups that are financed by the Novo Nordisk Foundation. At the same time, DNGC has worked on automating the technical solution for reporting other regionally funded WGSs, which is why it has not been possible for the regions to report these in 2023.

Table 2. Main goals for 2023

Goal	Status, December 2023	
Continued expansion of the genome and variant databases with an increasing number of genomes.	Achieved	The genome database has increased by 14,119 genomes (144.32%) in 2023.
Increasing number of research projects gain access to genome and variant data.	Partly achieved	POC initiated and access to data-base is expected in first half of 2024.
DNGC has ensured access to HPC-capacity for 2024 and onwards.	Not achieved	A 1-year extension to mid-2025 with DTU has been negotiated, and is awaiting approval in the Ministry of Finance and in the Ministry of Interior and Health (MIH), respectively. DNGC is further awaiting approval from the MIH regarding new housing-facility at SSI-Campus as well as negotiations between MIH and Danish Regions regarding financing of operations from 2025 onwards.
DNGC has implemented a national analysis platform.	Achieved	A prototype has been delivered and is being tested by the relevant research projects.

Staff overview

Staff at the Danish National Genome Center (DNGC) may be divided into three broad categories; it-, health- and administrative staff. As of 31 December 2023, DNGC had a total of 50 full-time employees and 4 student assistants. A more detailed overview of staff employed at DNGC from 2019-2023 can be found in Table 3. In addition, DNGC has engaged a number of external experts on an ongoing basis.

Table 3. Overview of staff at the Danish National Genome Center (2019-2023)

	2023		2022		2021		2020		2019	
	FT	SA	FT	SA	FT	SA	FT	SA	FT	SA
Personalised Medicine Development Unit (IT)										
Project manager	3	1	4	1	2					
Bioinformatician	7	1	11	1	12	1	11	1	5	
IT-development	9		7		12		10	1	4	
IT-operations	4		8		9		7	2	5	
Health Professional Unit										
Medical doctor	1		2		2		2		1	
Molecular biologist	1		1		1		1		1	
Academic staff	1		2		3		1			
National Whole Genome Sequencing Center										
Academic staff					5	1	4		3	
Management Secretariat										
Secretaries/PA's	3		4	1	3	3	3	1	2	2
Legal	2		2		2		2		1	
Compliance	2	1	2		2	1	2			
Economy	4		5		4		4		6	1
Policy and communication	5	1	5	1	6		6		4	
Research and international relations	5		5		5		1			
Executive board	3		3		3		3		2	
Total	**50**	**4**	**61**	**4**	**71**	**6**	**57**	**5**	**34**	**3**

Notes:
The staff overview reflects an end-of-year snapshot across organisational units and staff categories, rather than a detailed overview of the in – and outflow of staff. For example, if a member of staff initiates employment in May 2021 and terminates employment in May 2023, the individual is included in 2021 and 2022 only.

Moreover, it may be difficult to compare staff numbers and compositions across the years, as DNGC has been going through different phases of development and organisational adjustments.

FT = full time (end of year); SA = student assistant (end of year).

Financial reporting

In November 2023, Danish National Genome Center (DNGC) updated the budget submitted with the Playbook, as part of the quarterly financial reporting.

Table 4 details the new budget from November 2023. The new budget for 2023 was DKK 214.2 million. Closing of the financial year 2023 shows a total spending of DKK 220.7 million, thus an overspending in 2023 of approx. DDK 6.5 million. Compared to the Playbook Budget, the overspending is approx. DKK 72.5 million in 2023.

Investment costs, payroll costs and operating costs are approximately in balance in 2023. Investments for the Whole Genome Sequencing Center in 2023 includes the purchase of two new NovaseqX+ machines for the facilities.

The deviation of DKK 6.5 million between the new budget (November 2023) and the final accounts 2023 is primarily due to a lower level of income from DNGC's clinical services than expected.

Table 4. Budget details from Playbook and the new budget, November 2023 (DKK million)

	2019	2020	2021	2022	2023	2024	2025	Total [11]
Playbook Budget	133.2	179.3	244.4	265.4	148.2	20		990.6
New Budget, Nov 2023	42.2	111.2	188.2	250	214.2	146.4	39.9	992.1
Accounted 2019-2023	42.2	111.2	188.2	250	220.7			
Deviations					6.5			

Note: 1 Roundings may occur.

In table 4, the initial Playbook budget and the latest budget from November 2023 are displayed. The 2023 accounts have been updated in the table as well. As a result of this, DNGC has revised the budget 2024-2025.

Whole genome sequencing operating costs 2024-2025
A significant portion of the grant has been used to build analysis capacity at the National Whole Genome Sequencing Center. This was done by purchasing sequencing machines, robots and reagent kits as well as by funding FTEs. Early in the process, it was found that the goal of 60,000 genome equivalents could not be reached by the end of the grant on 1 July, 2024. Therefore, an earmarked budget line was reserved to ensure the financing of the National Whole Genome Sequencing Center's reagent kit expenses until the goal of 60,000 genome equivalents was reached.

Moreover, the Danish State provides a total of DKK 97.9 million for the operation of the national infrastructure for personalised medicine in 2024.

External funding
DNGC have received external funding from other external donors:

- European Commission, co-financing the EU project "European Genomic Data Infrastructure (GDI)"
- Innovations Fonden, co-financing the Translate project

In 2023, DNGC has also participated in an application for another EU project, Genome of Europe, where the European Commission provides funds for the initiation of a mutual European collection of reference genomes. The result of this application is expected during spring 2024.

[11] There is a difference of DKK 1.5 million between the budget in the Playbook and the two grants awarded to DNGC by the Board of Directors of NNF. It is the amounts from the two grants awarded by the Board of Directors of NNF that apply.

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