PRECISION MEDICINE

The Swedish Industry Guide 2018

Mapping the Swedish Precision Medicine Industry Landscape

COLLABORATION FOR SUCCESS

How AstraZeneca, Pfizer and Thermo Fisher Scientific are collaborating with Swedish companies and universities to advance precision medicine.

MIKAEL DAMBERG, MINISTER FOR ENTERPRISE AND INNOVATION

"Contemporary life science is data and technolgy-driven. Therefore, infrastructure and enabling technologies are national priorities for resource allocation".

5 HOT SPOT REGIONS IN SWEDEN

A vibrant start-up scene across Sweden with R&D driven small sized companies in close connection to Sweden's major universities.

This report is published by SwedenBIO with financial support from Business Sweden and Vinnova and in collaboration with Arthur D. Little.

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The Swedish Life Science Industry Organization

BUSINESS SWEDEN
THE SWEDISH TRADE & INVEST COUNCIL

VINNOVA

Arthur D Little

"Swedish precision medicine is a real area of growth and home to a vibrant start-up scene."

Thank you!

We would like to express our special thanks to everyone who helped and contributed to making this report a reality, without whose contribution it would not have been possible to assemble the companies and content presented in the report. Thanks are due to, by no means exclusively, to all the science parks, incubators, regions, other supporting organizations and individuals who shared their valuable knowledge and insights.

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The Swedish precision medicine industry landscape at first glance

This report, published by SwedenBIO – the Swedish Life Science Industry Organization, presents the results of the first mapping of the Swedish precision medicine industry landscape. It is a guide to 76 companies, all of which are developing innovative products and services with the potential of advancing the field. At the end of the report, there is a listing of their relevant R&D projects as well as launched products.

The precision medicine landscape is complex and consists of overlapping and intersecting elements, including biomedical research, clinical information, and lifestyle parameters, plus the enabling tools of digital health, "-omics" technologies, and computational health sciences. How are Swedish companies active in this field and contributing to realizing the promise of precision medicine? To gain more knowledge about this SwedenBIO initiated a project mapping the Swedish industry and the result is presented in this report.

Using our considerable network of organisations and individuals around Sweden, we invited a wide selection of companies to participate in a survey by describing their business and research programmes. In parallel, we identified a range of additional companies through database searches and these were also invited to participate. Details of this process can be found in the methods section on the last page.

In this first edition, we focused on Swedish companies with a business-to-business model. Therapeutic projects were excluded as these are regularly presented in "The Swedish Drug Discovery and Development Pipeline" report[1]. Sweden is also home to many high quality service providers and business-to-consumer companies, also part of the precision medicine landscape. In the future, we intend to revisit and report on these latter groups of companies to complement the present picture.

We have primarily focused on companies developing research tools suitable for stratification of patient subpopulations, diagnosis and/or prognostication of disease progress. Examples of such tools are: new validated biomarkers, companion diagnostics, diagnostic assays based on "-omics" technologies, sequencing technologies or software programs for analysis of complex and large datasets.

Secondly, we decided to highlight the outstanding Swedish research and development happening in complex data-computing, bio-imaging, bioinformatics, and large databases. It is becoming increasingly apparent how these technologies are being transformed into companies developing new methods based on machine learning and artificial intelligence. These IT-intensive companies are developing advanced imaging techniques using CT, MRI, PET or microscopy, or developing advanced bioinformatic programming and decision support software programmes. We envisage that these efforts of integrating multidisciplinary research areas will have the potential to really transform precision medicine in the future.

Many global enterprises have a significant presence in Sweden with both R&D and manufacturing sites, as well as through their many collaborations with academia and innovative Swedish companies. For this report, we asked AstraZeneca, Pfizer and Thermo Fisher Scientific about their perspective on precision medicine and how they take an active part in advancing the field through Swedish collaborations. Finally, we have included a description of selected research infrastructures, such as Science for Life Laboratory – a national resource for "-omics"-based research and development – to complete the picture by including a view of public sector effort in this field.

Our conclusion is that Swedish precision medicine is an area of substantial growth and home to a vibrant start-up scene. In the last four years, 26 companies were established within this area. The vast majority (97%) of companies are small with 50 employees or less. These companies are strongly connected to academia, with 72% having been spun out from the academic sector. The spin-off clusters are located around Sweden's larger cities with the majority originating from Karolinska Institutet in Stockholm, Lund University and Uppsala University. Linköping, in the heart of southern Sweden, has developed into a national arena for analysis of medical imaging using for example, artificial intelligence.

Our report encompasses the following topics:

- A map of technologies used by the companies
- Description of areas of rapid technology advancement
- Presentation of Swedish research infrastructures including Science for Life Laboratory
- AstraZeneca, Pfizer and Thermo Fisher Scientific views on precision medicine and their presence in Sweden
- The list of companies and their projects

This report has been published with support from Business Sweden, the Swedish Trade and Investment Council, and Vinnova, the Governmental Agency for Innovation, and in collaboration with management consulting firm, Arthur D. Little.

1. Learn more about Swedish Drug Discovery and Development at **www.swedenbio.se/reports**

Foreword by Mikael Damberg
Minister for Enterprise and Innovation
"Contemporary life science is data and technology-driven. Therefore, infrastructure and enabling technologies are national priorities for resource allocation"

Learn more about the first mapping initiative of the Swedish precision medicine industry landscape!

Highlight: Biomedical imaging
Linking basic molecular studies with phenotypic clinical manifestations of disease to promote an accurate diagnosis.

A–Z
18

An exclusive list of 76 companies developing innovative products and services that have the potential of advancing the precision medicine sector.

Highlight: Oncology
The increased understanding of the biology of different cancers is now leading to the development of new diagnostic methods.

CONTENT

SwedenBIO – the life science industry organization

We are always open to collaboration and we hope this report will serve as an invaluable source of information for companies, investors and other parties seeking collaboration and business opportunities in Sweden in this exciting area.

Sweden is ranked as one of the most innovative countries in the world. Our strong academic base and world-leading infrastructure for research form the basis for a successful and innovative life science industry accounting for nearly ten percent of our net export. The sector is highly prioritized, and the government recently established a permanent office for life sciences within the Government Offices in order to generate a coordinated policy, clearer priorities and a higher pace in working towards a competitive life science sector in Sweden.

As outlined in this report, the tradition of innovation development continues to thrive in precision medicine, an area where Swedish companies are developing novel products and technologies for a global market. Accessible biobanks, quality registers and well-developed platforms for interaction between academic scientists, clinicians and companies together with our early-adopter mindset, all contribute to making Sweden an ideal location for R&D in precision medicine.

SwedenBIO is the national association for the life science industry in Sweden with close to 250 member companies. Our mission is to promote an environment which brings success and growth to our life science industry. To accomplish this, SwedenBIO is active in the public debate and represents the industry in a continuous dialogue with authorities and politicians. We facilitate the building of professional networks and hold several inspirational and educational meetings, round table discussions, workshops and informal get-togethers throughout the year. SwedenBIO's investor-only meeting – vc2vc – encourages investors in life sciences to co-invest in each other's portfolio companies. Nordic Life Science Days, SwedenBIO's international investor and partnering meeting, held annually in September, has rapidly grown to become the largest business meeting in the Nordic region. This event will next take place on September 10-12, 2018 in Stockholm (www.nlsdays.com) and is by far the most efficient way to meet the Swedish life science community and its many innovative companies.

We are grateful to our partners for making the production of this report possible and wish you, as a reader, an informative and enjoyable insight into how Swedish companies contribute to advancements in precision medicine.

Visit us at www.swedenbio.se and www.nlsdays.com

Jonas Ekstand, PhD
Director General SwedenBIO

Photo: Kristian Pohl

Sweden is a major player on the life science arena, offering a thriving life science environment which is technology-driven and characterised by close collaboration between academia, health care, industry and patient organisations. As a logical consequence of this, life science is a dominating line of business and a cornerstone of the Swedish economy. Supporting research, innovation and co-creation in the life science sector has been a long-standing strategic priority of the Swedish government.

The threats to human health are escalating rapidly across the globe, rendering human health a major global challenge. Accordingly, in 2015, our National Innovation Council, which is chaired by the Prime Minister, launched an innovation partnership programme in life science to further accelerate progress in research and innovation, and promote co-creation involving all major stakeholders. And, in February 2018, an Office of Life Science was established in the Government Offices, a first assignment of which is to develop a national strategy for life science.

“In February 2018, an Office of Life Science was established in the Government Offices”

Mikael Damberg
Minister for Enterprise and Innovation

The digitalisation revolution has been a prerequisite for efficient handling of ‘big data’ arising from the new technologies and will continue to speed up progress in life science and clinical medicine. Here, Sweden has competitive advantages. Our public health care system, along with the personal identification numbers introduced in 1947, has made generation of unique, comprehensive patient registers and functional biobanks possible. Sweden is also internationally lauded for its performance in information and communication technology, including technologies for managing big data and mobile technologies that hugely benefit the Swedish life science sector.

Contemporary life science is data- and technology-driven. Therefore, infrastructure and enabling technologies are national priorities for resource allocation. A state-of-the art e-infrastructure is being created to facilitate coordinated and efficient use of the unique biobanks and national registers. The Science for Life Laboratory is a leading national and international infrastructure and research environment for molecular biosciences and drug development that receives long-term government support. MAX IV and the European Spallation Source (ESS), two major investments in high-resolution imaging, support a wide range of scientific areas and have been set up as core national and European infrastructures.

Precision medicine targets diagnosis and treatment tailored to the individual. Joint efforts in this area will result in improved health, strengthened international competitiveness for all stakeholders, increased export and new investments in Sweden. The Swedish government is strongly committed to supporting continued rapid development in the life science sector.

Business Sweden

The gateway to business in Sweden

Expect great things of Sweden!
In Sweden you will find a proven, business friendly environment that is characterized by forward thinking, sharp brains and open minds. Sweden is considered to be one of the world's most prominent research nations and provides full access to Europe. It is a place where not only will you get quality and efficiency beyond your expectations, but also stability and sustainability by default.

Life sciences is a sector of high strategic importance to Sweden. The foundation that underpins innovation in the Swedish life sciences sector is the fruitful collaboration between academia, industry and healthcare, where all stakeholders demonstrate an open-minded and boundary-spanning approach. Our long track record of investing heavily in research and development has borne fruit and is yet another reason to choose Sweden for life science business development, licensing, partnerships or direct investments.

About Business Sweden
Business Sweden's purpose is to help Swedish companies to grow their international revenues and international companies to invest and expand in Sweden. For Swedish companies, we provide strategic advice, sales execution and operational support. For international companies we ensure that they can rely on our knowledge, experience and extensive network to identify new business opportunities and achieve an accelerated return on investment. Business Sweden is present in 50 of the world's most promising markets and owned by the Swedish Government and commercial sector, a partnership that provides access to contacts and networks at all levels.

Visit us at www.business-sweden.com

Photo: Patrick Trägårdh

Ulrika Cederskog Sundling
Executive Vice President Invest & Region Sweden

Elisabet Nielsen, Programme Manager, International Division.
Laurent Saunier, Head of Department, Health Division.

Vinnova

Sweden – an innovation leader

According to the Global Innovation Index[1], Sweden is rated as the second most innovative country in the world. It offers an environment where you can find entrepreneurship, strong R&D clusters, and a thriving start-up scene.

Supporting innovation
Vinnova, the governmental agency for innovation, funds innovation and research projects. Every year, the agency invests around SEK 3 billion (> USD 371 million) in promoting innovation. Funds are generally allocated using a "calls for proposals" system.

Precision medicine is an interdisciplinary field that is expected to drive the health research and innovation agenda for years to come. To continue enabling advances in this sector to be made, Vinnova stimulates collaboration between companies, universities, higher education institutions, public services and civil society, as well as working to strengthen international cooperation.

Vinnova is a member of the EC-funded network "The International Consortium for Personalised Medicine" (ICPerMed)[2]. In addition, we fund projects in this field via our national programmes such as the Strategic Innovation Programmes (SWELife and Medtech4Health) and Challenge Driven Innovation. We are also engaged in promoting international calls for propsosals under the Horizon 2020 framework, as well setting up a Nordic call for proposals within Personalised Medicine.

Visit us at www.vinnova.se

1. Global Innovation Index 2017 Report, www.globalinnovationindex.org
2. ICPerMed www.icpermed.eu

PRECISION MEDICINE

Providing the right treatment to the right patient at the right dose and the right time.

The advent of "precision medicine" has long been predicted – essentially ever since, when in 1990, scientists began decoding the human genome. There is no 'single' definition of the concept of precision medicine, but one that has gained strong support is that precision medicine is defined as the stratification of patients into groups based on biological information and biomarkers at the molecular level as a result of our increased understanding of disease pathways and within the fields of genomics, proteomics, metabolomics, epigenomics and pharmacogenomics, thus allowing doctors and drug makers to match a patient to a drug that is likely to work. That is, precision medicine aims at improving the targeting of drug treatment to boost the efficacy of drugs and to reduce their adverse reactions. It is not just about developing new drugs but also about identifying those patients who are most likely to respond to existing products, and therefore aimed at reducing the number of ineffective therapies clinicians may need to test on a patient before finding the right one. Although the term 'personalized medicine' is also sometimes used to describe this process, it actually denotes a unique treatment designed and manufactured for an individual patient, as for example, the Novartis chimeric antigen receptor therapy (Car-T).

The opportunities within precision medicine have attracted much interest, not only from scientists, drug makers and patients but also from funders and decision makers. In 2015, former US President Barack Obama announced the Precision Medicine Initiative, launched with a $215 million governmental backing in the presidential 2016 Budget to advance precision medicine in the USA. In the EU, the European Commission has invested heavily into precision medicine within the FP7 and Horizon 2020 frameworks, alongside other several major national initiatives such as Genomics England, France Medécine Genomique and the Danish National Strategy for Personalized Medicine. And in Asia, countries like South Korea have declared that the government will establish obligatory data platforms and ease regulations to encourage innovation in precision medicine. In Sweden, initiatives such as Genomic Medicine Sweden are in progress, aimed at building a new type of infrastructure in the Swedish healthcare system by the introduction of new genetic screening technologies to enable implementation of precision medicine throughout the country. A further example is the recent significant investment in precision medicine in oncology by the Sjöberg Foundation in collaboration with the Swedish Regional Cancer Centers.

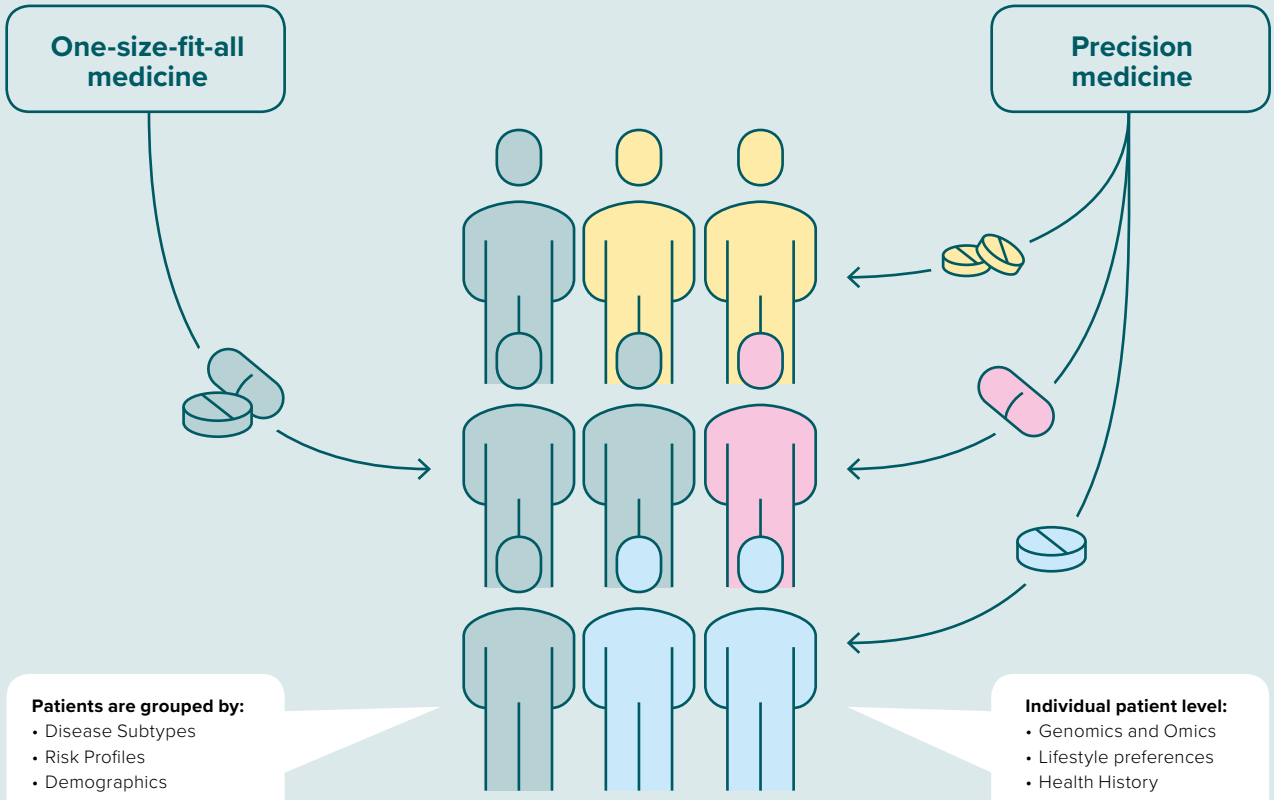
Ulrica Sehlstedt, PhD
Partner, Arthur D. Little

"The opportunities within precision medicine have attracted much interest, not only from scientists, drug makers and patients but also from funders and decision makers"

Delivering on promises with precision medicine is inextricably linked to technological advancement of biomarker technologies, digitalization and big data management. The steep decrease in the cost of sequencing a genome has played, and still does play an important part in advancing the field, as do the high speed development and application of data mining, artificial intelligence (AI) and machine-learning to predict which patients will respond to specific therapies. The in-

New paradigm shift in treatment

Transitioning from the ”One-size-fits-all” to ”Precision Medicine” model with multi-level patients stratification.



Precision medicine is about the stratification of patients into groups, based on biological information and biomarkers at the molecular level – to match a patient to a drug that is likely to work.

creasing availability and selection of devices and wearables for collecting “real-world” data from patients means that biomarker information can be combined with data about individual differences in lifestyle and environment to provide researchers with further tools to discover paths towards delivering precision medicine.

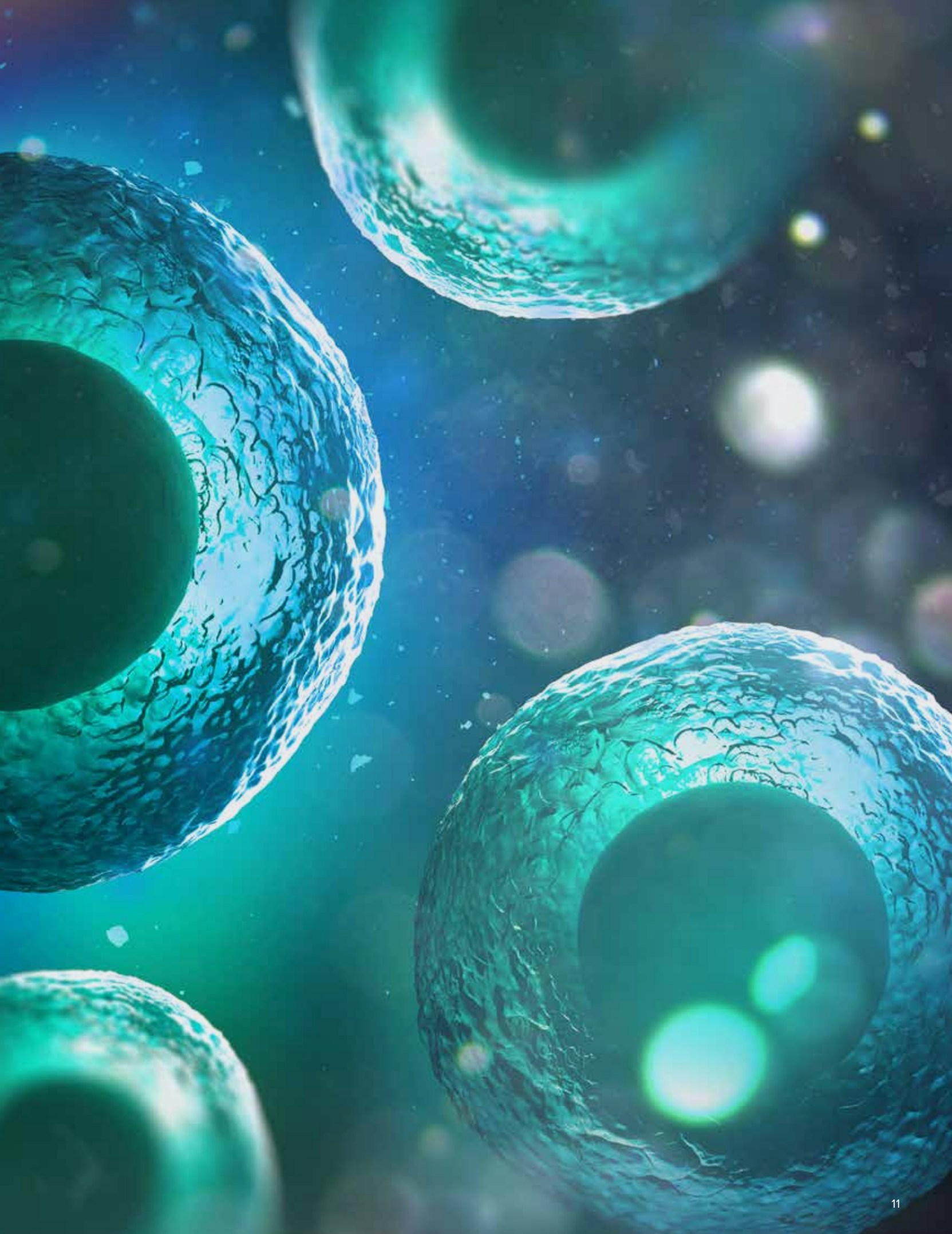
Precision medicine has the potential to fundamentally alter the existing business logic in the healthcare landscape in several ways – by creating a more segmented market through increased interdependency between industrial partners and by the expected transition from volume-based payment towards outcome-based payment. One of the major determining factors which will either drive or hinder the broader uptake of precision medicine is whether or not healthcare providers will be adequately reimbursed for using the drugs and associated diagnostic tools. Being able to prove the value of the associated improvement in care quality or health outcomes will become increasingly important for drug and diagnostic suppliers if they are to obtain approval for their precision medicine solutions, and also have them reimbursed and implemented in the market.

Sweden, with its long tradition in biomolecular research and its comprehensive biobanks and quality registers, is very well positioned as a front runner in the field of precision medicine. In this report, we highlight Swedish companies that currently innovate, develop and supply researchers and drug makers with all the important tools and technologies that are a prerequisite for the discovery, development and implementation of precision medicine for the benefit of patients in Sweden and elsewhere.

“Sweden, with its long tradition in biomolecular research and its comprehensive biobanks and quality registers, is very well positioned as a front runner in the field of precision medicine.”

The future of tailored treatment is about

HAVING A BETTER UNDERSTANDING OF BIOLOGICAL MECHANISMS AND ENVIRONMENTAL INTERACTIONS

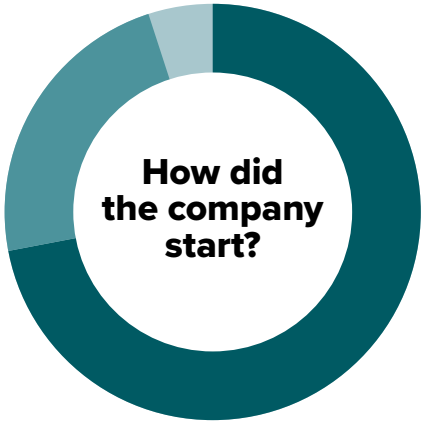


An initial map of the Swedish precision medicine industry

In this report, we have prepared a guide to 76 companies developing innovative products and services that have the potential of advancing the precision medicine sector. The companies are clustered in five major regions, where the capital region Stockholm-Uppsala is home to almost 50%. The vast majority has been spun out of academic institutions.

Commercialisation of academic research – 72% of companies are university spin-offs

Nearly three out of four companies in this report have been founded based on research and innovative technologies developed at academic institutions. Sweden has the second highest R&D expenditure in Europe as a percentage of GDP[1] and a well-established academic and corporate research culture. The proximity between the universities and the healthcare sector, as well as the public research infrastructures, are plausible reasons why so many academic innovations are now being commercialised. Below is a list of companies spun out of the major universities.



- Spin-off from academia, 55
- Independent, 17
- Other, 4

Karolinska Institutet
Adduct Analys, Affibody, Athera Biotechnologies, AroCell, Chundsell Medicals, Clinical Gene Networks, CyberGene, DoubleStrand Bioinformatics, iCellate Medical, InDex Pharmaceuticals Holding, Pelago Bioscience and VLVbio.

Lund University
Akuru Pharma, Diaprost, Immunovia, Medviso, Qlucore, Reccan Diagnostics, Respiratorius, SAGA Diagnostics, SensoDetect, SenzaGen, Spectronic Medical.

Uppsala University
Astrego Diagnostics, BioArctic, Biovica, CADESS Medical, CRAY Innovation, Gradientech, Olink Bioscience, Olink Proteomics, Q-linea.

Chalmers Technical University and Gothenburg University
1928 Diagnostics, Alzinova, Eigenvision, Elypta, Medfield Diagnostics, Metabogen, Multid Analyses, PExA and TATAA Biocenter.

Linköping University
AMRA Medical, BioReperia, ContextVision, Glycobond and Sectra.

Umeå University
AcureOmics, HiloProbe, InfiCure and UmanDiagnostics.

Strong association to incubators and science parks

In close connection to the universities, the incubators and science parks provide start-ups with relevant business tools in the commercialisation process. It is therefore no surprise that about 50% of the companies are associated with an incubator or science park. The densest innovation hubs are naturally collocated with Sweden's most populated regions and largest universities, with the principal ones being the SMILE incubator and Medicon Village Science Park in Lund, and the Karolinska Institutet Incubator and Science Park in Stockholm.

1. Business Sweden, Why Sweden leads the innovation game (www.business-sweden.se/en/Invest/industries/Manufacturing/innovation)

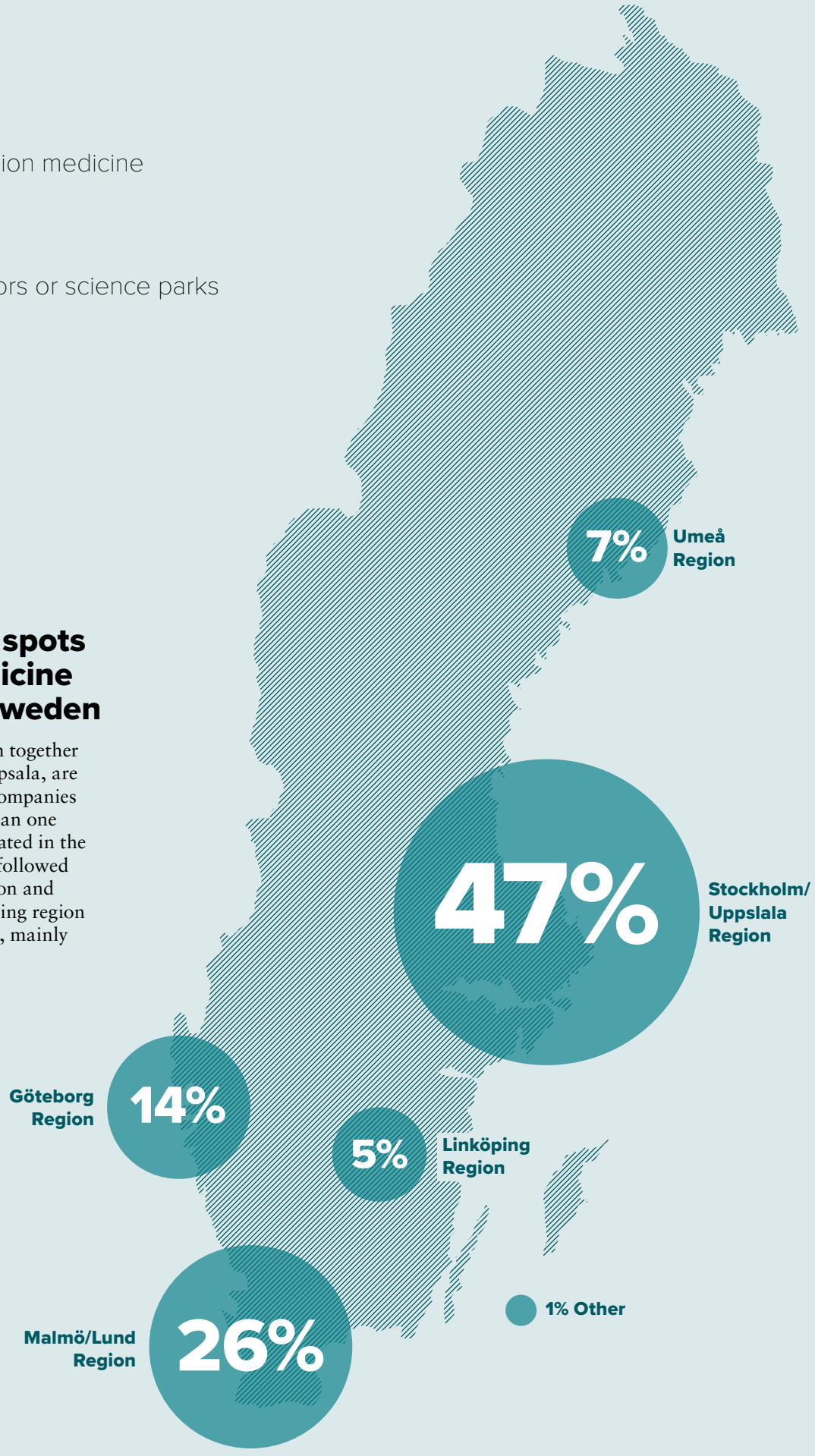
76
companies within precision medicine

50%
associated with incubators or science parks

72%
spin-offs from academia

Five Swedish hot spots for precision medicine development in Sweden

The capital region of Stockholm together with its northern neighbour Uppsala, are home to almost half of the 76 companies included in this report. More than one fourth of the companies are located in the southern Malmö-Lund region, followed by 14% in the Gothenburg region and 7% in the Umeå region. Linköping region also hosts 5% of the companies, mainly within imaging technologies.



Small companies – driving innovation

All but two of the 76 companies presented in this report, Elekta and Sectra, have less than 50 employees (n=74) and most of these can be classed as micro- or virtual companies (n=61). These small research based companies, are part of the vibrant Swedish start-up scene, which is further fuelled by a well-established network of funding organisations, support organisations such as incubators and science parks, contract research organizations and other expert service providers. This all contributes to Sweden's well-established position as a global innovation leader, which is due to the country's attractive research infrastructure, high-level of competence and skills, as well as a flourishing, cross-disciplinary learning and testing environment.[1]

Elekta and Sectra are the two largest Swedish companies active in the field of precision medicine. These two companies employ about 250 people each in Sweden, and 3581 and 616 worldwide, respectively. Together, the 76 companies mentioned in this report employ the equivalent of 1000 FTEs in Sweden.

We asked the companies how they see their company developing over the next three years, and more specifically if they plan to recruit within their R&D departments. As many as 77% of the companies plan to recruit more staff, and 47% plan to increase their number of specialised consultants/contractors. In answer to the question as to which competencies were being sought, the response was that the highest demand is for expertise in bioinformatics and software skills, and interestingly also, several companies are looking for skills in artificial intelligence.

As many as 77% of the companies plan to recruit more staff, and 47% plan to increase their number of specialised consultants/ contractors

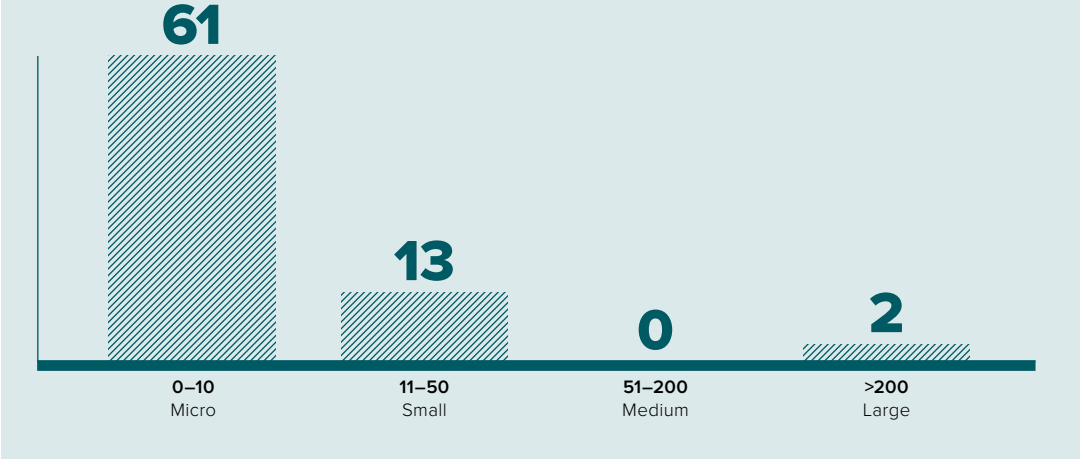
26 companies founded over the last four years

The high activity within the area of precision medicine is manifested by the significant number of newly founded companies measured over the last four years. On average, more than 6 new companies were founded each year (2014: +7; 2015: +5; 2016: +10; 2017: +4).

2014	2015	2016	2017
1928 Diagnostics	Bionamic Data Consulting	Akuru Pharma	Astrego Diagnostics
Antaros Medical	BioReperia	CADESS Medical	CartaNA
CRAY Innovation	Eigenvision	Doctrin	DoubleStrand Bioinformatics
Gnosco	EMPE Diagnostics	HiloProbe	Elypta
Life Genomics	Neodynamics	InDex Pharmaceuticals Holding	
PExA		Liv Diagnostics	
Reccan Diagnostics		Medsens	
		Olink Proteomics	
		Oncosignature	
		Saga Diagnostics	

^ N. B. Companies InDex Pharmaceuticals Holding and Olink Proteomics were registered in 2016, but existed previously in the form of other company structures.

The majority of the 76 companies have less than 50 employees



1. Business Sweden, Why Sweden leads the innovation game (www.business-sweden.se/en/Invest/industries/Manufacturing/innovation)

Stratification of patients and development of new technologies is on the agenda for Swedish companies

We are all unique. Our health is determined by our inherent genetic differences combined with our lifestyles and environment. Precision medicine is about having a better understanding of biological mechanisms and environmental interactions that govern health and disease.

Various diagnostic methods and instrumentation platforms serve to facilitate our ability to identify changes in the human body. It is the combination of the information we observe or diagnose by these means, and our increasing knowledge of human biology (through ongoing advances in "-omics" technologies) that enables us to determine our individual risk of developing disease, detect illness earlier, and to choose the most effective interventions to help improve our health, be it through medicines, lifestyle choices, or even simple changes in diet.

A model for describing the overlapping and intersecting elements that make up the field of Precision Medicine are shown in the diagram in this section. The figure depicts these individual elements, which include biomedical research, clinical information, and lifestyle parameters, plus the enabling tools of digital health, "-omics" technologies, and computational health sciences. When integrated, these elements can inspire the development of new research and technologies which eventually can lead to more precise and predictive healthcare.

Based on the data provided by the companies participating in the survey, it can be concluded that Swedish companies in the field are numerous and work across a broad spectrum of research and methods. For purposes of this report, they have been divided into groups with the focus being on two groups of companies:

– Those working with stratification of patients based on genetic and phenotypic patterns.

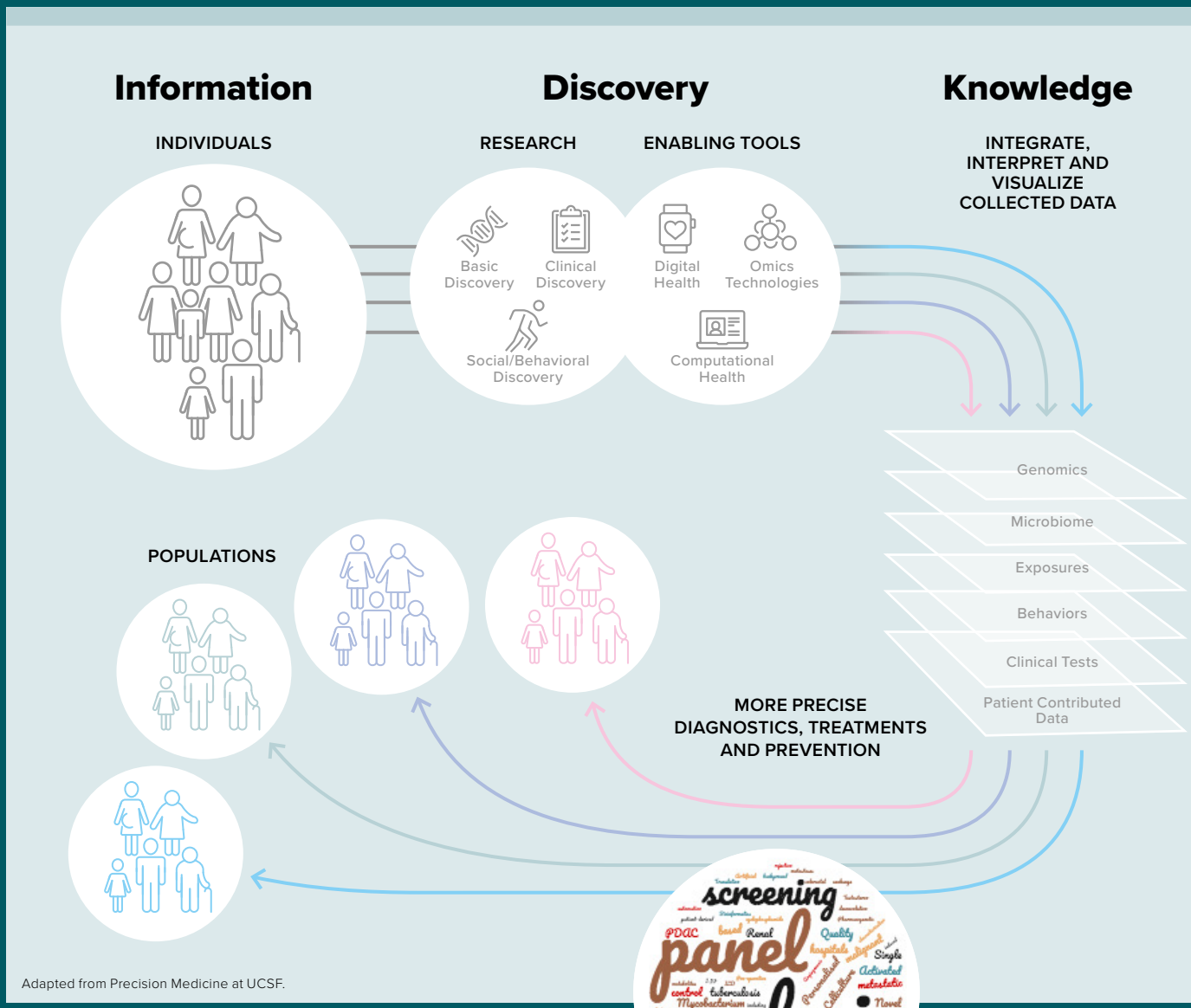
These include companies developing methods and products for: companion diagnostics, biomarker discovery and validation, molecular diagnostics, mutation analysis by sequencing, expression profiling, bioinformatics, genomics, proteomics, pharmacogenomics, metabolomics, translational imaging with PET-ligands, or next generation sequencing (NGS) of whole genomes.

– Those working on development of new technologies and instrumentation. These companies are primarily developing new diagnostic methods such as: sampling techniques (biopsies), patient monitoring, bio-imaging and medical imaging and clinical-decision support systems. Companies developing new software and advanced programming technologies are also placed in this group.

The companies were asked if their technological sectors are typical for precision medicine. The top five technologies listed were bioinformatics, data management (big data), machine learning, patient monitoring and predictive analytics. For more information, see page 18-19.

Sweden is home to outstanding research and development in complex data computing, bioinformatics and large databases, and these technologies are now being translated into companies developing new methods based on artificial intelligence or machine learning. These IT-intensive companies are developing advanced imaging techniques using CT, MRI, PET or microscopy, or developing advanced bioinformatics programming and decision support software programmes.

Big data analytics, based on the wealth of information held in Sweden's large and numerous databases, is becoming an important area of research in precision medicine. Handling large amounts of data requires the type of new software development that is needed for artificial intelligence (AI)



Adapted from Precision Medicine at UCSF.

and machine learning programs. AI and machine learning algorithms are now also being applied to practices such as diagnostic processes, treatment protocol development, patient monitoring and care.

We also asked the companies about their projects and products. The majority have applications in specific therapy areas. The strongest area is by far oncology followed by infection. New diagnostic tools for Alzheimer's disease and cardiovascular diseases are also in focus for several companies. In addition to disease specific tools, several companies are developing new instrumentation for improved bio-imaging techniques as well as technologies within biopsy instrumentation. All the projects and products reported by the companies, totalling more than 200, are listed on the last pages.

This "wordle" captures and measures the words used by the companies when describing the applications of their products.

COMPANIES A-Z

Company	Bioinformatics 29	Data management (Big Data) 28	Machine learning 25	Patient monitoring 23	Predictive analytics 23	Artificial intelligence 17	Proteomics 14	Expression profiling 13	Liquid biopsy 13	Next generation sequencing (NGS) 11	Translational imaging 11	Single cell analysis 10	Gene mutation analysis 9	Transcriptomics 9	Metabolomics 7	Biosensors 6	Identification of circulating DNA 6	Pharmacogenomics 6	Whole genome sequencing 6	Epigenomics 5	Single molecule imaging 4	Other 20
1928 Diagnostics	●	●	●	●	●					●								●				
AcureOmics	●		●	●	●	●	●								●							
Adduct Analys				●													●					
AMRA Medical		●	●		●	●					●											
Affibody											●											
Akuru Pharma	●													●								
Alzinova	●				●						●					●						
Antaros Medical		●	●								●											●
AroCell				●	●										●							●
Ascelia Pharma				●																		●
Astrego Diagnostics											●	●										
Athera Biotechnologies							●															
Atlas Antibodies		●					●															
Axcentua Pharmaceuticals	●							●					●	●				●				
BioArctic		●		●	●				●		●										●	●
Biomotif	●						●															
Bionamic	●	●	●		●	●		●	●													
BioReperia	●	●	●		●	●				●				●				●				
Biovica				●					●													
CADESS Medical	●	●	●			●																
Calmark Sweden																						●
CartaNA	●	●	●					●		●		●	●	●						●	●	●
Chundsell Medicals	●				●			●														
Clinical Gene Networks	●	●						●														
ContextVision		●	●			●																●
Corpus Data & Image Analysis		●	●		●																	
CRAY Innovation	●	●			●		●	●	●			●		●								
CyberGene																						●
DanPET											●										●	
Diaprost																						
Doctrin		●	●		●	●																
DoubleStrand Bioinformatics	●	●	●		●	●	●	●		●			●	●					●	●		
Eigenvision																						
Elekta																						
Elypta	●			●		●			●						●							
Emotra		●														●						●
EMPE Diagnostics				●				●								●	●					
Glycobond				●				●	●													

We listed a selection of technologies typical for precision medicine and asked the companies to mark relevant areas for their business. The result is outlined below. The following companies did not participate in the web-based questionnaire, but do touch upon precision medicine and are therefore also briefly mentioned in the report: Alpha Biotech, Apodemus, BiBBInstruments, Cavidi, Chromalytica, Hermes Medical Solution, ImaGene-iT, Molecular Fingerprint Sweden, Phase Holographic Imaging, Sensabues, SyntheticMR.

Company	29	28	25	23	23	17	14	13	13	11	11	10	9	9	7	6	6	6	6	5	4	20
	Bioinformatics	Data management (Big Data)	Machine learning	Patient monitoring	Predictive analytics	Artificial intelligence	Proteomics	Expression profiling	Liquid biopsy	Next generation sequencing (NGS)	Translational imaging	Single cell analysis	Gene mutation analysis	Transcriptomics	Metabolomics	Biosensors	Identification of circulating DNA	Pharmacogenomics	Whole genome sequencing	Epigenomics	Single molecule imaging	Other
Gnosco		●	●			●																
Gradientech		●																				
HiloProbe																						●
iCellate Medical	●			●					●	●		●	●				●	●	●			
Immunovia	●				●		●															
InDex Pharmaceuticals Holding																						
InfiCure Bio												●										
Life Genomics													●					●				
Liv Diagnostics					●						●											●
Lytics Health	●	●	●	●	●	●																●
Medfield Diagnostics		●	●	●		●																
Medsens				●												●						
Medviso		●	●			●																●
MetaboGen	●			●						●			●		●				●			
Multid Analyses	●							●		●		●										
Neodynamics																						●
Olink Bioscience				●			●	●	●			●	●				●					
Olink Proteomics	●	●	●	●	●		●	●	●													
OncoSignature	●	●	●		●	●	●				●											
Pelago Bioscience	●			●	●		●								●					●		●
PExA				●	●		●		●	●				●	●							
Q-linea	●	●	●						●			●				●					●	●
Qlucore	●		●		●					●												
Reccan Diagnostics	●						●									●	●			●		
Redhot diagnostics																						
Respiratorius																						
SAGA Diagnostics	●	●	●	●	●				●	●			●				●		●			
Sectra		●	●			●					●											●
SensoDetect		●	●	●	●	●																
SenzaGen	●		●											●								
Single Technologies																						
Spago Nanomedical																						●
Spectronic Medical		●	●	●		●																●
Symcel				●																		
TATAA Biocenter	●						●	●	●	●		●	●	●	●		●	●	●	●		
Truly Translational Sweden								●	●		●	●										
UmanDiagnostics				●																		
VLVbio																						●

ONCOLOGY

The inceased understanding of the biology of different cancers is now leading to the development of new diagnostic methods.

According to the World Health Organization (WHO) cancer is, after ischemic heart disease and stroke, the second leading cause of morbidity and mortality worldwide. Cancer was responsible for 8.8 million deaths in 2015. The number of new cases of cancer is expected to rise by about 70% in two decades, from 14 million in 2012 to 22 million by 2030.

Lung, prostate, colorectal, stomach and liver cancer are the most common types of cancer in men, while breast, colorectal, lung, cervix and stomach cancer are the most common among women.

Finding and treating cancer at an early stage can save lives

Cancer mortality can be reduced if cases are detected and treated early. Screening programmes and early diagnosis are two major components of early detection. Figures from Cancer Research UK suggest that more than 90% of women diagnosed with breast cancer at the earliest stage survive their disease for at least 5 years compared to around 15% for women diagnosed with the most advanced stage of the disease.

The promise of precision medicine is that treatments will one day be tailored to the genetic changes in an individual's cancer. Information about genetic changes in a tumour will help decide which treatment will work best for that person. However, it is now known that cancer is an extremely heterogeneous disease, which explains differences not only between cancer cells from different patients, but also between cancer cells within a single patient. This calls for new and better sampling technologies, an increased understanding of the genetics behind cancer development and better screening and diagnostic methods.

The future is approaching

The arrival of next-generation sequencing (NGS) has accelerated the implementation of genomic profiling in the care and management of patients with cancer. Initial efforts have focused on target identification in patients with advanced cancer. Prognostication, resistance detection, disease monitoring, and early detection efforts are also underway.

Our increased understanding of the biology of different cancers is now leading to the development of new diagnostic methods for detecting biomarkers specific for certain cancers and different stages of the cancer.

Improved diagnostics in breast cancer

Breast cancer is one of the most common cancers with more than 1,300,000 cases and 450,000 deaths occurring annually worldwide.[1] Breast cancer diagnostics today include the diagnostic management of the breast as well as the axillary lymph nodes. Since no validated serum biomarkers for breast cancer have yet been identified, there is a great clinical need for a better non-invasive test that allows correct diagnosis as well as prognosis and recurrence.

Prediction of the risk of the cancer reoccurring, especially in parts of the body distant to the breast, is difficult using current clinical and histopathological parameters. Consequently, a number of patients are over and/or non-optimally treated, resulting in largely unnecessary side-effects for patients and increased costs for healthcare providers. Thus, tools for predicting the metastatic migration behaviour of cancer cells are needed.

A number of Swedish companies are currently engaged in this race to fight breast cancer. The methods they are developing span a variety of technologies – from improved biopsy methods, analysis of cancer specific enzymes and biomarkers to cell migration assays and diagnostic tools based on machine learning.

Since no validated serum biomarkers for breast cancer have yet been identified, there is a great clinical need for a better non-invasive test that allows correct diagnosis

1. WHO, GLOBOCAN 2012

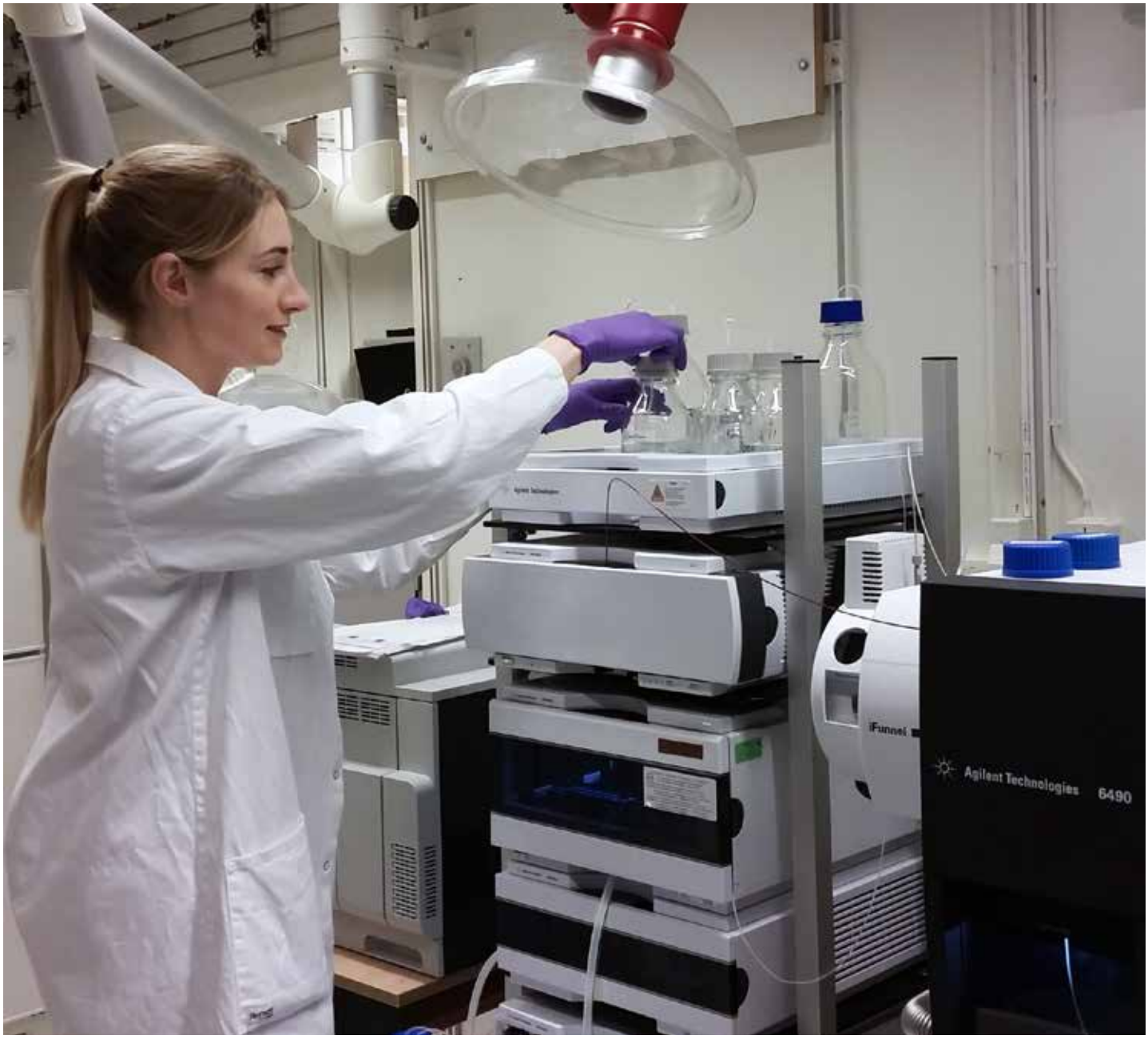


Photo: AcureOmics

Company	Technology	Application/s
Affibody	HER2 PET imaging agent.	Imaging in metastatic breast cancer. In clinical validation.
AroCell	TK1 serum biomarker ELISA analysis of serum.	Monitoring treatment efficiency and survival in stage 2 breast cancer.
Biovica	Analysis of TK enzyme activity in blood.	Monitor and predict treatment response in stage 2 breast cancer therapy. In clinical validation.
ContextVision	Digital diagnostics / machine learning.	Analysing tumour proliferation speed as a decision support tool/treatment plan.
Immunovia	Panel of breast cancer biomarkers on microarray platform /software algorithm.	Early detection of breast cancer. Possible prediction of development of distant metastases.
Liv Diagnostics	Lab-on-a-chip, analysis of cells from biopsy.	Diagnosis and follow-up of breast cancer. Measure of tumour invasiveness.
Neodynamics	Biopsy system with ultrasound guided imaging with end sampling.	Tissue sampling of small lesions and axillary lymph nodes. Product launched.

A number of Swedish companies are currently engaged in this race to fight breast cancer.

In the future of precision medicine, treatments will be tailored to the genetic changes in an individual's cancer

The challenges of prostate cancer

There is no question that screening can help find many prostate cancers early. Until recently, PSA (prostate specific antigen) tests for prostate cancer were considered to be exemplary for successful early cancer detection leading to improved treatment outcomes. But over the last few years, a series of studies has suggested that the tests are not sensitive enough: frequent false positives lead to too many unnecessary medical procedures, and false negatives give men a false sense of security. Even if screening detects prostate cancer, doctors are often unable to tell if the cancer is truly aggressive. Because of an elevated PSA level, some men may be diagnosed with a prostate cancer that would otherwise have gone unnoticed, not caused any symptoms nor led to their death. As a result, most healthcare authorities in Europe, including Sweden and around the world, do not recommend introducing screening for prostate cancer with the PSA test.[2]

Consequently, there is a need for more accurate diagnostic tests than are presently available. In the future of precision medicine, treatments will be tailored to the genetic changes in an individual's cancer, but they will also be taking account of the normal variations seen in healthy individuals. Indeed, in a recently published paper, a genome-wide association study suggested that 40 genetic regions could together predict nearly 10 percent of normal variation in PSA levels in men who do not have prostate cancer.[3]

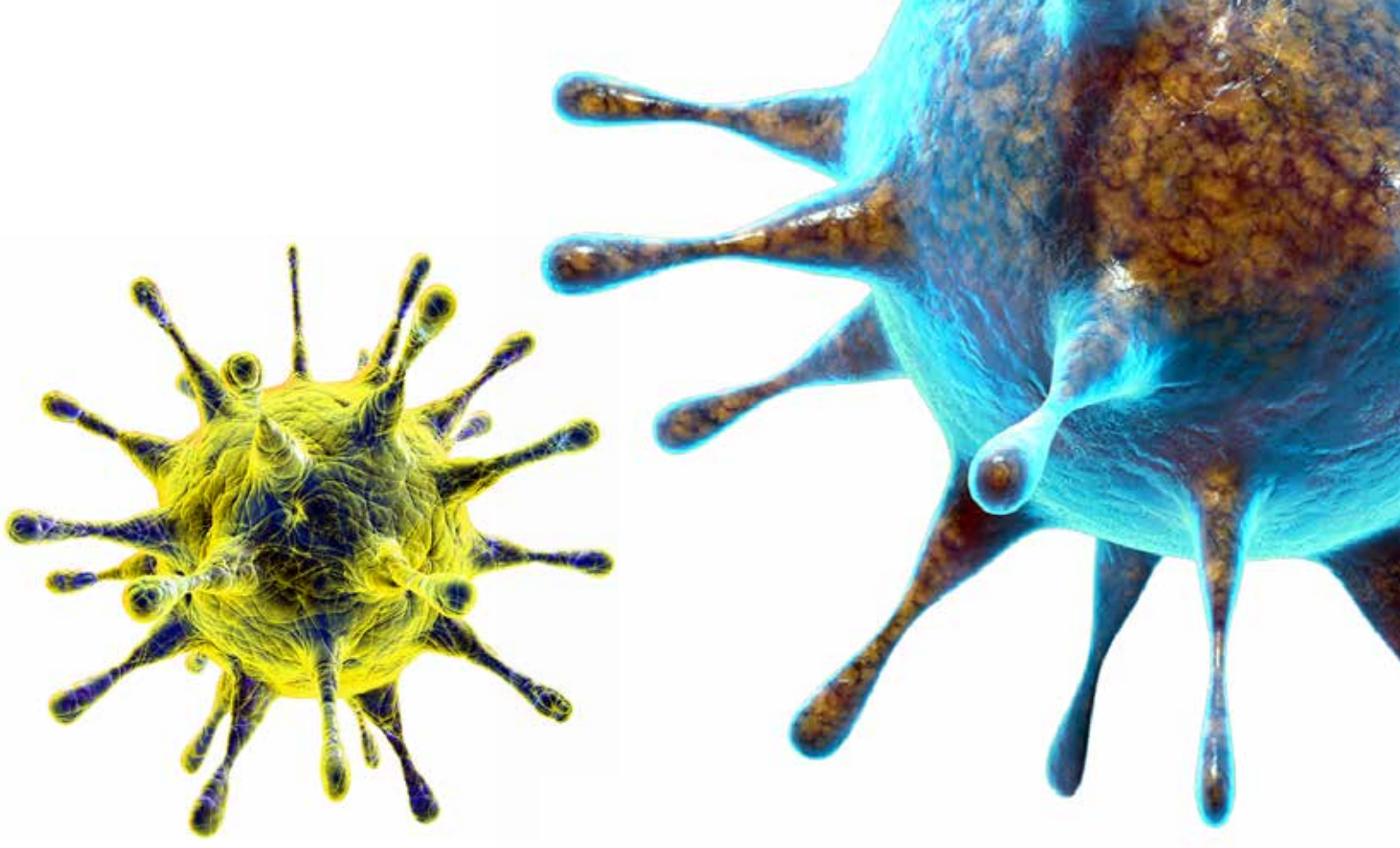
Once the prostate cancer is diagnosed there are other challenges in the treatment regime that need to be addressed. Androgen deprivation therapy (ADT) is generally the first choice for the management of advanced prostate cancer. Unfortunately, after an initial response to ADT, prostate cancer eventually loses responsiveness to the androgen blockade and progresses into castration-resistant prostate cancer (CRPC). Again, the way to successfully targeting CRPC lies with the advancement of precision medicine i.e. analyse gene mutations and expressed genes in tumour samples and combine these with patient data.

A promising on-going research project in Sweden is the combination of the "Stockholm3 test" with magnetic resonance imaging scans to further improve the identification of aggressive prostate cancer. The "Stockholm3 test" is a blood-based prostate cancer test that predicts the risk for aggressive prostate cancer at biopsy by analyzing five protein markers, more than 100 genetic markers and clinical data. The hope, now, is that the combinations of different biomarkers and imaging techniques will lead to better detection and prediction of prostate cancer.

In Sweden, there is a growing number of companies developing new methods and analysis tools for more accurate diagnosis of prostate cancer.

Company	Technology	Application/s
AroCell	TK1 serum biomarker ELISA analysis.	Prognostic and monitoring treatment efficiency in prostate cancer.
CADESS Medical	Cloud-based decision support system based on digital imaging analysis of biopsies.	Identification of malignant glands in tissue images and prognosis of the prostate cancer development.
Chundsell Medicals	Combination of gene expression, of IGFBP3, F3 and VGLL3, with clinical parameters.	Decision support Prognosis of aggressive prostate cancer and survival for various treatment options. Product launched.
ContextVision	Digital diagnostics / machine learning.	Analysing tumour proliferation speed as a decision support tool/treatment plan.
CRAY Innovation	Genetic analysis of loss of chromosome Y (LOY) in blood cells.	Predict risk for all-cause mortality of prostate cancer in men.
Diaprost	Mab-PET-ligand (anti-hK2) in combination with anatomical imaging (CT/MR).	In vivo screening for identification and detection of prostate cancer.
Elypta	Platform based metabolic profiling analysis (machine learning algorithms) of 20 cancer-type specific metabolites in blood or urine.	Early detection, differential diagnosis, surveillance of recurrence and monitoring or prediction of treatment response.
iCellate Medical	Whole genome sequencing (of CTC and ctDNA) and germ-line DNA, from normal blood samples.	Analysis of aggressive prostate cancer. Risk profiling in hereditary investigation. In clinical validation.
Immunovia	Panel of prostate cancer biomarkers on microarray platform /software algorithm.	Early detection of prostate cancer.
Spectronic Medical	Software that provides AI driven technology to enhance radiotherapy by enabling MRI.	Treatment planning for MRI only radiotherapy planning. Ongoing registration of the product.

2. The National Board of Health and Welfare (Socialstyrelsen)
3. Witte, & Van Den Eeden, 2017. Nature Communications



Cancer of the pancreas
According to WHO, hepatocellular pancreatic cancer is probably the most lethal tumour, forecast to become the second most fatal cancer by 2020 in developed countries. Pancreatic cancer often does not cause any signs or symptoms in the early stages, making early diagnosis difficult. Detection at a curable stage demands screening intervention for early detection and differential diagnosis. However, to date, no successful strategy or image technology has been found to offer an effective approach. Currently, the hope for this cancer is to be able characterise relevant non-invasive biomarkers.
Axcentua Pharmaceuticals is developing specific biomarkers for stratification of pancreatic cancer patients. This project is currently in clinical validation.
Elypta is developing a blood- and urine-based liquid biopsy platform for detection and classification of multiple cancer indications, one of which is pancreatic cancer.
Immunovia is working on a diagnostic multiplexing serum test for early detection of pancreatic ductal adenocarcinoma.
Reccan Diagnostics is investigating a serum biomarker panel for pancreatic cancer. This project has reached clinical validation.

Liver cancer
Hepatocellular carcinoma (HCC) is responsible for causing over 700,000 deaths annually. HCC diagnosis is usually achieved using biomarkers and early diagnosis is critical for successful treatment. Today, only 10% of HCC patients are diagnosed at an early stage and there is a significant unmet need for diagnostic markers enabling early detection.
AroCell is developing a screening test based on measuring TK1 levels to monitor cancer therapy with activated T-cells for liver cancer. This project is currently in clinical validation.
Ascelia Pharma, detection and localization of primary liver cancer. Clinical validation of this project is on-going.
Glycobond has developed an ELISA-based assay that detects aberrant and cancer-specific glycosylation on alpha-1 acid glycoprotein. The protein is secreted into the blood stream where analysis can be performed on a simple blood sample. This product is launched.

Kidney or renal cancer
The two most common types of kidney cancer are renal cell carcinoma and transitional cell carcinoma. The different types of kidney cancer have different long-term outcomes and need to be staged and treated in different ways.
Akuru Pharma is using a bioinformatics platform for identification of novel surface molecules that can serve as biomarkers for renal cancer. This project has reached clinical validation.
Elypta is developing response monitoring and recurrence detection of renal cell carcinoma.

THE FIGHT AGAINST INFECTIOUS DISEASES

Sweden is deeply committed to the global fight against the development of multidrug resistant pathogens. In 2016, the Swedish government presented the Swedish strategy to combat antibiotic resistance. The Public Health Agency of Sweden contributes to the Global AMR Surveillance System through both the WHO and bilateral cooperation with e.g. India, China and EU. The Unit for Antibiotics and Infection Control of the Agency has in fact been designated as a WHO Collaborating Centre for Antimicrobial Resistance Containment.

Serious bacterial infections need to be treated rapidly to maximize a patient's chance of survival. In some infections, such as ventilator associated pneumonia and sepsis, and in certain critical situations, minutes can matter. Traditional bacterial identification relies primarily on culture-based methodologies requiring 12 to 24 hours for isolation and an additional 24 to 48 hours for species identification. In the absence of rapid diagnostics, empiric therapy, based on an "educated guess" as to the causative agent of the infection, has become the standard.

A benefit of adopting precision medicine for bacterial and viral infection is that improved diagnostics will help drive new drug development for novel antimicrobials and antivirals, particularly agents to be reserved for resistant pathogens or agents that are intended for use only against a limited range of pathogens. New, rapid diagnostics can support development of narrow spectrum agents and targeted therapy that will generate new business models for antibacterial and antiviral agents, to focus treatments to the right patients at the right time.

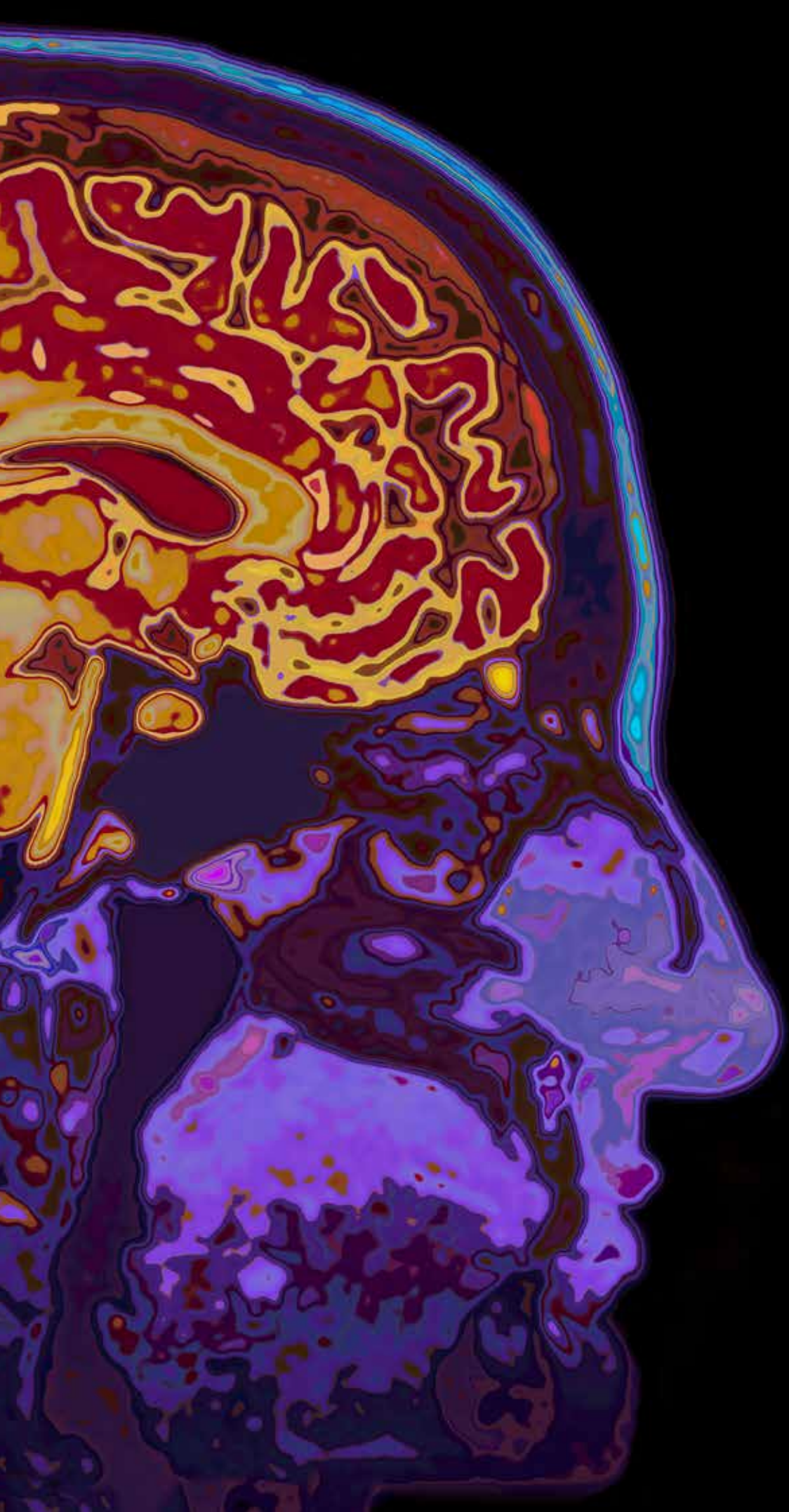
The development of transformational diagnostics and biomarkers that can easily be used to diagnose infections directly from clinically relevant specimens should focus on features such as being inexpensive, simple, rapid and having a high degree of accuracy. Furthermore, being able to distinguish both bacterial and viral etiologies as well as colonizing organisms from infecting pathogens is also crucial to future developments.

A number of Swedish companies are developing new tests and platforms to push diagnostics to the next level. These are shown in the table below:

A number of Swedish companies are developing new tests and platforms to push diagnostics to the next level.

Company	Pathogen	Methods	Application
1928 Diagnostics	Bacteria	Software platform for whole genome sequencing data.	Antibiotic resistance detection and surveillance.
Alpha Biotech	Bacteria	PCR	Detection of Rickettsia bacteria in cerebrospinal, bronchial lavage, synovial fluid.
Apodemus	Virus	PCR, NGS, Immunology.	Presence of different viruses.
Astrego Diagnostics	Bacteria	Microfluidics, real time imaging.	Antibiotic susceptibility. Testing in urinary tract infections.
CAVIDI AB	Virus	Reverse Transcriptase assay.	Automated drug resistance testing in near-patient HIV viral load.
EMPE Diagnostics	Bacteria	Padlock probe-dependent DNA rolling circle amplification and lateral flow biosensors.	Antibiotic susceptibility testing; Detection of bacteria, virus, fungi, and other microbes.
Gradienttech	Bacteria	Microfluidics, real-time imaging.	Rapid antibiotic susceptibility testing.
Q-linea	Bacteria	Padlock probes and circle-to-circle isothermal nucleic acid amplification technology (C2CA).	Fully automated multiple antibiotic susceptibility testing.
Symcel	Bacteria	Real-time cell calorimetry.	Multiple antibiotic resistance testing.

BIO-MEDICAL IMAGING PLAYS A CRITICAL ROLE IN PRECISION MEDICINE



Imaging in the era of precision medicine

Biomedical imaging plays a critical role in precision medicine including screening, early diagnosis, guiding treatment, evaluating response to therapy, and assessing likelihood of disease recurrence.

Precision medicine aims to identify and employ the specific biomedical problem of an individual patient's disease by integrating detailed information from multiple sources in a holistic manner. Biomedical imaging techniques and imaging-guided interventions can link basic molecular studies with phenotypic clinical manifestations of disease to promote an accurate diagnosis, to be followed by a tailored and minimally invasive therapy and adequate response assessment.

Molecular imaging enables the visualization of the cellular functions and the follow-up of the molecular processes in living organisms. This technique also contributes to improving the treatment of medical disorders by optimizing the pre-clinical and clinical tests of new medication. *Medical imaging* is the process whereby internal structures, often hidden by skin and bones, can be revealed to diagnose and treat disease.

New, exciting imaging technologies, Swedish companies are working on are in already existing imaging fields such as microscopy techniques, X-ray technology, computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Much of this research and development is devoted to improving the output from molecular and medical imaging – digitalization of images gives better resolution by using new software, machine learning and artificial intelligence. These new or improved imaging software tools will help to detect disease early, stratify patients and provide greater possibilities for giving better and more precise diagnoses.

Machine learning and artificial intelligence

Because of the growing volume and complexity of imaging data, new software algorithms will be required to help researchers handle the most essential patient data to enable patient stratification. To achieve this goal, there is a demand to develop machine learning techniques and artificial intelligence. A machine with artificial intelligence (AI) is any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. An AI-machine has abilities to ”learn” and ”solve problems”. There are great expectations of AI, both in a number of medical settings as well as within many other research areas.

Machine learning software solutions have implications in image-intense clinical departments such as radiology, breast imaging, pathology, orthopaedics, and cardiology but also other areas including the needs of dermatology and ophthalmology departments. Machine learning and AI will be instrumental in the analysis of the vast number of images emanating from the analysis of microscopy slides. The traditional glass slides are converted into digital slides that can be viewed, managed, shared and analysed on a computer monitor to achieve even better, faster and cheaper diagnosis, prognosis and prediction of cancer and other diseases.

CADESS develops cloud-based imaging analysis software and decision support systems for hospital and commercial pathology laboratories involved in diagnosis and prognostication of prostate cancer. *ContextVision* is currently developing decision support tools, based on new machine deep learning, to quickly identify relevant image slides and provide automatic calculations and evaluations of tumour stages. *Gnosco* is working on an algorithm for image recognition for early detection of melanoma and *Doctrin* is involved in a project with deep learning image recognition

used to identify potential malignant melanomas. In the field of lung cancer, *Corpus Data & Image Analysis* is developing methods for pattern recognition by machine learning in medical imaging of lung nodule screening

Elekta, *Sectra* and *Hermes Medical Solution* are among the many Swedish companies heavily involved in developing a number of imaging software methods where machine learning and AI are essential components. Their software enables processing, archiving, integrating, and visualising imaging data from different imaging modalities and devices within molecular imaging, radiology and MR analysis.

MR imaging and CT scanning

MRI, magnetic resonance imaging is a medical application of NMR, nuclear magnetic resonance. Computed tomography (CT) makes use of computer-processed combinations of many X-ray measurements taken from different angles to produce cross-sectional images. Compared to CT, MRI scans take longer and are noisier but also do not carry the risk of exposing the patient to ionizing radiation. MRI is the investigative method of choice for a number of tissues and organs due to its superior soft tissue contrast, and that it can be used for improved organ or tumour definition, for example, of the brain. It has a role in the diagnosis, staging, and follow-up of different tumours.

Development of new MRI and CT processing methodology

By using new software algorithms, a single, rapid MR scan can be synthesized to generate a range of reproducible images. Standardized, rapid MR scanning and tissue segmentation could decrease MR examination costs significantly and also provide a more accurate patient follow-up. There are a number of companies active in this sector in Sweden.

AMRA Medical is an international digital health company with a technogly that transforms images from a rapid, whole-body MRI scan into precise, 3D-volumetric fat and muscle measurements. *Eigenvision* is developing an automated system for quantification of skeletal tumour burden by combining the information from a PET image, a CT image and bone segmentation software. *Spectronic Medical* is working on the development of advanced image analysis products for health care and medical industry. The machine-learning driven algorithm creates synthetic CT images with organs-at-risk delineations from standard MR images. *Synthetic-MR* is creating a software for synthetic MRI where conventional contrast images can be synthesized, and tissues can be recognized automatically with synthetic tissue mapping, providing objective, quantitative, decision support. *Medviso* is developing image processing algorithms for both MRI and CT in cardiovascular imaging.

There are also a number of ongoing projects for improving contrast agents for MRI. *Ascelia Pharma* is developing a contrast agent which enables enhanced MRI images, especially where use of gadolinium-based contrast agents may be medically inadvisable or cannot be administered.

Further innovative developments include those being made by *Spago Nanomedical*, working on nanomaterials with paramagnetic manganese ions that selectively and passively accumulate in tumour tissue via the EPR-effect. This allows a longer time-window for tumour visualization with MRI than that possible with clinically available small-molecule MRI-contrast agents.

PET

Positron Emission Tomography (PET) is a nuclear medicine technology for non-invasive, real-time 3D-imaging of physiological processes in the body. The radioactive isotope in the PET-ligand is measured as it decays.

Confirmation by PET-ligand imaging markers to ascertain that drugs reach their targets is central to successful clinical proof-of-concept testing. By extension, the PET-ligand may be labelled with therapeutic radionuclides to target and treat a particular disease. The PET-ligand can therefore be used both for diagnostic, as well as therapeutic purposes. This dual use of a PET-ligand is termed ”theragnostics”.

This means that imaging and diagnosis of the disease can be effectively followed by personalised treatment utilizing the same targeting molecules. Hopes are in the future that cyclotrons, needed for generating the radioisotopes used in PET-ligands, will be available at more medical centres and thus allowing PET imaging techniques to be used more extensively than today.

A number of Swedish companies are actively developing PET-ligands, some of which are also designed to work in theragnostic PET-ligand imaging. These include: *Affibody*, *Antaros Medical*, *Ascelia Pharma*, *Athera Biotechnologies*, *BioArctic*, *DanPET*, *Diaprost* and *Respiratorius*.

Truly Translational (as Truly Labs) is currently engaged in the development of pre-clinical imaging biomarkers for MRI, CT and PET for lung fibrosis. They collaborate with researchers at Lund University in the European project TRISTAN and are funded in part by the Innovative Medicines Initiative (IMI).

Advanced imaging with Elekta and Sectra, two global Swedish enterprises

Elekta was founded in 1972 by the Swedish neurosurgeon Lars Leksell, the inventor of the Gamma Knife. Elekta today is active in several more areas than stereotactic radiosurgery; e.g radiation therapy, brachytherapy, advanced imaging, oncology informatics, and treatment planning. The equipment and software are used to improve, prolong and save the lives of people with cancer and brain disorders. Elekta is now working with future technologies for cancer care, like AI-based clinical decision support system but also with magnetic resonance radiation therapy (MR/RT). MR/RT enables clinicians to confidently see and track difficult to visualize soft-tissue anatomies. More than 6,000 hospitals worldwide are using Elekta’s technology. Elekta employs 3,600 people around the world, with headquarter in Stockholm, Sweden

Sectra, founded in the late 1970s, works with translational imaging by integrating findings in different imaging disciplines in the clinical workflow, primarily radiology and pathology. Sectra is also active in medical informatics, in particular imaging informatics in medicine, as well as interactive machine learning and AI-based decision support in imaging diagnostics. Sectra’s ties with the research community remain strong. The Center for Medical Image Science and Visualization in Linköping, the Karolinska Institute in Stockholm, Lund University, Utrecht University in the Netherlands and University Hospitals in Cleveland in the US are a few examples of Sectra’s research partners. More than 1,700 healthcare providers worldwide currently use Sectra’s systems and services. The headquarter is located in Linköping, Sweden.

PFIZER PRECISION MEDICINE

Photo: AMRA

Anders Mälarstig,
Human Genetics Director,
Pfizer Worldwide Research and Development

While Pfizer's internal research activities are based at our sites in the United Kingdom and on the East and West coasts of the United States, equally important are our many partnerships with scientists all over the world. Several such partnerships involve new exciting precision medicine technologies and approaches that build on the amazing opportunities that now exist with genetics, proteomics, health informatics in combination with biobanks, mobile sensor technology and deep learning for analysis of vast amounts of data. Sweden and the Nordics region are important to us, not only because of the unique nation-wide disease registries and biobanks but also because several novel precision medicine technologies were born in the region.

Working with AMRA, a company specialising in MR image analysis based in Linköping, Sweden, we are mapping the relationship between fat and muscle distribution in the body and metabolic health in participants from the UK Biobank, using AMRA's unique platform for body composition profiling. Pfizer is also working with technology from the Uppsala, Sweden based company Olink Proteomics to profile patients in Pfizer trials or from population based studies of disease.

In another study, we are working with scientists at the *Lund University Diabetes Centre* to disentangle the complexity of diabetes –a chronic condition with severe complications and increasing prevalence. Beyond the well-known types of diabetes, type-1 and type-2, a recent study suggests that there may be 5 or more subtypes of diabetes, can be hypothesised that new treatments tailored to each respective subtype would be more effective than broad targeting.

In 2014, Pfizer entered into a research collaboration with the *Centre for Molecular Medicine, Karolinska Institutet*. The work, which is conducted in close collaboration with the academic scientists, aims to characterise biological pathways that may be amenable to therapeutic intervention and define patient populations that are more likely to respond to emerging drug candidates. For example, it is known that only 1/3 of patients with rheumatoid arthritis (RA) respond well to TNF-alpha inhibitors but so far no reliable biomarkers for predicting drug response are available. By deep clinical and molecular characterisation of patient samples from non-responders we are hoping to understand what disease mechanisms that are not addressed with current treatments in RA, which in turn will guide development of new treatment approaches.

Last but not least, Pfizer recently completed a study in collaboration with *Region Skåne*, which involved deep profiling in 1,550 patients in the BioFinder study of dementias. Proteomic profiling has numerous applications, including finding the right patient population for a clinical trial, predicting response to therapies and discovery of new drug targets. For the latter, we are working with 20 international academic groups in the *SCALLOP consortium* to discover protein biomarkers that also cause disease by combining genetics and proteomics.

Working together for a healthier world

At Pfizer, we apply science and our global resources to bring therapies to people that extend and significantly improve their lives. We strive to set the standard for quality, safety and value in the discovery, development and manufacture of health care products. Our global portfolio includes medicines and vaccines as well as many of the world's best-known consumer health care products. Every day, Pfizer colleagues work across developed and emerging markets to advance wellness, prevention, treatments and cures that challenge the most feared diseases of our time. Consistent with our responsibility as one of the world's premier innovative biopharmaceutical companies, we collaborate with health care providers, governments and local communities to support and expand access to reliable, affordable health care around the world. For more than 150 years, we have worked to make a difference for all who rely on us.

Visit us at www.pfizer.com.

Olink and Pfizer collaboration

New findings on the role of proteins in cardiovascular diseases

In collaboration with researchers from Pfizer R&D, and a research group from the Unit for Cardiovascular Medicine at Karolinska Institutet, Olink Proteomics innovative automated analytical methods have enabled systematic large-scale studies of hundreds of plasma proteins in large patient groups. The researchers measured 92 proteins in blood from 3,400 patients with diabetes and high body mass index. The biomarkers identified a large number of genetic mechanisms that control the production of proteins in blood and mapped which of these proteins can play an active role in cardiovascular diseases. Some are particularly interesting to identify as they can serve as a target for new drugs.

An innovative provider of protein biomarker discovery and development solutions for precision medicine

Olink was founded in 2004 in Uppsala. Following the early successes of its PEA-based high-multiplex immunoassay panels, the company went through a split in 2016 so that Olink Proteomics could focus entirely on this biomarker discovery platform.

In recent years, the company has more than tripled in size, established a sales presence in several key European countries, opened a US office and service lab in Boston and is currently planning to establish a first foothold into Asia. During this time, Olink Proteomics has developed more than a dozen biomarker panels totalling around 1000 validated protein assays.

Partnering with several independent service labs across the US and Europe, Olink has made its technology widely accessible: almost 450 000 samples have now been run globally using the Olink platform. Olink Proteomics continues to expand its global business, which achieved sales of more than 120 million SEK in 2017.

Cardiovascular diseases are the number 1 cause of death globally: more people die annually from cardiovascular diseases than from any other cause. (WHO)

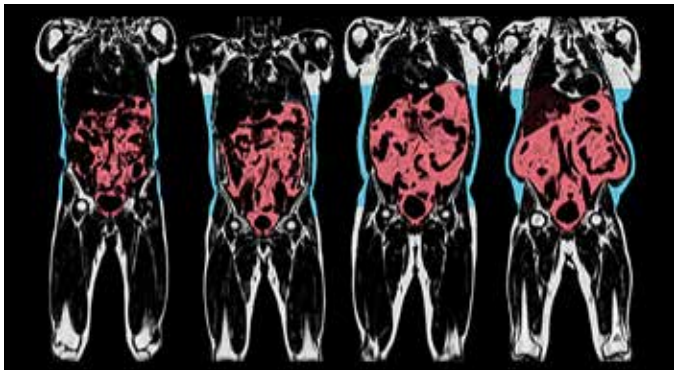


Photo: AMRA

Four men with the same body mass index (BMI).
Different Body Composition. Different Metabolic Risk.

AMRA and Pfizer Collaboration

Unlocking New Insights on the Road to Precision Medicine

In 2015, AMRA announced an international collaboration with Pfizer Inc. to assess fat and muscle measurements from MR images in 6,000 subjects through the UK Biobank registry. The objective of the collaboration was to provide a better understanding of the relationship between body composition and the risk for obesity-related disease, as well as a broader understanding of conditions linked to body composition. Following the Pfizer collaboration, the company launched a Global Co-Marketing Agreement with GE Healthcare in 2016. In 2017, the company also received 9 MUSD from Pfizer Venture Investments, Novo Seeds, and Industrifonden, which supported its operational expansion into the US.

In these years, AMRA has also received several impressive awards and recognitions, including: Nordic Star Award 2015; three consecutive years on Sweden's Top 33 List; Scrip Pharma Award finalist as "Best Technological Development in Clinical Trials, Patient-Focused" 2016; Winner of Sweden's DI Digital Startup Tour 2016; Clinical and Research Excellence Awards finalist "Best Patient-Focused Technological Development" 2017; and one of Europe's Top 20 Health & Medtech Startups in 2018.

AMRA was founded in 2010 as a spin-off of the Center for Medical Image Science and Visualization at Linköping University, Sweden. The company is the first in the world to transform images from a rapid, 6-minute whole body MRI scan into precise, 3D-volumetric fat and muscle measurements. AMRA is the only company that offers an individualised, holistic approach to understanding the relationships between fat, muscle, and the development of disease. This is the game-changer, a disruptive technology that will become the new global standard in understanding our bodies, in deciding upon and tracking treatments, in choosing who should participate in a clinical trial, and in identifying who is at highest risk of developing metabolic diseases. Thus, AMRA originated and operates with precision medicine in mind, changing health care, one person at a time.

Cutting-edge technologies in biopsy

Biopsies – sampling of matter from the body – are prerequisites in the process of determining a medical diagnosis and/or evaluation of an indication for treatment.

Tissue biopsies

Solid tumour tissue biopsy is currently the gold standard as a source for clinical molecular analyses. Regular biopsies can be intrusive and may result in associated side effects, such as bleeding or infection.

Tissue biopsies provide essential information, such as the histology and grade of the tumour, and other tumour characteristics necessary to determine the best choice of treatment. However, the quality of the biopsy is dependent on the local doctors performing biopsies; in the MATCH trial study, done in the US during 2015-2016, researchers found that 10 to 20 percent of the samples did not yield enough cancer tissue for DNA testing, didn't have enough malignant cells to analyse, in most cases because the biopsy had been poorly done. Consequently, there is a need for improvement of tissue sampling, specifically of small lesions and other hard-to-sample cases, such as deeply situated tumours, so that an earlier and more accurate cancer diagnosis can be achieved.

BiBBInstruments and *NeoDynamics* are examples of two Swedish companies who are refining the traditional method of collecting biopsies from solid biological tissues. Both companies are developing new instruments for earlier and more accurate diagnosis for the most common forms of tumours.

Liquid biopsies

Due to their non-invasive nature, liquid biopsies are becoming increasingly popular.

Liquid biopsies can help clinicians screen and detect disease early, stratify patients into the most suitable treatment groups, provide real-time monitoring of treatment response and resistance mechanisms, and an estimated prognosis. The source of liquid biopsy can vary and includes, among others: blood, cerebrospinal fluid, bronchial lavage, synovial fluid and urine.

Liquid biopsies can serve as a standalone biopsy or as an important adjunct to invasive biopsies. Molecular profiling of circulating molecules or cells in plasma or serum is regarded as a major advance and has led to the successful introduction of several non-invasive multi-marker tests into the clinic.

The analysis of circulating tumour cells (CTC), or their DNA (known as cell-free DNA, or cfDNA) is a rapidly expanding field in liquid biopsy. The CTC or cfDNA can be analysed for the presence of mutations in cancer-causing genes, and the proportion of DNA carrying these mutations can be monitored over time with multiple blood tests. There are a number of Swedish companies developing new DNA/RNA-assays based on detection and analysis of CTC and cfDNA from blood: *iCellate Medical* has developed methods for isolation and analysis of CTC and cfDNA; *Saga Diagnostics* is developing a test to quantify cfDNA; *Olink Bioscience* has a detection platform for liquid biopsies in which cfDNA can be analysed; *TATAA Biocenter* is developing rare mutation detection methods for cfDNA as well as single cell expression profiling. *Truly Translational* is involved in a joint project in the detection of CTC together with *Phase Holographic Imaging*, *ImaGene-iT*, Malmö University, Lund University and Umeå University; *CRAY Innovation* is working on developing cancer risk assessment methods to detect loss of chromosome Y in blood.

Further examples of Swedish companies active in developing methods to analyse other biomarkers in blood or plasma include: *Biovica* who is developing tests for the analysis of enzyme activity in blood serum samples by the incorporation of bromodeoxyuridine in synthetic DNA strands; *Elypta* who is developing a liquid biopsy platform for detecting metabolites specifically deregulated in cancer; *Olink Proteomics* which have an automated analytical method enabling systematic large-scale studies of hundreds of plasma proteins; *Q-linea* is working on the development of a platform for identification of, and antibiotic susceptibility testing of pathogens directly from blood, without the need for traditional blood culturing.

Breath analysis

The potential of *exhaled breath sampling* and analysis has long attracted interest for medical diagnosis and disease monitoring. This interest is attributed to its non-invasive nature, access to an unlimited sample supply (i.e. breath), and the potential to expedite a rapid patient diagnosis.

Swedish companies, for example *SensAbuse*, are working on refining techniques for collecting exhaled metabolites. Other developments are being undertaken by companies such as *PExA* and *Chromalytica* to improve the analysis of metabolites in exhaled air and to create large genomic, proteomic and biomarker datasets. *Molecular Fingerprint Sweden* is currently refining the technology of Label-free IR spectroscopy to work with the analysis of exhaled air.

Photo: Biovica

Thermo Fisher Scientific

Serving science to enable better health outcomes

Researchers and clinicians are helping unlock individuals' complex molecular profiles through a wide range of "-omics" technologies, a critical component to advance precision medicine efforts worldwide. Thermo Fisher Scientific is committed to facilitating this collaboration and the sharing of information to support the larger goal of bringing the right medical interventions to the right patients at the right time.

Thermo Fisher's longstanding partnership with Novartis is an example of its commitment to accelerate precision medicine. The U.S. Food and Drug Administration (FDA) has approved a new cell therapy for the treatment of patients up to 25 years of age with B-cell precursor acute lymphoblastic leukemia that is refractory or in second or later relapse. The Novartis chimeric antigen receptor T cell (CAR-T) cell therapy, Kymriah[1], is the first FDA-approved CAR-T immunotherapy, and uses specifically developed Cell Therapy Systems Dynabeads[2] technology, part of Thermo Fisher's Cell Therapy Systems portfolio. The magnetic beads isolate, activate and expand T cells that have been genetically engineered to recognize and fight cancer cells in each individual patient.

SwedenBIO asked Alan Sachs, Chief Scientific Officer at Thermo Fisher, about how Thermo Fisher currently plays in precision medicine and what role they plan to play in the future.

Thermo Fisher is committed to partnering with governments, academia, healthcare and the wider life sciences industry to advance precision medicine. The company invests in research & development to develop technologies that support a changing healthcare infrastructure, where personalized molecular data is foundational to prevention, diagnosis and disease management.

"We invest in research & development to develop technologies that support a changing healthcare infrastructure"

– When you look across our portfolio, we have unique capabilities scanning the areas of population stratification, translational research, molecular diagnostics and targeted therapeutics. Through joint projects, our customers can participate in and contribute to precision medicine studies. Our precision medicine science centers are designed to be open laboratory settings that allow both our internal staff and our collaborators to continuously improve.

Thermo Fisher focuses on innovative technologies that are designed to lower healthcare costs while improving patient outcomes to support their relentless pursuit of clinical utility. They also have digital science efforts focused on fostering knowledge and data sharing amongst stakeholders globally to advance precision medicine.

– In the future, I would expect that physicians will have available to them through their patient's electronic health record not only their genetic risks, but also summarized data derived from the patient's "on board" monitoring systems, including activity measures, biochemical measures, and cardiovascular measures.

"Our precision medicine science centers are designed to be open laboratory settings that allow both our internal staff and our collaborators to continuously improve."

Alan Sachs, Chief Scientific Officer, Thermo Fisher

All of this information will be interpreted with methods using artificial intelligence tools, and presented to the physician so they can pursue the right avenues for more accurate diagnosis and/or treatment. Further testing will utilize many of the systems we build at Thermo Fisher, including metabolite, protein, and nucleic acid analysis. Ultimately, all of the test results will be combined with other clinical information to allow for even better detection, treatment, or monitoring of disease.

In your opinion, what are the main drivers of the precision medicine field?

– Better health outcomes are a main driver. Decreasing the overall cost of healthcare is another. And, the insights coming from basic and translational research is a third.

Better health outcomes will result from even better detection, treatment, and monitoring decisions by physicians. By using diagnostic tests that accurately inform on what is of interest to the physician, whether they be biochemical, imaging, or physical, the best decisions for the next steps will be reached. Since this improved performance by the physician will result in fewer patients receiving incorrect diagnoses, ineffective treatment, or insufficient information to detect disease and/or its recurrence, the overall cost of treating patients should decrease.

– And, of course, as basic and translational researchers continue to make great strides in understanding the molecular basis for disease, this information will lead to the creation of more powerful methods to detect, treat, and monitor disease.

Swedish Phadia now part of Thermo Fisher

The Swedish company Phadia was originally a part of the Pharmacia group of companies and an offshoot of the diagnostics division that developed out of Pfizer and Pharmacia & Upjohn (all Uppsala-based companies). Phadia became a global leader in allergy and autoimmunity diagnostics, and in 2011 it was acquired by Thermo Fisher and became the ImmunoDiagnostics Division (IDD). IDD has 1,600 employees worldwide, and is the world leader in in vitro diagnostics of allergy and leaders in autoimmune diagnostics in Europe. The Uppsala site is the headquarters for the IDD with 600 employees. The site develops, manufactures and markets diagnostic tests for allergy, asthma and autoimmune diseases.

Jon-Sverre Schanche, Vice President of Global R&D, ImmunoDiagnostics Division in Uppsala, Sweden

Jon-Sverre Schanche, Vice President of Global R&D, ImmunoDiagnostics Division in Uppsala, Sweden, highlights on-going projects and collaborations with Swedish organizations.

– To begin with, I would like to mention the Stockholm3 test, a project in the area of prostate cancer, where the development is done in a close public/private collaboration between academia, industry and healthcare providers. We are developing this test together with the oncologist Professor Henrik Grönberg and project leader Martin Steinberg from the Karolinska Institutet.

The test is a cancer-detecting blood test, that detects the risk of aggressive prostate cancer by combining five protein markers, more than 100 genetic markers, clinical data and a proprietary algorithm. The latest data showed that the non-invasive blood test increases the detection of hazardous, treatment-intensive prostate cancer by about 20%, and reduces the number of unnecessary biopsies by 50% compared to current clinical practice. The method may have a significant positive impact on society by reducing individual harm from over-diagnosis, mortality and overall healthcare costs. The Stockholm3 test has been tested on nearly 60,000 men from Stockholm in the STHLM3 study. The project has been developed with the support of European Institute of Technology (EIT) Health and in part financed by Stockholm County Council.

– We also have an ongoing collaborative project on early diagnosis of rheumatoid arthritis (RA) together with Professor Lars Klareskog, Karolinska Institutet. This project originates from the Innovative Medicines Initiative (IMI) project ”Be The Cure” and now we will further explore the findings and validate potential new biomarkers. The outcome for RA-patients will be a new method of early diagnosis, and thus enabling of early treatment for RA. We have indications that if you start treating these patients early, ideally prior to any symptoms, this could result in slowing the onset of symptoms which would result in increased life quality for the patients as well as large cost savings for the healthcare system.

The project ”Be The Cure” gained new insights in the pathology of Rheumatoid Arthritis (RA), a chronic disease affecting about 1% of the population. This pan-European project included patient cohorts from many countries and close to 3500 biospecimens were tested. Thermo Fisher provided a platform for multiple analysis of antibody specificities and assays for clinical evaluation for known autoantibodies specificities.

– I would also like to mention ISAC (Immuno Solid-phase Allergen Chip) development as the first multiplex in vitro diagnostic tool, a chip with 112 different allergens that is based exclusively on allergen components.

By a single, 40 microlitre blood sample, it is possible to distinguish between more serious allergies, like life-threatening nut- or peanut allergies, from more harmless allergies. ISAC enables allergy specialists to understand a patients complex allergy sensitization patterns to propose treatments and/or avoidance or life-style changes.

If companies are interested in approaching you with new ideas for collaboration what should they consider before reaching out?

– There are many companies and researchers coming with their ideas and projects, and we are happy to collaborate. First, the project must be one of your company’s main activities, not a small side project you don’t prioritize yourself. Second, we prioritize projects that overlap or complement research areas of Thermo Fisher.

Finally, what do you consider are the benefits with being situated in Sweden?

– In my experience, the collaborative climate is excellent, including easy access to scientific specialists as well as consultants in various areas. We collaborate with both companies and academic groups primarily in the Uppsala/Stockholm region and I have met highly trained and skilled people, doing a tremendous work within the scientific community.

In Sweden, you’ll find well-synchronized registers with good infrastructure. There are a number of excellent Swedish registers containing longitudinal data as well as the Swedish national health care registers with data from many thousands of patients. In addition, there are extensive biobanks; containing blood samples, biopsies, synovial fluids, etc.

– Sweden is well suited for developing future Precision Medicine methods by combining the information in the registers, the biobanks, the top-of-the line analytic instrumentation the Swedish research community provides, as well as the Swedish advances in computing research.

About Thermo Fisher Scientific
Thermo Fisher Scientific Inc. is the world leader in serving science, with revenues of more than $20 billion and approximately 65,000 employees globally. Our mission is to enable our customers to make the world healthier, cleaner and safer. We help our customers accelerate life sciences research, solve complex analytical challenges, improve patient diagnostics, deliver medicines to market and increase laboratory productivity. Through our premier brands – Thermo Scientific, Applied Biosystems, Invitrogen, Fisher Scientific and Unity Lab Services – we offer an unmatched combination of innovative technologies, purchasing convenience and comprehensive services.

1. Kymriah is a trademark of Novartis.
2. Dynabeads products are for research use only or for the manufacturing of cell-, gene- or tissue-based products.

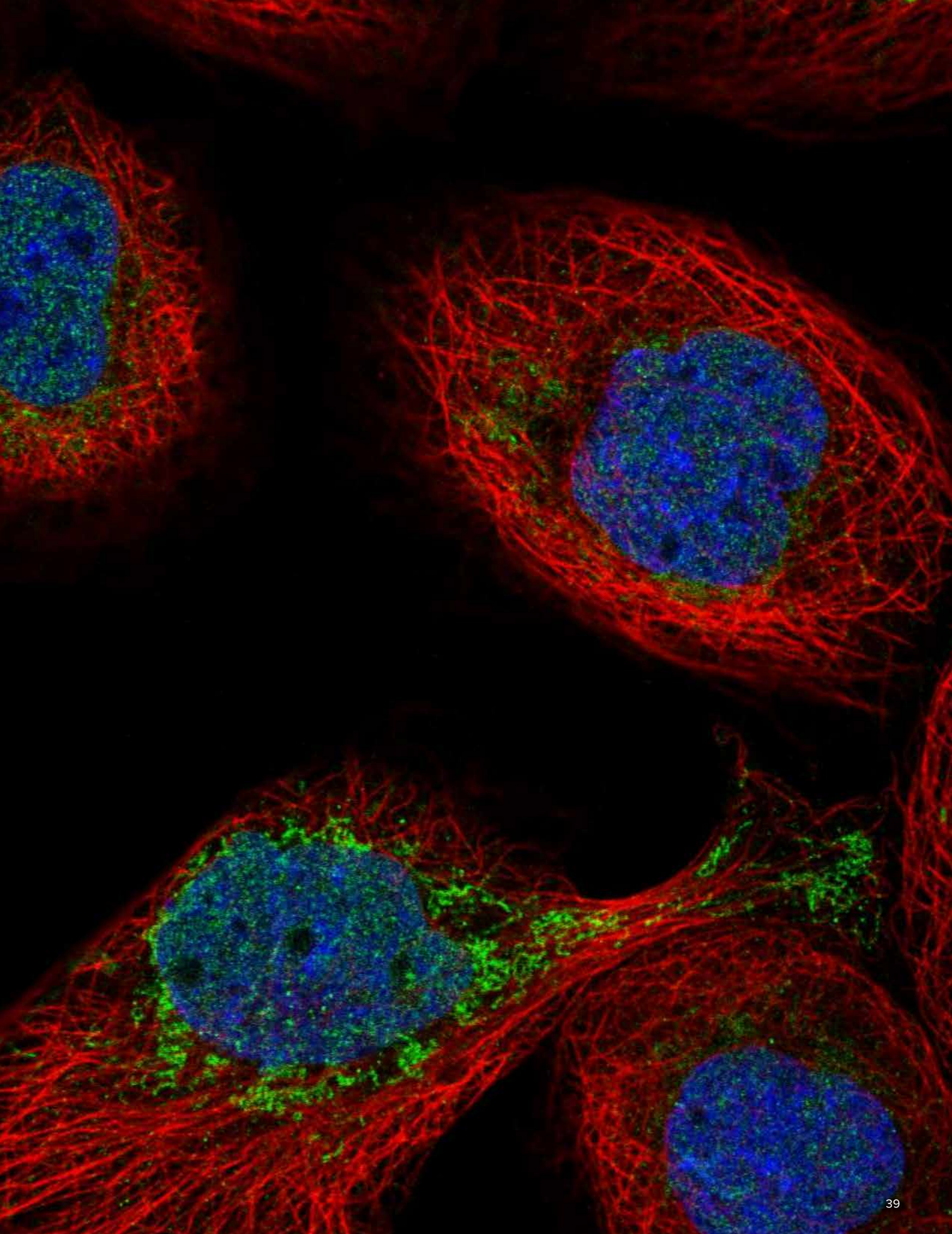
“We collaborate with both companies and academic groups primarily in the Uppsala/Stockholm region and I have met highly trained and skilled people, doing a tremendous work within the scientific community.”

Jon-Sverre Schanche, Vice President of Global R&D, ImmunoDiagnostics Division in Uppsala, Sweden

Photo: Thermo Fisher

In an effort to continue driving innovation in precision medicine,

THE SWEDISH GOVERNMENT PROVIDES GRANTS TO SEVERAL SWEDISH NATIONAL PLATFORMS



RESEARCH INFRASTRUCTURES IN SWEDEN

In an effort to continue driving innovation in precision medicine, the Swedish Government provides grants to several Swedish National Platforms. Private initiatives, such as the Knut & Alice Wallenberg Foundation have also generously pledged significant funding towards developing and making available new scientific tools to the Swedish academic research community.

The most recent governmental initiative, Genomic Medicine Sweden, is a first step in the long-term implementation of precision medicine in the Swedish healthcare system and will be implemented via medical genomics centres based at the country's university hospitals. This initiative will eventually lead to and provide access to world-leading diagnostics and precision medicine, primarily focused on hereditary diseases and cancer, and at a later stage, on other more complex diseases and microbiomics.

The initiative builds on already existing structures in the Swedish system, such as national biobanks, regional cancer centers and national quality registries, and will act as a national resource for academia and industry for the development of pharmaceuticals, diagnostics and software.

Science for Life Laboratory – accelerating research in molecular precision medicine

Funded by the Swedish government since 2010, the national research infrastructure Science for Life Laboratory (SciLifeLab) is operated jointly by its four host universities: the Royal Institute of Technology (KTH), the Karolinska Institute, Stockholm University and Uppsala University.

The hub functions as an accelerator for research into molecular precision medicine and precision healthcare across all sectors of the life sciences. It provides a world-class biomolecular research infrastructure by facilitating pioneering technology development and research and promoting cross-disciplinary collaboration. The organization operates 10 technology platforms and aims to provide academic as well as industry scientists throughout Sweden access to the latest research tools and technologies.

SciLifeLab provides ready access to nearly all key technologies required for molecular precision medicine research. The platforms are open and available to all researchers in Sweden and support some 3000 projects annually. Projects originate from an academic research base, or as a collaboration between the healthcare system and industrial sector, at both a national and international level.

The platform's services and expertise span areas of competence including genomics, transcriptomics, proteomics and metabolomics, microbiome studies, single cell biology, structural biology, molecular and cellular imaging as well as translational platforms to advance diagnostic and therapeutic applications.

SciLifeLab technology platforms

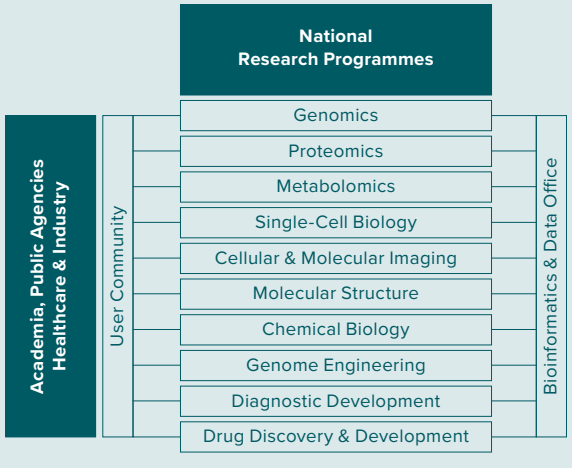


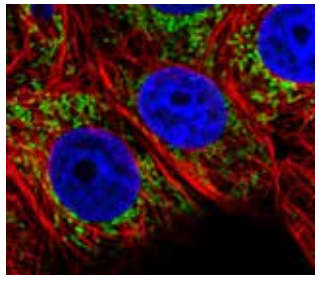
Photo: Mikael Wallerstedt / SciLifeLab

The Human Protein Atlas (HPA)
The Human Protein Atlas is a Swedish-based programme initiated in 2003 with the ambitious and far-reaching goal to map all the human proteins in cells, tissues and organs using integration of various "-omics" technologies, including antibody-based imaging, mass spectrometry-based proteomics, transcriptomics and systems biology.

The HPA portal programme was recently selected as a European core resource due to its fundamental importance for the wider life science community. The programme has so far contributed to several thousands of publications in the field of human biology and disease.

The portal serves as a publicly available database with millions of high-resolution images showing the spatial distribution of proteins in normal human tissues and different cancer types, as well the sub cellular localisation in single cells. It consists of three separate parts, each focusing on a particular aspect of the genome-wide analysis of the human proteins: the Tissue Atlas showing the distribution of the proteins across all major tissues and organs in the human body, the Cell Atlas showing the subcellular localisation of proteins in single cells, and finally the Pathology Atlas showing the impact of protein levels for survival of patients with cancer.

The HPA consortium is funded by the Knut and Alice Wallenberg Foundation, and led by Professor Mathias Uhlén.



The "Cell Atlas" is one of the three interactive databases in the Human Protein Atlas. It contains a multitude of high-resolution confocal images and provides insights in the spatial distribution of proteins within cells, based on mRNA expression profiles. The databases are open to scientists both in academia and industry.

National Biobanks and Quality Registries

The introduction in Sweden of personal identification numbers in 1947, together with the nation's long standing heritage of high-quality biomedical research, has enabled the development of comprehensive patient registers and functional biobanks. The Swedish government is investing in the country's biobanks and registries by an increase in funding to the Swedish Research Council of SEK 50 million for the period from 2018 to 2020.

Biobank Sweden, supported by the Swedish Research Council, aims to optimise the collection, storage, withdrawal and use of biobank samples and data to benefit medical research, patient care and the life science industry. Currently, around 150 million samples are stored in Swedish biobanks for healthcare, quality assurance and/or research purposes.

The Nordic Council of Ministers and other actors have initiated and supported a large number of Nordic policy groups, networks, pilot projects and surveys for research and research infrastructure related to the domain of health and welfare. The Nordic countries' ambition is to provide researchers access to high-quality study materials in all the Nordic countries by having patient samples stored in biobanks together with associated longitudinal, environmental and clinical information.

A SELECTION OF NATIONAL RESEARCH INFRASTRUCTURES

Analytic Imaging Diagnostic Arena (AIDA)
Analytic image-based diagnostics aiming for large scale usefulness derived from artificial intelligence and big data analytics in healthcare.

Diagnostics Development and Clinical Genomics Facilities
Translating next-generation sequencing into clinical use.

National Bioinformatics Infrastructure (NBIS)
The Swedish node in ELIXIR – the European infrastructure for biological information.

National Genomics Infrastructure (NGI)
Next generation sequencing and genotyping.

National Microscopy Infrastructure (NMI)
Use and support of advanced microscopy in life science.

Swedish Metabolomics Centre
Metabolomic analyses in biological tissues and fluids.

Swedish National Infrastructure for Computing (SNIC)
User support for large scale computation and data storage.

Swedish National Mass Spectrometry Facility (BioM)
Biological mass spectrometry and proteomics.

Swedish NMR Centre
State-of-the-art nuclear magnetic resonance instrumentation and methodology.

Photo: Johan Spinnell / SciLifeLab

The Swedish Research Council – facilitating the big data revolution.

The Swedish Research Council (SRC) is the governmental agency that provides funding for basic research of all scientific disciplines as well as funding for research infrastructures of national interest. The objective is for Sweden to be a leading research nation, thereby contributing to the development of society. For personalised medicine to become a reality, it is essential to make the best use of the big data revolution.

Facilitating the use of registries and biobanks

Importantly, the Swedish government has recognised the need for the efficient use of registries and biobanks in order to reach full potential for research and innovation. The SRC has, since 2013, a specific commission to facilitate the use of registry data in research. Its focus is on establishing research infrastructures that can visualise the contents of Swedish registries and biobanks at metadata level, and also on developing other support systems for researchers. Further investments have also been made into developing research databases. In addition, the SRC has provided support to Biobank Sweden which serves as the national infrastructure for biobanking in 2017.

Coordinating open access to research data

In 2017, the SRC was also commissioned by the government to coordinate the national effort towards open access to research data. Emphasis is being put on FAIR (Findable, Accessible, Interoperable, Reusable) data management. Sensitive data will require special attention to its management in this context.

European collaboration on the agenda

In the European arena, the Swedish Research Council together with Vinnova is part of the International Consortium of Personalised Medicine (ICPerMed) that aims to align and coordinate European and international efforts within the area in order to facilitate more efficient development and implementation of Personalised Medicine.

www.vr.se

AstraZeneca

THE PRECISION MEDICINE APPROACH

The precision medicine approach – to develop innovative, targeted medicines for every individual that needs them – and to match those treatments to patients most likely to benefit from them – is now becoming a reality. AstraZeneca (AZ) uses this knowledge to develop diagnostic tests that doctors can employ to help prescribe the best treatment for each patient. Indeed, it has now become common practice for patients with cancer to be offered such diagnostic tests before their treatment plan is agreed.

AZ has launched 16 linked diagnostics in key markets, aligned to four targeted AZ treatments, for patients with some of the most challenging diseases of our time, including lung and ovarian cancers. AZ is now starting to use the same approach in respiratory and cardiovascular diseases.

AstraZeneca also harnesses the power of genomics – the study of the complete genetic blueprint for life – through the AstraZeneca-MedImmune Genomics Initiative. This strategy – to analyse 2 million genomes by 2026 – is an industry first in scale and scope. It is enabling the company to identify new targets and new biomarkers for medicines by putting genomics at the heart of drug discovery and development.

Importantly, AZ recognizes that it is impossible to achieve the ambitions alone. AZ is thus working with some of the best partners in the world – an extensive network of diagnostic companies, academic partners and genomics biotechs – to accelerate delivery of targeted medicines and linked diagnostics.

In 2017, over 90% of AZ's clinical pipeline has a precision healthcare approach, compared to 10% in 2009.

One tangible example is how AZ followed the exciting new science to explore the DNA mutations that cause cancer. AZ developed medicines targeted at mutations in epidermal growth factor receptor (EGFR) – frequently found in tumours of patients with non-small cell lung cancer. As science advanced, the company was able to develop diagnostic tests that matched patients best suited for these new treatments.

"When we started out, our ambitions were very modest. We set ourselves the goal to have just one approved diagnostic linked to a medicine within five years. Only eight years later, we have launched 16 diagnostic tests linked to four innovative, targeted medicines. We are using a much broader range of technologies – and developing them across all our main disease areas," explains Dr. Ruth March, Senior Vice President, Precision Medicine and Genomics, IMED Biotech Unit at AstraZeneca.

Only now can the science of precision medicine draw on a broad range of cutting-edge technologies: genomics, next generation sequencing, point of care devices, molecular image analysis, transcriptomics, proteomics, digital pathology, sensors, 'big data' statistical analytic techniques and artificial intelligence. These exciting developments mean that biomarkers and diagnostic tests can benefit many more patients across disease areas.

AZ has several R&D collaborations in this area in Sweden, across all AZ therapy areas. The 12-year collaboration with the PET center at Karolinska Institutet demonstrates target engagement, supports compound dose optimization in clinical trials and develops imaging biomarkers for proof of concept studies. It is also providing evidence for novel mechanisms of action and thereby supporting new therapeutic indications.

A number of on-going AZ collaborations with SciLifeLab have the aim to discover, qualify, validate and deliver biomarkers fit for clinical use. This includes biomarkers such as molecular entities (genetic, protein or metabolic signatures), imaging methodologies and functional physiological outcomes (such as EEG or other physiological measurements) as well as supporting systems biology and bioinformatics research. Other examples include modelling neuronal disease using induced pluripotent stem cells (iPSC) for biomarker identification, thus pinpointing cellular and molecular disease phenotypes and establishing cellular disease models.

Another line of research is focused on identifying circulating tumour DNA (ctDNA) to use as a personalised biomarker for treatment prediction and monitoring in prostate and breast cancer. In other projects, phenotypic asthma markers as well as sub-phenotype biomarkers in systemic autoimmune diseases are identified. Significant progress has also been made by the mapping of metabolomics and epigenetic signatures in type 2 diabetes and obesity – at rest and after exercise – to uncover novel biomarkers and targets by leveraging the SciLifeLab -omics platforms to analyse small samples of human blood and tissue. In parallel to this, the use of new hybrid systems such as integrated PET-CT and PET-MRI will provide combined information of human morphology and function.

AstraZeneca and Pelago Bioscience collaborating in the Nanoscale Precision Medicine project

One of the most recent collaborations AstraZeneca has embarked upon in Sweden in this area is the Nanoscale Precision Medicine project. It aims to reshape and align existing drug discovery pipelines with precision medicine strategies. The platform is based on testing drug efficacies in patient derived cancer cells and iPS cells at nanoscale and will represent a new paradigm for prioritizing between projects and associated drug leads. The consortium includes Karolinska Institutet, the Royal Institute of Technology, Science for Life Laboratory, AstraZeneca, Karolinska University Hospital, Labcyte, Takara Bio Europe and the Swedish company Pelago Bioscience (more on their CETSA technology on page 50).

LIST OF PROJECTS AND PRODUCTS

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
1928 Diagnostics	1028D platform	Clinical decision support for antibiotic resistant bacterial infections	Is available	Infection	Launched
1928 Diagnostics	RapiShare	Data sharing between hospitals	In-house development	Infection	Clinical validation
AcureOmics	Metabolic profiling	Diagnostic & personalized medicine			
Adduct Analys	TailorDose	Determination of the active dose of cytostatic drugs		Oncology	Clinical validation
Adduct Analys	TailorDose-CPA	Determination of the active dose of cyclophosphamide (CPA)		Oncology	Clinical validation
Affibody	ABY-025	Metastatic breast cancer, HER2 PET imaging agent	In-house development	Oncology	Clinical validation
Affibody	ABY-025	Metastatic gastric cancer, HER2 PET imaging agent	In-house development	Oncology	Clinical validation
Akuru Pharma	RCCSCAN	Imaging diagnosis for Renal Cancer	Is available	Oncology	Clinical validation
Alzinova	ALZ-201	Diagnostic for Amyloid Beta oligomers in CSF	In-house development	CNS	Feasability studies
AMRA Medical	AMRA® Profiler Research	Academic & Clinical Research			
AMRA Medical	AMRA® Profiler Research	Executive Health / Private-Pay Preventive Care			
Antaros Medical					
AroCell (publ)	TK 210 ELISA	Early stage research in drug development, Cellculture Application	Is available	Oncology	Feasability studies
AroCell (publ)	TK 210 ELISA	Monitor treatment effect of different drugs and combinations of drugs, Cellculture Application	Is available	Oncology	Feasability studies
AroCell (publ)	TK 210 ELISA	Early stage research in drug development, Xcenograft Application	Is available	Oncology	Feasability studies
AroCell (publ)	TK 210 ELISA	Monitor treatment effect of different drugs and combinations of drugs, Xcenograft Application	Is available	Oncology	Feasability studies
AroCell (publ)	TK 210 ELISA	Evaluate TK 210 ELISA as a complement in Sarcoma	Other	Oncology	Clinical validation
AroCell (publ)	TK 210 ELISA	Follow sarcoma patients during diagnosis, treatment and follow up	No answer	Oncology	Analytical validation
AroCell (publ)	TK 210 ELISA	Monitor Cancer therapy with Activated T-cells, Livercancer	No answer	Oncology	Clinical validation
AroCell (publ)	TK 210 ELISA	Monitor Cancer therapy with Activated T-cells, glioblastoma	No answer	Oncology	Clinical validation
Ascelia Pharma	Mangoral	Detection and localization of liver metastases	In-house development	Oncology	Clinical validation
Ascelia Pharma	Mangoral	Detection and localization of primary liver cancer	In-house development	Oncology	Clinical validation
Astrego Diagnostics	qUTI	System for point-of-care diagnostics of Urinary Tract Infections	Have partner/s	Infection	Feasability studies
Athera Biotechnologies	CVDefine (R)	Diagnostic kit, Identify patients of higher risk for vascular inlflammation	Is available	Inflammation	Launched
Athera Biotechnologies	CVDefine (R)	Identify patients eligible for treatment with PC-mAb	Is available	Inflammation	Launched

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Atlas Antibodies	Enhanced validation of Triple A polyclonals	Oncology	Have partner/s	Oncology	Launched
Atlas Antibodies	Enhanced validation of Triple A polyclonals	Neuroscience	Have partner/s	Other	Launched
Atlas Antibodies	Biomarker Licensing and Services	Oncology	Is available	Oncology	Other
Atlas Antibodies	Biomarker Licensing and Services	Clinical pathology	Is available	Other	Other
Axcentua Pharmaceuticals	Disease specific biomarkers for pancreatic cancer patients	Stratify patients with pancreatic patients	Is available	Oncology	Clinical validation
Axcentua Pharmaceuticals	Disease specific biomarkers for pancreatic cancer patients	Personalised medicine	Is available	Oncology	Clinical validation
Axcentua Pharmaceuticals	Pharmacogenomics using identified biomarkers	Determine which patients with pancreatic cancer to treat with Axcentua´s patent protected drug	Is available	Oncology	Clinical validation
Axcentua Pharmaceuticals	Pharmacogenomics using identified biomarkers	Personalised medicine	Is available	Oncology	Clinical validation
BioArctic	Biochemical biomarkers Alzheimer's and Parkinson's	Diagnosis and treatment biomarker	In-house development	CNS	Analytical validation
BioArctic	Antibody baset PET imaging Alzheimer's and Parkinson's	Patient identification and treatment effects	In-house development	CNS	Analytical validation
Biomotif	pI Trap Instrument	Deep Proteomics	In-house development	Other	Analytical validation
Biomotif	pI Trap Instrument	Biomarker ID and validation	Is available	Other	Analytical validation
Biomotif	pI Trap2 Instrument	Automated Deep Proteomics	Have partner/s	Other	Analytical validation
Biomotif	pI Trap2 Instrument	Automated biomarker ID and validation	Is available	Other	Analytical validation
Biomotif	De-Salinator Instrument	De-salting of biological samples prior to MS analysis	Is available	Other	
Biomotif	De-Salinator Instrument	Buffer exchange methods prior to MS	Is available		Analytical validation
Biomotif	AnESI	Automated nano-spray ESI mass spectrometry	In-house development	Other	Analytical validation
Bionamic	Software platform	Integration and analysis of antibody discovery/development data	Is available	Oncology	Launched
Bionamic	Custom data integration and analysis platforms	Fully customized tools for integration, automation and analysis of multiple experimental data sources	In-house development	Not applicable	Not applicable
Bionamic	Custom data integration and analysis platforms	Analysis and report generation for life science data	In-house development	Not applicable	Not applicable
BioReperia	PDX zebrafish methodology	Determine drug effect of growth and metastatic ability on PDX (patient-derived xenografts) in vivo	In-house development	Oncology	Clinical validation
BioReperia	PDX zebrafish methodology	Drug induced transcriptome changes	In-house development	Oncology	Analytical validation
BioReperia	PDX zebrafish analysis software	Determine tumour growth and metastasis detection	In-house development	Oncology	Analytical validation

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
BioReperia	PDX zebrafish companion diagnostics	Companion diagnostic test	In-house development	Oncology	Other
Biovica	DiviTum	Early efficacy evaluation in metastatic breast cancer	Is available	Oncology	Clinical validation
Biovica	DiviTum	Efficacy evaluation in other solid tumours	Is available	Oncology	Clinical validation
Biovica	New liquid biomarker	Pharma drug development efficacy assay	Is available	Oncology	Feasability studies
Biovica	New liquid biomarker	Clinical application as above	Is available	Oncology	Feasability studies
CADESS Medical	CADESS(TM)	Decision support solution for diagnosis and prognostication of prostate cancer	In-house development	Oncology	Analytical validation
Calmark Sweden	Neo – LDH	LDH test for newborns	Is available	Other	Other
Calmark Sweden	NEO – Bili	Bilirubin test for newborns	Is available	Other	Other
Calmark Sweden	NEO – Glucose	Glucose test for newborns	Is available	Other	Other
CartaNA	Cell type mapping	Brain cell type mapping in mouse and human brain	Other	CNS	Analytical validation
CartaNA	Cell type mapping	Immune cell mapping in tumours	Other	Oncology	Feasability studies
CartaNA	Tissue gene expression	mapping tissue RNAseq data on tissue morphology	Is available	Other	Analytical validation
CartaNA	Tissue gene expression	Studying tissue heterogeneity	Is available	Other	Analytical validation
CartaNA	Gene editing and mutations in tissues	Stydying locattion of many gene editing sites and mutations in tissues	In-house development	Other	Feasability studies
Chundsell Medicals	Prostatype	Intermediate prostate cancer	Is available	Oncology	Launched
Clinical Gene Networks	AtheroCode	Coronary and carotid Artery Disease	Is available	Cardiovascular	Clinical validation
ContextVision	DST, decision support tool	Diagnosis and progn. of prostate cancer	In-house development	Oncology	Feasability studies
ContextVision	DST, decision support tool	Lung cancer, breast cancer	In-house development	Oncology	Feasability studies
ContextVision	Ultrasound on tablets	Image enhancement on android systems	In-house development	Not applicable	Launched
ContextVision	XR	Image enhancement	In-house development	Not applicable	Feasability studies
Corpus Data & Image Analysis	DermaSuspect	Malignant melanoma diagnosis, screening instrument	Is available	Dermatology	Clinical validation
Corpus Data & Image Analysis	DermaSuspect	Skin condition characterization, screening instrument	Is available	Dermatology	Feasability studies
Corpus Data & Image Analysis	Pattern recognition methods	Lung nodule screening	Is available	Oncology	Feasability studies
Corpus Data & Image Analysis	Pattern recognition methods in medical imaging by Machine Learning		Is available	Not applicable	Other
CRAY Innovation	biomarker LOY (loss of chromosome Y in blood)	Predicting increased risk for cancer	No answer	Oncology	Other
CRAY Innovation	biomarker LOY (loss of chromosome Y in blood)	Predicting increased risk for Alzheimer's disease	No answer	CNS	Other
CyberGene	ChromoQuant STaR Optima	Prenatal QF-PCR	In-house development	Obstetrics	Launched
CyberGene	ChromoQuant AZF	Male infertility	In-house development	Other	Launched
CyberGene	ChromoQuant Optima PLUS	Pregnancy Loss – miscarriage	In-house development	Obstetrics	Launched

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
DanPET	18F-NS14490	Diagnosis & stratification of vulnerable plaque	Have partner/s	Cardiovascular	Other
DanPET	18F-NS14490	Angiogenesis	Have partner/s	Oncology	Other
DanPET	18F-NS12137	Cognitive Reserve Stratification in Alzheimer´s	Have partner/s	CNS	Other
DanPET	18F-NS12137	ADHD diagnosis	Have partner/s	CNS	Other
DanPET	NS10712	Tardative Dyskinesisa	Have partner/s	CNS	Other
Diaprost	hu11B6	Diagnostics of Prostate Cancer	Is available	Oncology	Feasability studies
Diaprost	hu5A10	Diagnostics of Prostate Cancer	Is available	Oncology	Feasability studies
Doctrin	Doctrin Flow	Digitization of Patient Journey	No answer	Not applicable	Launched
Doctrin	Diagnosis decision support	Use Machine Learning to automatically generate diagnosis suggestions	No answer	Not applicable	Analytical validation
Doctrin	Skin lesion screening	Deep learning image recognition used to identify potential malignant melanomas	No answer	Dermatology	Analytical validation
DoubleStrand Bioinformatics	software	Interactive web-based analysis suite for omics data	Is available	Not applicable	
DoubleStrand Bioinformatics	Antigen discover and profiling	Deep learning based antigen recognition (developed for client)	Have partner/s	Not applicable	
DoubleStrand Bioinformatics	Drug sensitivity analysis environment	Project: Interactive analysis and reporting for oncology drug screening (developed for client)	Is out-licensed	Not applicable	
DoubleStrand Bioinformatics	Lipid supplement optimization	Machine learning based optimization of tissue culture media lipid supplements (developed for client)	Is available	Not applicable	
Eigenvision	Computerized vision to quantify severeness of skinn diseases	Malignt melanoma	Is available	Oncology	
Eigenvision	Computerized vision to quantify severeness of skinn diseases	Rashes		Dermatology	
Elekta					
Elypta	Diagnostic kit & software	Response monitoring and recurrence detection of Renal Cell Carcinoma	Is available	Oncology	Analytical validation
Elypta	Diagnostic kit & software	Diagnosis and followup applications in prostate cancer and several others	Is available	Oncology	Analytical validation
Emotra	EDOR®		In-house development	Other	Launched
EMPE Diagnostics	mfloDx® MDR-TB	Detection of multidrug resistant Mycobacterium tuberculosis complex	Is available	Infection	Clinical validation
EMPE Diagnostics	mfloDx® XDR-TB	Detection of Extensively resistant Mycobacterium tuberculosis complex	Have partner/s	Infection	Analytical validation
EMPE Diagnostics	mfloDx® Direct-TB	Automated detection of MDR/ XDR-TB	In-house development	Infection	Feasability studies
EMPE Diagnostics	mfloDx® DoMI	Detection of 25 infections in one test	In-house development	Infection	Feasability studies
Glycobond	HepaCheC	Aid in diagnosis of HCC (hepatocellular carcinoma)	In-house development	Oncology	Launched

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Gnosco	DERMICUS	Image recognition algorithm as decision support for early detection of malignant melanoma	In-house development	Dermatology	Clinical validation
Gnosco	DERMICUS	Multidisciplinary cooperation in severe wounds through a new approach and a telemedicine platform	Is available	Dermatology	Clinical validation
Gradientech	QuickMIC	Antibiotic susceptibility testing of sepsis samples for approriate antibiotic treatment	Have partner/s	Infection	Analytical validation
HiloProbe	ColoNode	IVD test, A new dimension of lymph node status evaluation in colorectal cancer	In-house development	Oncology	Clinical validation
iCellate Medical	CTC isolation	Pharma development	Is available	Oncology	Clinical validation
iCellate Medical	CTC isolation	Complement to prostate screening	Is available	Oncology	Clinical validation
iCellate Medical	Genetic sequencing	Whole genome sequencing (of CTC and ctDNA)	Is available	Oncology	Clinical validation
iCellate Medical	Genetic sequencing	Targeted sequencing (germline DNA)	Is available	Oncology	Clinical validation
iCellate Medical	ctDNA analysis	Complement to CTC analysis	Is available	Oncology	Clinical validation
iCellate Medical	Germline DNA	Risk profiling in hereditary investigation	Is available	Oncology	Clinical validation
Immunovia	IMMray®	Diagnostic multiplexing serum test. Differentiating NSCLC from healthy	Have partner/s	Oncology	Feasability studies
Immunovia	IMMray®	Diagnostic multiplexing serum test. Early detection of PDAC (pancreatic cancer)	Have partner/s	Oncology	Analytical validation
Immunovia	IMMray®	Diagnostic multiplexing serum test. Detection of stage I-IV PDAC	Have partner/s	Oncology	Analytical validation
Immunovia	IMMray®	Diagnostic multiplexing serum test. Differentiation of SLE from other autoimmune diseases	In-house development	Other	Feasability studies
Immunovia	IMMray®	Diagnostic multiplexing serum test. Early detection of SLE	In-house development	Other	Feasability studies
Immunovia	IMMray®	Diagnostic multiplexing serum test. Detection of PDAC in NOD (new onset diabetic) patients	In-house development	Oncology	Feasability studies
Immunovia	IMMray®	Diagnostic multiplexing serum test. Early detection of prostate cancer		Oncology	Feasability studies
InDex Pharmaceuticals Holding	DiBiCol	Diagnostic test for IBD	Is available	Gastro-Intestinal	Launched
InfiCure Bio	Kinetics of kidney fibrosis	Efficacy test for new drugs		Immunology	
InfiCure Bio	Kinetics Liver fibrosis	Efficacy test for new drugs		Immunology	
InfiCure Bio	N-IF as a model for NASH	Efficacy test for new drugs		Diabetic/Metabolism	
InfiCure Bio	NFL as a model for NASH	Efficacy test for new drugs		Diabetic/Metabolism	
Life Genomics	Pharmacogenetic test	Pharmacogenetic test for the private healthcare and consumer market	Have partner/s	Not applicable	Clinical validation

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Liv Diagnostics	CellRACE	Quantification of cell migration capacity to provide predictive information about the risk of metastasis	In-house development	Oncology	Not applicable
Lytics Health	Predictive analytics end stage renal disease	End stage renal disease seamless care organization analytics (USA)	Is available	Other	Clinical validation
Lytics Health	Predictive analytics end stage renal disease	Dual demo patients predictive analytics (USA)	Is available	Other	Clinical validation
Lytics Health	Predictive analytics for SWEDEHEART	Identify high risk patients	Is available	Cardiovascular	Feasability studies
Medfield Diagnostics	MD100	Stroke	Is available	Cardiovascular	Clinical validation
Medfield Diagnostics	MD100	Traumatic brain injury	Is available	Cardiovascular	Clinical validation
Medfield Diagnostics	MD200	Imaging	Is available	Cardiovascular	Feasability studies
Medsens	Hard and software	Detection of prostate cancer		Other	
Medviso	Platform for efficient processing of large study cohorts	Analytic software for large scale image analytics Machine learning tools	Have partner/s	Cardiovascular	Analytical validation
Medviso	Platform for efficient processing of large study cohorts	Population research, Clinical usage	Is available		
Medviso	Patient-specific biomarkers for heart failure	Prognostics	In-house development	Cardiovascular	Feasability studies
Medviso	Patient-specific biomarkers for heart failure	Diagnostics			
MetaboGen	Stratification/ microbial intervention in NAFLD patients	Prevention/early treatment of NAFLD/NASH	Is available	Diabetic/Metabolism	Clinical validation
MetaboGen	Stratification/ microbial intervention in Type 2 Diabetes	Microbial intervention for prevention/early treatment of T2D	Is available	Diabetic/Metabolism	Clinical validation
MetaboGen	Microbiome biomarker for Intrahepatic Cholestasis in Preganancy	Preventive treatment for high risk ICP patients	Is out-licensed	Obstetrics	Clinical validation
Multid Analyses	GenEx 7		In-house development	Not applicable	Launched
Multid Analyses	GenEx 7				
Multid Analyses	GenEx on cloud	qPCR and RNA-seq. data analyse tool	In-house development	Not applicable	Feasability studies
Multid Analyses	GenEx on cloud	Data analyse tool in Pitbul EU project	Have partner/s	Infection	Launched
Neodynamics	NeoNavia	Diagnosis of breast cancer	Is available	Oncology	Launched
Neodynamics	NeoNavia	Diagnosis of lymph nodes and substitution of axilla surgery		Oncology	
Olink Bioscience	Automated molecular analysis of cells and tissue sections	Detection and identification of proteins and nucleic acids for research and diagnostics	Is available	Not applicable	Not applicable
Olink Bioscience	Detection platform for liquid biopsies	Rare variant detection in cancer and non invasive prenatal testing	Is available	Not applicable	Feasability studies
Olink Proteomics	Olink	Multiplex immunoassay Cardiometabolic panel for protein biomarker research and development	In-house development	Diabetic/Metabolism	Launched
Olink Proteomics	Olink	Multiplex immunoassay Cell Regulation panel for protein biomarker research and development	In-house development	Not applicable	Launched

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Olink Proteomics	Olink	Multiplex immunoassay Cardiovascular II panel for protein biomarker research and development	In-house development	Cardiovascular	Launched
Olink Proteomics	Olink	Multiplex immunoassay Cardiovascular III panel for protein biomarker research and development	In-house development	Cardiovascular	Launched
Olink Proteomics	Olink	Multiplex immunoassay Development panel for protein biomarker research and development	In-house development	Not applicable	Launched
Olink Proteomics	Olink	Multiplex immunoassay Immune Response panel for protein biomarker research and development	In-house development	Immunology	Launched
Olink Proteomics	Olink	Multiplex immunoassay Immuno-Oncology panel for protein biomarker research and development	In-house development	Oncology	Launched
Olink Proteomics	Olink	Multiplex immunoassay Inflammation panel for protein biomarker research and development	In-house development	Inflammation	Launched
Olink Proteomics	Olink	Multiplex immunoassay Metabolism panel for protein biomarker research and development	In-house development	Diabetic/Metabolism	Launched
Olink Proteomics	Olink	Multiplex immunoassay Neurology panel for protein biomarker research and development	In-house development	CNS	Launched
Olink Proteomics	Olink	Multiplex immunoassay Oncology panel for protein biomarker research and development	In-house development	Oncology	Launched
OncoSignature	Identification of a drug-tailored protein-based biomarker signature	Stratification of AML patients for treatment	Have partner/s	Oncology	Analytical validation
OncoSignature	Identification of a drug-tailored protein-based biomarker signature	Novel therapeutic combination strategies			
Pelago Bioscience	CETSA Classics	Target Engagement quantification in physiological relevant sample matrices	Is available	Not applicable	Launched
Pelago Bioscience	CETSA Classics	Translation from in vitro to in vivo to man	Is available	Not applicable	Launched
Pelago Bioscience	CETSA HT	Compound library screening	Is available	Not applicable	Launched
Pelago Bioscience	CETSA HT	Small sample volume testing	Is available	Not applicable	Launched
Pelago Bioscience	CETSA MS	Safety and selectivity profiling of candidate drugs	Is available	Not applicable	Launched
Pelago Bioscience	CETSA MS	phenotypic deconvolution	Is available	Not applicable	Launched
Pelago Bioscience	CETSA MS driven Biomarker Discovery	Biomarker ID and validation	Is available	Not applicable	Launched
Pelago Bioscience	CETSA MS driven Biomarker Discovery	Predictive and diagnostic biomarker validation	In-house development	Oncology	Analytical validation
PExA	Proteo-/genomics based analysis + directed biomarker analysis	Discovery of non-invasive biomarkers, in respiratory diseases	Is available	Other	Feasability studies
PExA	Proteo-/genomics based analysis + directed biomarker analysis		Is available	Transplantation	Feasability studies
PExA	Non-invasive measurements of biomarkers	Predict risk for rejection of lungs prior to transplantation			
PExA	Non-invasive measurements of biomarkers	Discovery of biomarkers, respiratory conditions in mechanically ventilated patients			

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
PExA	Quantify drug substances in PEx samples	A new non-invasive method to measure drugs concentration in the lung			
Q-linea	ASTar™ Instrument System	Susceptibility and concentration testing of 48 different antimicrobials on specific pathogens	Is available	Infection	Analytical validation
Q-linea	ASTar™ Blood Culture kit	In vitro determination of antibiotic susceptibility of microbial pathogens derived from clinical specimens	Is available	Infection	Analytical validation
Qlucore	Qlucore Omics Explorer Version 3.4	Bioinformatics analysis software with single cell RNA-seq support including t-SNE visualizations	In-house development	Other	Other
Qlucore	Qlucore Omics Explorer Version 3.4	Generic data analysis	In-house development	Other	Other
Reccan Diagnostics	Serum biomarker panel for pancreatic cancer	Serum biomarker panel for pancreatic cancer	In-house development	Gastro-Intestinal	Clinical validation
Reccan Diagnostics	Proteomic pancreatic cancer biomarker panel predicting severity	Proteomic pancreatic cancer biomarker panel predicting severity	In-house development	Gastro-Intestinal	Clinical validation
Reccan Diagnostics	Histone 1.3	Novel prognostic biomarker in pancreatic cancer tissue	In-house development	Gastro-Intestinal	Clinical validation
redhot diagnostics	Diagnostic kit	PEth determination of long term alcohol use	In-house development	Other	Launched
redhot diagnostics	Diagnostic kit	MMA analyzes of B vitamin deficiency	In-house development	Other	Analytical validation
redhot diagnostics	Diagnostic kit	Testosteron analyzes of deficiency	Is available	Endocrinology	Feasability studies
redhot diagnostics	Diagnostic kit	Thyroid hormone analyzes	Have partner/s	Endocrinology	Feasability studies
Respiratorius	RESP3000	Cardiovascular Imaging	Is available	Cardiovascular	Feasability studies
SAGA Diagnostics	IBSAFE	Oncology companion diagnostics – therapy selection	Is available	Oncology	Clinical validation
SAGA Diagnostics	IBSAFE	Therapy response monitoring and drug resistance	Is available	Oncology	Clinical validation
SAGA Diagnostics	IBSAFE	Oncology companion diagnostics – therapy selection	Is available	Oncology	Clinical validation
SAGA Diagnostics	IBSAFE	Therapy response monitoring and drug resistance	Is available	Oncology	Clinical validation
SAGA Diagnostics	KROMA	Diagnosis of cancer minimal residual disease and metastasis	Is available	Oncology	Clinical validation
SAGA Diagnostics	KROMA	Therapy response monitoring and drug resistance	Is available	Oncology	Clinical validation
SAGA Diagnostics	ActionSEQ	Oncology companion diagnostics – therapy selection	In-house development	Oncology	Analytical validation
SAGA Diagnostics	ActionSEQ	Therapy response monitoring and drug resistance			
Sectra	Software system for all medical images, management and diagnostics	Radiology diagnostics	In-house development		Launched
Sectra	Software system for all medical images, management and diagnostics	Pathology diagnostics	In-house development		Launched

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Sectra	Vendor-neutral platform for AI-based decision support in imaging diagnostics	Radiology diagnostics	Have partner/s		Launched
Sectra	Vendor-neutral platform for AI-based decision support in imaging diagnostics	Pathology diagnostics	Have partner/s		Launched
Sectra	Imaging software systems to support precise orthopedic surgery	Pre-operative planning for orthopedic surgery	In-house development	Other	Launched
Sectra	Imaging software systems to support precise orthopedic surgery	Post-operative follow-up for orthopedic surgery	In-house development	Other	Launched
Sectra	Interactive machine learning software for diagnostic decision support	Radiology diagnostics	In-house development	Oncology	Analytical validation
Sectra	Interactive machine learning software for diagnostic decision support	Pathology diagnostics	In-house development	Oncology	Launched
SensoDetect (publ.)	SensoDetect	Fast and reliable objective test for ADHD, Schizophrenia and Autism	Is available	Other	Launched
SensoDetect (publ.)	SensoDetect	Also under development Depression and OCD.	Is available	Other	Clinical validation
SensoDetect (publ.)	SensoDetect	Test for drug treatment in brain response, for ADHD, Autism and Depression	Is available	Other	Clinical validation
SensoDetect (publ.)	SensoDetect	Sstudies on several drugs as well as tobacco, alcohol	Is available	Other	Clinical validation
SensoDetect (publ.)	SensoDetect	Fast and reliable screening to exclude healthy for non healthy in e.g. ques and emergency hospitals	Is available	Other	Clinical validation
SenzaGen	GARDskin	In vitro allergy test, primary application to assess chemical skin sensitizers	Is available	Dermatology	Registration
SenzaGen	GARDpotency	In vitro allergy test, primary application to classify the potential of chemical skin sensitizers	Is available	Dermatology	Registration
SenzaGen	GARDair	In vitro allergy test, primary application to assess chemical respiratory sensitizers/irritants	In-house development	Other	Other
Single Technologies	Theta Sequencer	Worlds fastest scanner, a new typ of fluidics adopted for large areas and sequencing chemistry			
Spago Nanomedical	SpagoPix	MR imaging of solid tumours	Is available	Oncology	Other
Spectronic Medical (Nicole)	MR-OPERA	MRI only workflow for radiotherapy planning	In-house development	Oncology	Clinical validation
Spectronic Medical (Nicole)	MriPlanner	Radiotherapy planning in prostate cancer		Oncology	Registration
Spectronic Medical (Nicole)	MriPlanner	Radiotherapy planning in all anatomical regions	Is available	Other	Analytical validation

Company name	Product/ Project	Application	Partnering status	Therapeutic area	Current development phase
Symcel	In-vitro diagnostic device, calScreener	Customized antimicrobial susceptibility testing	Is available	Infection	Clinical validation
TATAA Biocenter	Two-Tailed PCR	Ultrasensitive microRNA quantification in body fluids and few (single) cell samples	Is out-licensed, but available	Not applicable	Analytical validation
TATAA Biocenter	Two-Tailed PCR	Rare mutation detection in eg., cell-free DNA in liquid biopsies	Is out-licensed, but available	Not applicable	Feasability studies
TATAA Biocenter	DeltaAmp	Quality control and integrity testing of RNA for profiling	Is out-licensed, but available	Not applicable	Launched
TATAA Biocenter	DeltaAmp	Quality control and integrity testing of DNA for analysis	Is out-licensed, but available	Not applicable	Launched
TATAA Biocenter	ValidPrime	Internal standard for copy number variation measurements	Is available	Oncology	Launched
TATAA Biocenter	ValidPrime	For suntraction of genomic DNA background in expression profiling measurements	Is available	Not applicable	Launched
TATAA Biocenter	GrandPerformance assays	Single cell expression profiling	Is available	Not applicable	Launched
TATAA Biocenter	GrandPerformance assays	Expression profiling in circulating tumour cells	Is available	Oncology	Launched
TATAA Biocenter	Cellulyser	Single cell expression profiling	Is out-licensed, but available	Not applicable	Launched
TATAA Biocenter	Cellulyser	storage of nucleic acids	Is available	Not applicable	Launched
Truly Translational Sweden	TRISTAN	Pre-clinical imaging biomarkers for ILD	Other	Other	Feasability studies
Truly Translational Sweden	TRISTAN	Pre-clinical imaging biomarkers for lung fibrosis	Is available	Other	Feasability studies
Truly Translational Sweden	Circulating tumour cells	Method for identification of circulating tumour cells	Have partner/s	Oncology	Feasability studies
UmanDiagnostics	Enable ultrasensitive detection of neurofilament light in blood	Traumatic brain injuries	Have partner/s	CNS	Launched
UmanDiagnostics	Enable ultrasensitive detection of neurofilament light in blood	Neurodegenerative disease		CNS	Launched
VLVbio	M30 Apoptosense® ELISA	Non-alcoholic Fatty Liver Disease (NAFLD)	In-house development	Diabetic/Metabolism	Launched
VLVbio	M30 Apoptosense® ELISA	Alcoholic Steatohepatitis (ASH)	In-house development	Diabetic/Metabolism	Launched
VLVbio	M30 CytoDeath ELISA	Oncology	In-house development	Oncology	Launched
VLVbio	M30 CytoDeath ELISA	Toxicology	In-house development	Other	Launched
VLVbio	M65 EpiDeath ELISA	Drug-Induced Liver Injury	In-house development	Other	Launched
VLVbio	M65 EpiDeath ELISA	Toxicant-associated Steatohepatitis (TASH)	In-house development	Other	Launched
VLVbio	M65 ® ELISA	Non-alcoholic Steatohepatitis (NASH)	In-house development	Diabetic/Metabolism	Launched
VLVbio	M65 ® ELISA	Oncology	In-house development	Oncology	Launched

Methods

Creating the first map of Swedish precision medicine companies

Identifying precision medicine companies across the country
In October 2017, SwedenBIO initiated an extensive search to identify companies within the precision medicine field using databases, conference attendee lists, and our own database of member companies. At the same time, we contacted incubators, science parks and investment promotion agencies across the country, and also initiated a collaboration with Patrik Hidefjäll, senior researcher at the Bioentrepreneurship Unit at the Karolinska Institutet in order to broaden the scope of the search and identification of relevant companies.

We prepared an online survey and invited five companies with differing profiles to test the survey prior to distribution to the complete company list. In December 2017 and January 2018, we invited the companies to participate in the survey and to provide answers to questions about their company in general, relevant technologies as well as information regarding their projects and products within the field of precision medicine. The invitation to participate was widely distributed and included in several of our collaborators' newsletters in order to reach out to a wider network of companies. Follow-up phone calls were made to inform the recipients about the initiative.

Selection process and analysis
In January and February 2018, the data from the survey was collated and follow-up interviews were performed both by phone and e-mail to ascertain proper relevance to the precision medicine field, and also to complement survey answers. Thorough web searches were performed to gather information on relevant precision medicine companies that we did not manage to get in touch with. The management consulting firm Arthur D. Little was of great support in the process. 94 companies answered the survey, of which 18 were excluded due to the delimitations. The rest, 76 companies are analysed in the report. Some companies that did not answer the survey are also mentioned, when found relevant.

Selection of companies
This is a first attempt to map the landscape of Sweden's precision medicine industry. We decided to focus on innovative Swedish companies i.e. those developing products and services, but we also included technologies possessing the potential of advancing precision medicine in other ways. We selected companies based on the following criteria: headquartered or with a major research and development site in Sweden and with a business-to-business model. Service providers and business-to-consumer companies were excluded. Drug development projects were also excluded, as these have already been presented in our report series called "The Swedish Drug Discovery and Development Pipeline" (www.swedenbio.se/pipeline).

Data sources
The database Swedish Life Sciences (swedishlifesciences.com) was used to search for relevant companies, as were SwedenBIO's member list (swedenbio.se/members), and conference attendee lists e.g. from Nordic Life Science Days (nlsdays.com). Corporate information was obtained from Allabolag (allabolag.se) and company web sites.