SciLifeLab

Towards technology- and data-driven life science

Roadmap 2020-2030 · ⟶

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Executive summary

SciLifeLab (Science for Life Laboratory) is a national center for molecular life science research and provides an attractive collaborative platform for cross-disciplinary research across academia in Sweden, engaging also medical, environmental, industrial and other societal sectors. In this roadmap document, we describe how SciLifeLab will leverage its national infrastructure for the benefit of Swedish research, recruitment, training, translation, innovation and utilization of life science data. This strategy focuses on what SciLifeLab can achieve together with all of its stakeholders, maximizing the capacity of the life science ecosystem as a whole.

The future role of SciLifeLab is interlinked with the increasing importance of life science in general. Life science encompasses basic research on all living species and their interactions, but is also central in medical research, healthcare, drug discovery, diagnostics, biotechnology, agriculture, forestry, biodiversity, evolution, environment, climate change and many other fields. Recent decades have witnessed a technology-driven revolution in life sciences where modern technologies (e.g. sequencing, mass spectrometry and imaging) can be broadly applied across the entire spectrum of life science. Therefore, single infrastructure technologies can benefit several organizations and disciplines and hence coordination of cost-effective and dynamic deployment of national infrastructure with high accessibility becomes critically important. At the same time, the amount of data produced from this infrastructure has exponentially increased, providing unprecedented opportunity for a deep comprehensive understanding of life, a data-driven approach to basic research, and for addressing major societal challenges. Given the trends in both technology- and data-driven science, SciLifeLab plays an increasingly important role in Sweden's ambition to be a globally leading life science nation.

As a national infrastructure, the primary mission of SciLifeLab has been to offer access to cutting-edge life science infrastructure, in support of ground-breaking life science research across Sweden. During 2020-2030, in collaboration with universities, industry, healthcare and national funding agencies, SciLifeLab will leverage its strong technology base through six strategic objectives, which synergize with each other:

Strategic objectives

1. **Provide Unique and Impactful Life Science Infrastructure.** Promote continuous development and early application of cutting-edge technologies and services to deconvolute fundamental biology, address human health and biodiversity, and thereby enable research that otherwise would not be possible in Sweden.

2. **Develop World Class Research Capabilities and Research Communities.** SciLifeLab will bring together national communities to enable new technology- and data-driven life science research. We will engage in multidisciplinary research programs on: i) data-driven cell biology, ii) data-driven research on individualized health, as well as iii) data-driven research on biodiversity and evolution.

3. **Create a National Framework for Data-Driven Life Science.** Coordinate a national framework for life science data management, meeting the requirements of tomorrow's open, real-time data sharing and data cycles.

4. **Attract Scientific Excellence and Provide Advanced Training.** Provide an attractive environment for recruitment of top international competence, and focus on advanced educational and training initiatives for a new generation of young scientists in technology- and data-driven life science.

5. **Promote Collaborations Across Sectors and Borders.** Promote collaboration and knowledge exchange between different sectors of society and individual organizations, many of whom would not otherwise interact, with the intent of increasing interdisciplinary research, mobility and international visibility.

6. **Build Translational and Innovation Capabilities.** Develop translational capabilities in diagnostics and drug development in collaboration with biobanks, healthcare and industry, promoting medical breakthroughs and enabling innovation in healthcare.
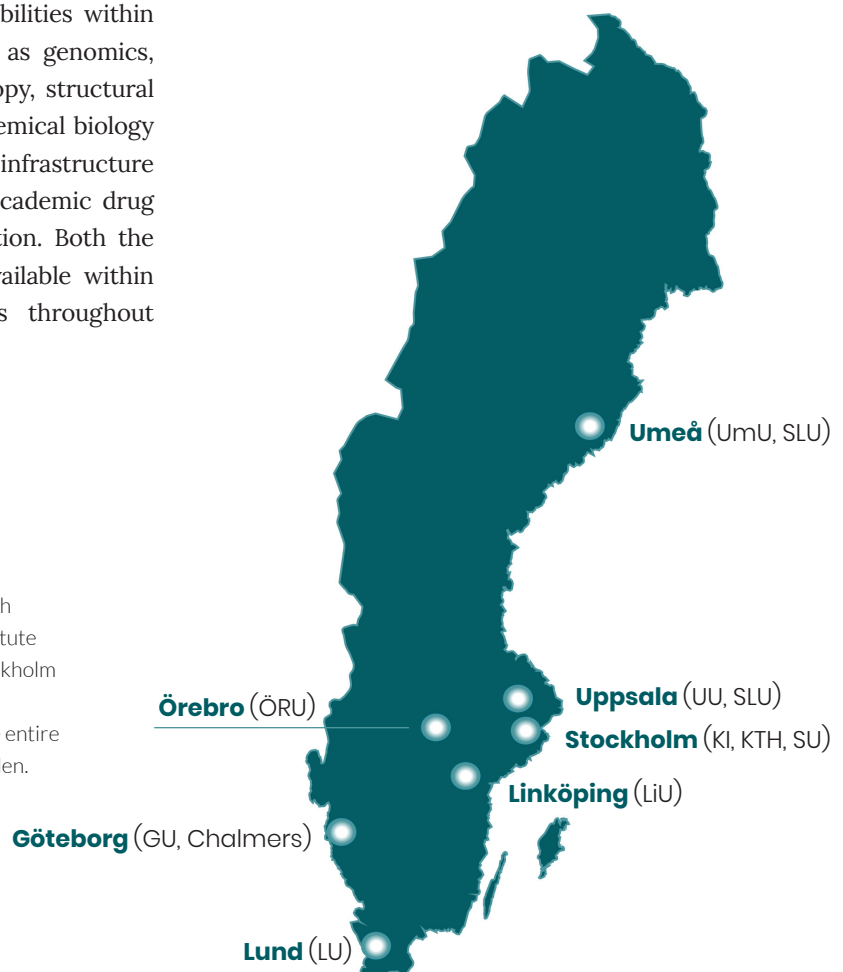
About SciLifeLab

Ten years ago, through strategic research funding (SFO) to its host universities (KTH, KI, SU, UU), the foundation of SciLifeLab was laid as a strategic research collaboration in life science. In 2014, SciLifeLab was appointed as a national life science research infrastructure by the government (*Förordning 2013:118*), with funding dedicated to make the infrastructure accessible nation-wide. SciLifeLab is governed by a national board, which represents the host universities, other universities, as well as industry. SciLifeLab host universities manage their research contributions via local SciLifeLab committees. A National SciLifeLab Committee representing other Swedish universities and stakeholders contributes with a national perspective to the operations. SciLifeLab's International Advisory Board ensures that SciLifeLab evolves in accordance with international trends and developments.

SciLifeLab today is a national resource with established operations across Sweden (Figure 1). The infrastructure and expertise at SciLifeLab provides unique capabilities within a multitude of molecular technologies such as genomics, proteomics, metabolomics, imaging, microscopy, structural biology, bioinformatics, single cell biology, chemical biology and gene editing. There are dedicated infrastructure platforms for diagnostics development and academic drug discovery, promoting translation and innovation. Both the technologies and the dedicated expertise available within SciLifeLab are available to all researchers throughout Sweden, including researchers active in the private sector, healthcare and other research entities. Today, there are over 400 staff active at SciLifeLab's infrastructure facilities, supporting over 1300 unique users and 3000 projects annually. Over half of these users are located outside the host universities, a testament to SciLifeLab's national accessibility and its successful implementation as a national research infrastructure. Importantly, the technologies provided are broadly applicable across the entire life science spectrum, supporting users from sectors outside of academia such as healthcare, industry, museums and other research institutes. In Stockholm, SciLifeLab-associated researchers and facilities are concentrated at Campus Solna, where some 600 scientists from the three Stockholm universities are co-located. In Uppsala and elsewhere, SciLifeLab activities are integrated within various established university departments.

Figure 1. SciLifeLab is a national research infrastructure hosted by KTH Royal Institute of Technology, Karolinska Institutet, Stockholm University and Uppsala University, and developed in close collaboration with the entire academic life science community in Sweden.

Umeå (UmU, SLU)

Örebro (ÖRU)

Uppsala (UU, SLU)

Stockholm (KI, KTH, SU)

Linköping (LiU)

Göteborg (GU, Chalmers)

Lund (LU)

Life Science 2020-2030

The future role of SciLifeLab needs to adapt to the global changes that are currently underway as well as those anticipated in life science as a whole. Life science is in the midst of a technological and digital revolution that will have a major impact on basic research, biotechnology, medicine and health, environmental science and many other fields. Concepts that until recently were considered science fiction – rapid and affordable whole genome sequencing, proteome profiling, gene editing, single cell biology, super-resolution imaging, systems biology, "big data" and artificial intelligence – are providing unprecedented opportunities for understanding the molecular complexity of life. The development of new technologies and the complexity and amount of data are only likely to increase in the future. On top of major opportunities in fundamental science, we face major societal challenges, as outlined in the UN Global Sustainable Development Goals [1] – a rapidly aging population, rising healthcare costs, environmental degradation, climate change, and lack of access to sustainable energy, food, clean air and water. How these challenges are tackled will have a broad and deep impact on our society in the future.

SciLifeLab's future strategy will consider developments in national research policy and Sweden's competitiveness internationally. In 2019, the Swedish government outlined a national life science strategy, defining eight priority areas for the development of Swedish life science in the future, with the ambition of making Sweden a leading life science nation[2]. Many of the priority areas indicated concern healthcare only, but they do overlap significantly with SciLifeLab's ambitions for the future (Figure 2). SciLifeLab can play a particularly important role in achieving the national strategy as outlined in priority area 6 – *Research and infrastructure*.

In order to perform cutting-edge research across the entire spectrum of life science, access to the latest advanced molecular technologies and expertise is necessary, along with the computational methods and e-infrastructure required to process the huge amounts of data produced. SciLifeLab technologies have already had a major impact on Sweden's ability to deliver life science research of the highest international quality. This roadmap proposes an ambitious new vision for SciLifeLab towards the next decade (2020–2030), with the intention of further strengthening Sweden's position within advanced research infrastructure, interdisciplinary research, collaboration, translation and innovation, and recruitment of the best talent. Our ambition is to increase quality and international competitiveness of Swedish research through continued efforts on technology-driven infrastructure, as well as a new focus on data-driven life science.

1	Structures for collaboration
2	Utility of healthcare data for research and innovation
3	Responsible, safe and ethical policy development
4	Integration of research and innovation in healthcare
5	Welfare technology for increased independence, inclusion and health
6	Research and infrastructure
7	Recruitment, talent attraction and life-long learning
8	International attractivity and competitiveness

Figure 2. Priority areas in the Swedish governmental life science strategy (translated from Swedish).

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[1] https://sustainabledevelopment.un.org/

[2] En nationell strategi för life science, Regeringskansliet, artikel nummer N2019.06

SciLifeLab Roadmap 2020-2030

Our mission and vision

The overall *mission* for SciLifeLab is to enable life science research in Sweden that is beyond what is possible for an individual researcher, an individual university or an individual research discipline. By providing access to the latest key technologies, SciLifeLab's infrastructure creates prerequisites for research and conceptually new forms of collaboration between individuals, groups and organizations.

*Our vision is for **Sweden to be a world-leading nation in life science.***

Our strategic objectives

Maintaining and developing the national research infrastructure and associated services is SciLifeLab's most important task and the foundation upon which other objectives are developed. The infrastructure enables and supports strong research capabilities and research communities, while new research discoveries and methodological innovations develop the national infrastructure in a reciprocal manner. This synergistic environment of infrastructure and research, when supported by a national framework for efficient data management, enables recruitment of international expertise, creates new opportunities for collaboration, and catalyzes translation and innovation (Figure 3).

Our values

The following statements encapsulate SciLifeLab's core values and define the manner in which we will achieve our mission to the Swedish life science community.

- *Our national infrastructure aims to strengthen and empower life science research across Sweden and across all sectors of life science.*

- *We are dedicated to advancing and disseminating knowledge in technology- and data-driven topics in life science.*

- *We strive for excellence, reproducibility and integrity of our research as well as open accessibility and dissemination of data, methods and results.*

- *We prioritize recruitment, training and career development of the best scientific talent, particularly young scientists.*

- *We facilitate collaboration across universities, disciplines, organizations and society sectors.*

- *We welcome diversity of individuals, opinions and experiences in a community of scientific excellence.*
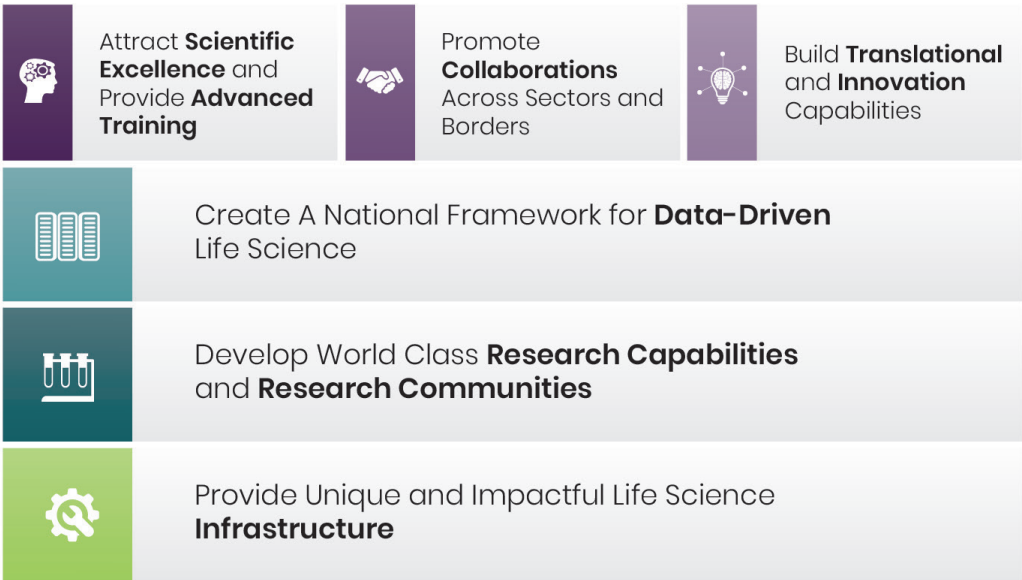

Figure 3. SciLifeLab's strategic objectives 2020–2030.

Strategic objective 1
Provide Unique and Impactful Life Science Infrastructure

We intend to continue development and coordination of the most relevant and advanced life sciences infrastructure and its availability for researchers throughout Sweden (Figure 4). The infrastructure should be i) unique and cutting-edge, ii) accessible and relevant to a large number of national users, iii) synergistic with other strategic research and infrastructure initiatives, iv) embedded in an excellent research environment, and v) utilize the best expertise available in the country. We will promote application of multiple SciLifeLab technologies and platforms and integration of associated data both within individual projects and in key strategic and/or translational initiatives. There is an increasing need to achieve a holistic understanding of life through the use of many new and established technologies as well as integration of the data acquired.

Evolving and continuously optimizing the role of national life-science infrastructure

Building on the current infrastructure platforms, we will initiate new platforms and facilities as technology evolves and needs arise. Recurrent international evaluation every four years will ensure consideration and prioritization of cutting-edge technologies and capabilities of broad national interest. Technologies will take advantage of regional strengths and

be supported where the best expertise in Sweden is available. This can take place as: a) a single dedicated national site, b) a hub/node model with a primary national hub and other sites providing collaborative expertise, or c) as an integrated network of nationally distributed facilities (Figure 5a). While we will ensure that the infrastructure evolves, we also need to secure sufficient focus and sustainability to create an internationally competitive mass of expertise in each field, given available funding. We will link to, but not duplicate, compete, or overlap with, local university infrastructure, international research infrastructures, and infrastructure provided through commercial sources (Figure 5b).

Improving life cycle management of the infrastructure

The process of how facilities and platforms are managed, launched and operated is already established around the 4-year international review-cycle. Given the rapid developments in life science, we will continue to develop the SciLifeLab infrastructure life-cycle, from early-stage technology development, scaling-up services from local to national scale, equipment renewals and upgrades, good infrastructure practice, training, strategic collaborations as well as translation and national dissemination (Figure 6).
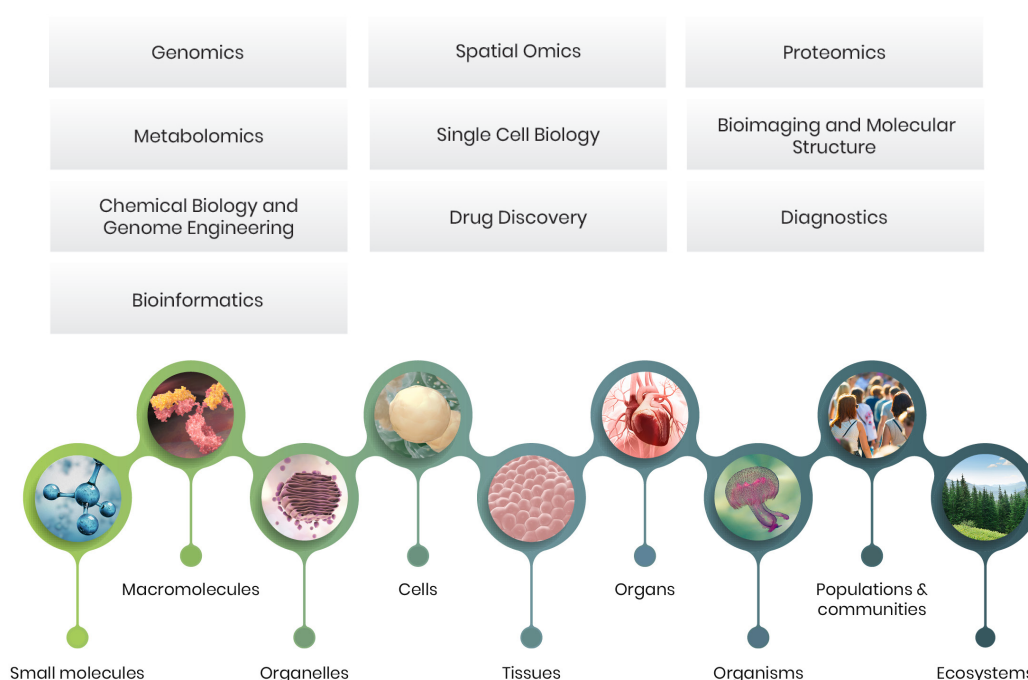

Genomics	Spatial Omics	Proteomics
Metabolomics	Single Cell Biology	Bioimaging and Molecular Structure
Chemical Biology and Genome Engineering	Drug Discovery	Diagnostics
Bioinformatics		

Small molecules · Macromolecules · Organelles · Cells · Tissues · Organs · Organisms · Populations & communities · Ecosystems

Figure 4. The SciLifeLab infrastructure service areas are provided as illustrated above (status of the infrastructure in 2019). SciLifeLab's technologies can be used for studying the molecular aspects of life ranging from the atomic scale up to entire ecosystems, and are available to all researchers in Sweden on equal terms and are applicable across a large spectrum of disciplines and research fields in life science.
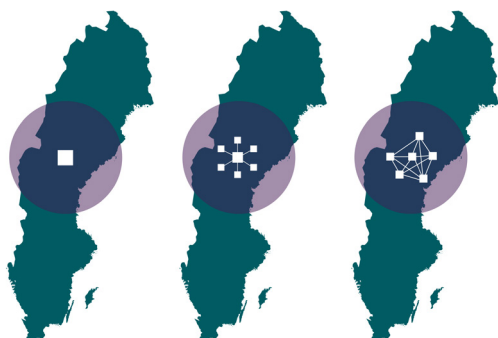
Figure 5a. SciLifeLab's infrastructure is operated in the most suitable format, depending on each platform, either as a single site (left), hub-and-node (center) or distributed network (right). The most appropriate and efficient model chosen may change over time depending on technology maturation, expense and expertise required, sample handling and other factors.

Figure 5b. SciLifeLab´s infrastructure is linked to local, national and international research infrastructures (academic and industrial).

Technology Development Projects (TDPs) will be funded to support infrastructure evolution within existing facilities and platforms as well as new openings. This continuous cycle is critical for agile responsiveness to new developments and will be coordinated through international evaluation, dialog and interaction with the National SciLifeLab Committee, International Advisory Board, host universities, our user community from all sectors and other key national stakeholders (e.g. URFI, KAW and VR-RFI).

Transitioning from facility-centric to platform-centric infrastructure

SciLifeLab has funded and managed about 40 independent facilities at any point in time. While this has worked well, similar services may arise and be offered by multiple facilities, resulting in redundancy. It has also been challenging for some users to find the most relevant technology for their research or to combine data from multiple facilities. We will gradually evolve this facility-based management model towards a platform-centric model, where individual facilities belong to a national platform, covering multiple related and often synergistic technologies. A part of national funding is directed through the platforms and through transparent processes based on expertise, objective demands and opportunities. Facilities and technologies within a platform can then evolve more rapidly as part of a larger context. Our aim is that platforms can guide users more efficiently towards the most relevant technologies and also increase the synergy between technologies.

Promoting Good Infrastructure Practice

We have established clear guidelines and expectations for what is required to be funded as a national SciLifeLab facility. Maintaining standards for Good Infrastructure Practice
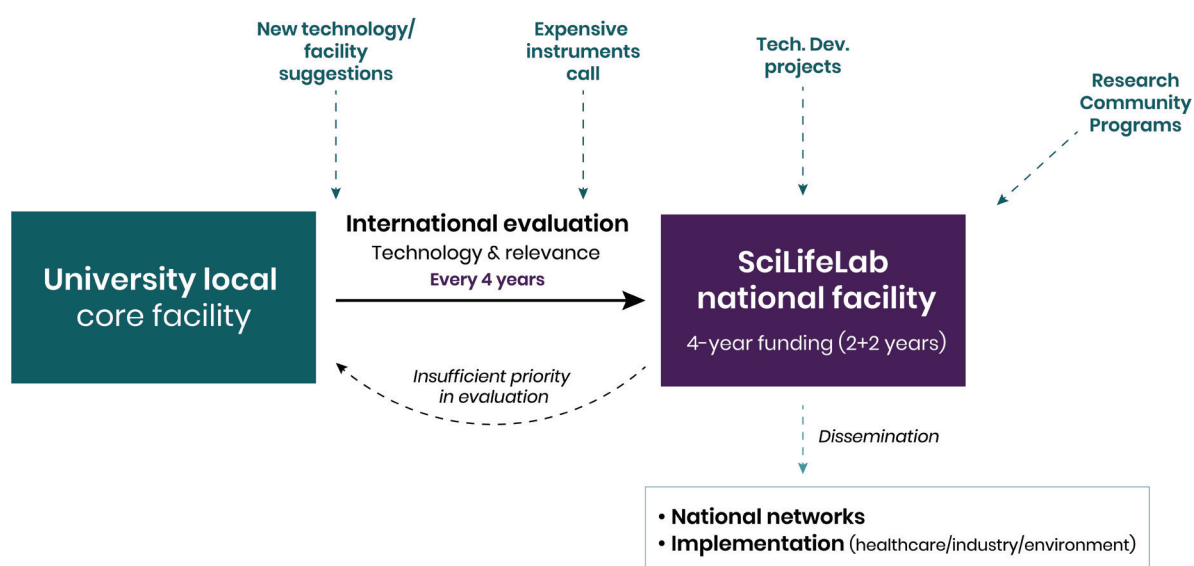

Figure 6. Processes for continuous development of the SciLifeLab infrastructure.

guarantees the highest level of quality, reproducibility, transparency and delivery in our operations and the data produced. These criteria will be enforced for all national SciLifeLab facilities, ensuring broad accessibility, quality and integrity of data. We will develop best practices on infrastructure management across our diverse infrastructure and share assets, such as software tools, data pipelines, and management of user needs in between the facilities, platforms and host universities.

Increasing national awareness of SciLifeLab infrastructure

We will increase national awareness of the capabilities that SciLifeLab infrastructure can provide to diverse research disciplines within academia, industry, healthcare, museums, environmental agencies and other applicable research organizations. Communication of SciLifeLab as a national resource will be achieved through dedicated events, visits, workshops, personal interactions and improvements of the SciLifeLab web page as a gateway to the facilities. We intend to set up local SciLifeLab "nodes" that may include an office, a contact point, advice and other functions at all Swedish major universities for guiding new users and promoting research collaborations. The current well-functioning bioinformatics help desk will be used as a base and as a model.

Promoting career development of infrastructure scientists

Key to SciLifeLab's success as a research infrastructure is the dedication and expertise of our outstanding staff scientists, who guide users towards application, disseminate knowledge to the community and develop technological advances. The increasing importance of these individuals in competitive research environments cannot be understated. However, their career development opportunities are often not aligned with traditional career paths within academic environments. In close dialogue with the universities where all staff are employed, we intend to design more predictable and attractive career paths for these infrastructure scientists, such as specialists and technical experts, who require more transparent professional development opportunities and continuous education and training. In addition, staff scientists ensure that we promote rapid adaptation of new technologies from international laboratories across the world, hence there is increased need for short-term visits, education, training and sabbaticals for staff.

Strategic objective 2
Develop World Class Research Capabilities and Research Communities

Infrastructure is an integral part of an excellent research environment, and conversely, an active research community is vital for the long-term development of world-class infrastructure (Figure 7). Research infrastructure that is not deeply embedded within an outstanding research community runs a significant risk of becoming rapidly outdated. National infrastructure should therefore be connected with excellent research environments in a multi-disciplinary setting. For example, the research environment at SciLifeLab has been key to aspects of new technology development, supported by the TDPs, which has ensured a flow of new capabilities for the national infrastructure.

Closer interaction of research and infrastructure, with distinct funding

While we want to continue to promote close links and interactions between research and infrastructure, it is important to distinguish that research performed in the SciLifeLab community is supported by a variety of dedicated university or external funds to specific research areas, while the national SciLifeLab infrastructure funding is dedicated to infrastructure services accessible widely throughout Sweden and across all research areas. We will further enhance our established research sites at SciLifeLab Campus Solna (KTH, SU and KI) and in Uppsala to create

Figure 7. The synergistic interplay of world-class research and cutting-edge infrastructure guarantees the best prerequisites to perform top level science and for continuous development of new technologies within SciLifeLab platforms.

collaborative research environments of excellence linked to the national infrastructure. Another initiative where strategic research is linked to SciLifeLab is the Wallenberg Centers for Molecular Medicine (WCMM) at Linköping, Umeå, Gothenburg and Lund Universities which together with SciLifeLab infrastructure and research form the National Molecular Medicine Program (NMMP). SciLifeLab will be keen to engage in other national collaborative initiatives and networks and will launch national research programs in three data-driven life science areas (see below).

Implementing the SciLifeLab Group Leader concept

We have defined criteria and expectations of a SciLifeLab Group Leader, a term that has so far been defined differently by different universities. The new definition will be implemented nationally across all universities and will be applicable for principal investigators (PIs), senior researchers and team-leaders in technology and data infrastructures. This concept defines the national SciLifeLab research and technology community and will help to build the research environment where new PIs and SciLifeLab fellows are recruited and where postdoc and PhD recruitments and training will take place (see strategic objective no. 4).

Building strong national research environments linking infrastructure with excellent research communities

We will continue and expand the recently-initiated SciLifeLab Research Community Programs (RCPs) and other efforts to promote interactions among selected research communities that share interest in common technologies or research areas. These efforts will extend SciLifeLab's impact by not just serving individual scientists one-at-a-time, but by providing a network of scientists with similar interests who can share best practices, expertise, ideas, seminars and events and who will collaborate both among themselves as well as with the infrastructure. This provides SciLifeLab also

formal access to the vast research expertise available in the greater Swedish scientific community.

Launching new research programs on data-driven life science (DDLS)

SciLifeLab will continue to bring technology-driven opportunities to all scientists in Sweden, and facilitate formation of strong collaborative communities in selected research fields. Going forward, we see that there are major opportunities for SciLifeLab to engage in strategic collaborative research programs in data-driven life science. DDLS implies how data will assume an ever-increasing and central place in life science.

The practice of life science is more and more data-dependent, the amount of data grows exponentially, but also becomes more complex, continuous, and needs to be openly available accessible and reusable in real-time to all. In the planning of any aspect of life science, be it research projects, infrastructure investments, education, career development, translation, societal impact or other, we will need to put data in the forefront. DDLS implies a comprehensive approach to data generation with clear strategies for what data sets to collect, how the data should be curated, analyzed and made available to the community, and how we derive life science knowledge from both newly-generated and existing data sets.

DDLS is not an alternative to hypothesis-driven science, but will help scientists to define research hypotheses better based on the previous data available locally or globally. Hence, every biologist needs to be able to better analyze and interpret data patterns, and integrate their own data seamlessly with the global life science data streams. DDLS is a paradigm shift already today, but over the next 10 years, the concept will substantially evolve and penetrate as a central theme in advanced training and education, reshaping research traditions, and practices on publication. Progress in science will evolve around the production, availability and analysis of openly available science across the entire life
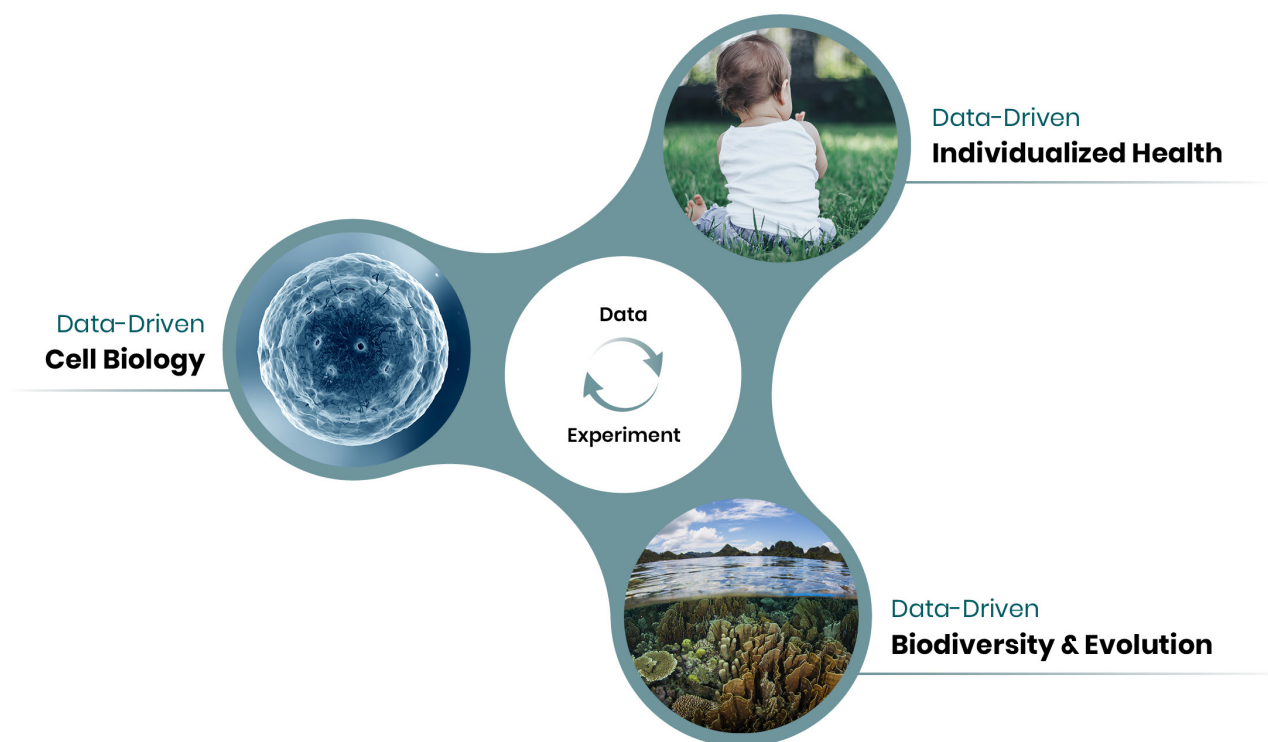
Figure 8. Focus areas for SciLifeLab data-driven life science Data-driven cell biology (DDCB), Data-driven individualized health (DDIH) and Data-driven biodiversity and evolution (DDBE)

science domain, with the latest tools in data science, such as modeling biological networks, machine learning and AI.

The DDLS program will promote all these developments. It will be national in scope and strongly aligned and making use of national initiatives in computational science, such as the Wallenberg Artificial Intelligence, Autonomous Systems and Software Program (WASP), AI centre in Lindholmen Science Park, high-performance computing facilities, the potential for quantum computing and other major technology advances, as well as with SciLifeLab data science and national and international bioinformatics expertise (e.g. SciLifeLab Data Centre, the bioinformatics platform, European Bioinformatics Institute (EBI), the European Life Science Infrastructure Initiative ELIXIR and other communities). We will also partner with major international data science initiatives.

We hope to create an extremely strong computational and data science base for the DDLS initiative. In terms of application areas, we are planning the following three broad data-driven application areas for DDLS (Figure 8), including collaborations across these three topics.

Finally, it will be necessary to set up a program to explore the ethical, legal and social implications (ELSI) of DDLS, both from the angle of human health, but also biodiversity, environment and other sectors of society.

Data-driven cell biology (DDCB)

The cornerstone of life science research is deep understanding of the molecular mechanisms and components of the prokaryotic and eukaryotic cell. Breakthrough technologies, such as single cell sequencing and proteomics technologies or microscopic and imaging technologies in terms of multiplexing, increasing resolution and live imaging, are helping to launch a new era of cell biology. Individual cells can be systematically characterized, visualized with unprecedented detail, and their interactions explored continuously and in real-time. Data from e.g. the Human Protein Atlas and the international Human Cell Atlas initiative, have already contributed to major international resources. Going forward, we will see real-time, increasingly automated, exploration of cell responses to a variety of stimuli and perturbations, such as genes, proteins, biologicals, chemicals, drugs, environmental substances etc. This will lead to comprehensive datasets and resources as well as better understanding on how cells function and react to their environment, eventually leading towards mathematical models predictive of cellular functions. Therefore, DDCB program will promote initiatives to create strong research environments, advanced multidisciplinary training and research efforts that place Sweden at the global forefront in next-generation data-driven cell biology research.

Data-driven individualized health (DDIH)

Genomics, transcriptomics, proteomics, metabolomics, microbiomics, single-cell profiling and many other new technologies will continue to enable massive amounts of informative data on human molecular health to be collected. This can be applied to explore human development and aging, life style changes, environmental exposures (exposome), transitions from health to disease as well as follow up of medical treatments. Understanding variability across individuals and finding individualized aging and disease trajectories will create new opportunities for sustaining health, preventing and diagnosing disease as well as for precision treatments. DDIH will enable a strong base for drug development in rare diseases and in disease subgroups defined by pathogenetic mechanisms. We will anchor DDIH initiatives with other Swedish, Nordic, EU and global efforts (e.g. Genomic Medicine Sweden (GMS), ELIXIR, 1 Million genomes initiative, Global Alliance for Genomics as well as phenotypic profiling efforts). DDIH initiative will also promote comprehensive collection and sharing of open, but privacy-protected data over time from research subjects and patients for use in machine learning and AI-based diagnostics. We wish to advance data-driven health interventions and clinical trials. New collaborative team-science studies on the same cohorts are needed to apply a range of methods systematically and over time, sharing the data, even in real-time. This would create major synergy as compared to the current extremely scattered medical research initiatives where data is often impossible to integrate. We will provide training and education on individualized health to students, scientists, medical professionals, decision makers and the public. The DDIH program will promote prevention and prediction of disease, such that people could in the future make real-time data-driven decisions of their own health. These types of proactive changes would be needed to increase the cost-efficacy and long-term sustainability of healthcare.

Data-driven biodiversity and evolution (DDBE)

We will intensify SciLifeLab's engagement in research on biodiversity, evolution as well as research on the impact of the environmental and climate change on global and local ecosystems. Using the latest technologies, we will promote systematic studies of ecosystems at multiple levels and over time. We will engage in partnerships with universities, infrastructures, environmental agencies, natural museums and others to take DDBE towards practical applications in evolution, biodiversity, molecular ecosystem monitoring and impact of climate change. We will anchor the DDBE initiative with major national and international research programs and biodiversity initiatives, such as the Earth BioGenome project. DDBE will go beyond existing initiatives to engage in data-driven analysis and modelling of the functional diversity of life on earth, analysis of evolutionary processes and time-trends. DDBE will match the data from functional studies of experimental ecosystem models in the laboratory with data streams from natural ecosystems over time to create data-driven predictions and deeper understanding of ecosystem changes. DDBE will undertake advanced training of a new generation of scientists in these emerging fields.

Strategic objective 3

Create A National Framework for Data-Driven Life Science

We envisage that future life science research is increasingly not only technology-driven, but also data-driven, as illustrated by SciLifeLab's three major data-driven research strategies. Throughout the life cycle of data, from project planning, data production, data analysis, data sharing, to publishing and reuse of data, researchers are dependent on advanced data analysis and e-infrastructures (Figure 9). SciLifeLab will take a lead in coordinating and supporting such activities, focussing on data arising from the use of SciLifeLab infrastructure platforms, both to promote research on adding value to data, research deriving biological knowledge from data, and infrastructure making data findable and available.

Data represents the most valuable and long-lasting products of SciLifeLab and we must ensure that it is handled according to FAIR criteria, open science standards and that its long-term value to the scientific community is maximized. We hope to collaborate with users of the infrastructure so that SciLifeLab can provide metadata and eventually full access to
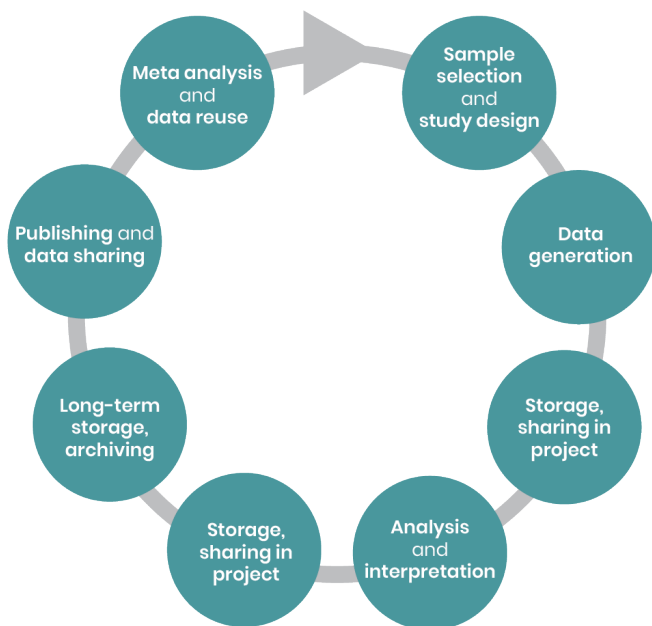
Figure 9. The flow of data in a cycle from production to analysis, sharing in projects, publication and re-use to initiate new studies characterizes data-driven life science.

all data generated through a dedicated access system, with curated systematic annotations. We want to promote not just open, but rapidly available, sometimes real-time access to data, but also access to analysis pipelines, algorithms, and software for data analysis. SciLifeLab's Data Centre and bioinformatics platform NBIS will increase coordination with other national stakeholders, such as universities and e-infrastructures, to build a national framework for data-driven life science. Transition towards data-driven life science is a major paradigm shift, and we envision substantial need for educational, training and collaborative programs with universities, research funders and the government. We will also support education and training on the ethical, legal and social implications (ELSI) of this work.

Strengthening IT for SciLifeLab's data production platforms

Swedish universities and e-infrastructures already provide IT services, including compute and storage solutions for individual researchers. In order to provide IT solutions that SciLifeLab's data-producing platforms require, we will efficiently utilize existing resources and push for new IT development that is aligned with the requirements that we expect will develop within the SciLifeLab infrastructure (Figure 10). This will be done together with Swedish universities and national e-infrastructures and in alignment with Nordic and international standards.

Providing services and infrastructure for data-driven life science

Data produced at SciLifeLab is governed by the university or the organization that hosts a research project. SciLifeLab will provide additional data stewardship, services and infrastructures that enable large-scale, complex and high impact data-driven projects that would otherwise not be possible. This will include hosting of data repositories, added-value databases, visualization and analytics, meta-data services through interaction with SciLifeLab data stewards, and facilitation of data publishing in international repositories using automated pipelines. Researchers will also need support and services to comply with international standards for data sharing, such as the FAIR principles and GDPR, and to improve the reproducibility of published results.

The ability to access and re-use data is central to data-driven science. In particular, this is of high importance for cross-disciplinary research such as the development and application of new AI-based methods. This will require high quality reference datasets and establishment of collaborative opportunities and relationships with national AI initiatives such as AIDA, WASP and AI Innovation of Sweden.

Developing processes for safe, secure and ethical way of handling sensitive data

SciLifeLab will build on our already strong international network of services, standards and infrastructure providers such as EMBL-EBI, ELIXIR, Global Alliance for Genomics and Health, and many others to develop services and resources for sensitive or confidential data. Such data, for example whole genome sequencing data from humans, have special demands on access control and data protection. Increased effort for sensitive data will support applications in healthcare and industrial collaborations in a safe, secure, ethical and responsible way. In particular, this will be required for data-driven precision medicine and to support large scale initiatives like the 1+ Million Genomes Project, where Sweden is one of 20 European nations committing to large scale human genome sequencing to improve health.

SciLifeLab will also engage in the development of national health data repositories as being developed within Genomic Medicine Sweden and act as a federated source for international initiatives such as the Nordic Commons digital infrastructure development and the European Open Science Cloud (EOSC). We will follow ongoing international research efforts on de-identifying data while still retaining sufficient information to perform research; this is critical for deep-learning applications in healthcare.

Simplifying access to services through data-centric integration

Researchers should be able to access SciLifeLab services and infrastructure in simple ways that best serve their research projects, without needing to know the details of the SciLifeLab infrastructure organization. Using a data-centric approach for infrastructure operations and a common project portal, we will improve how researchers can access services as well as track, edit, annotate and store information from all their SciLifeLab projects across all platforms.
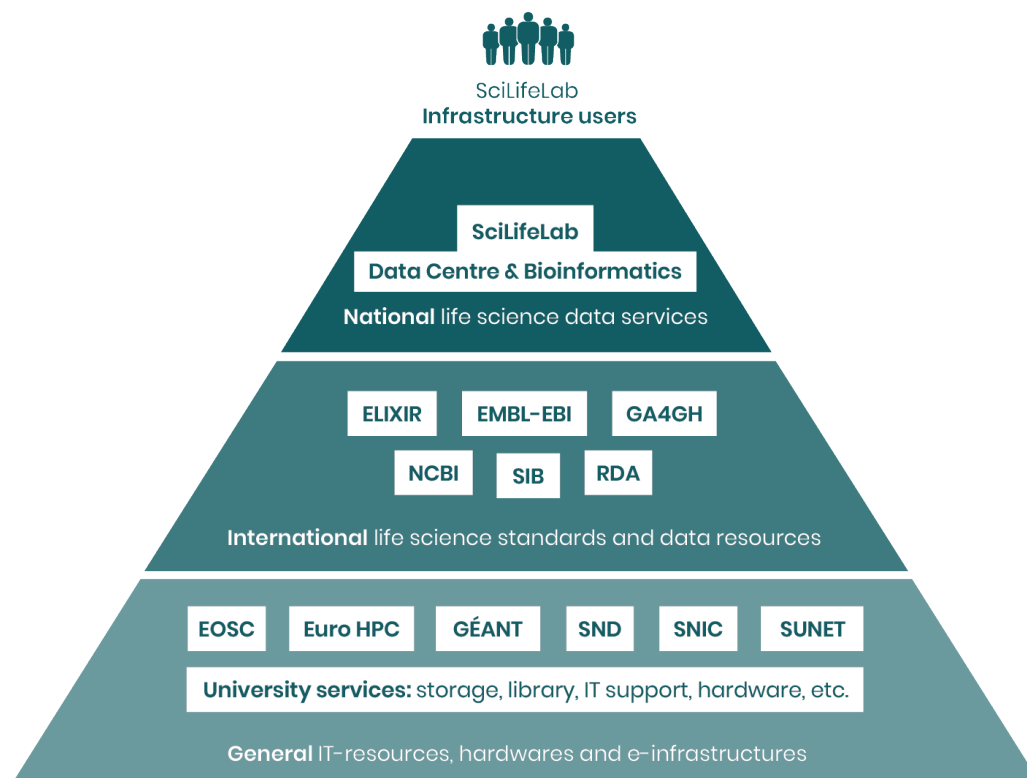

Figure 10. SciLifeLab provides life science specific services to its infrastructure users primarily by utilizing national and international general IT services and e-infrastructures (bottom level) and international life science data resources and standards (second level). All abbreviations explained on page 21.

Strategic objective 4
Attract Scientific Excellence and Provide Advanced Training

The quality of research performed in Sweden is highly dependent on the talent that we can attract and retain in our country and on the ability of individual researchers to keep up to date with the latest technologies, major research transitions and new capabilities in data-driven science. We will support a number of initiatives to help create excellent international life science research environments that attract talent to Sweden, and will help to retain, renew and expand critical expertise.

International recruitment of young PIs: Next-phase of the SciLifeLab fellows' program

SciLifeLab's host universities have recruited around 30 internationally renowned young researchers to start their academic careers in Sweden (mostly in Stockholm and Uppsala via SFO funding) as part of the SciLifeLab Fellows program. The success of the program (six years support for a position, including generous start-up funding) has already become apparent through the large number of

grants and awards that these young talented group leaders have received, including many ERC starting grants. This program will continue, depending on host universities ability to support it through strategic research funding, and will collaborate with similar efforts at other universities, such as the national WCMM program. The new research program on data-driven life science is expected to also involve recruitment of young PIs across Sweden. Finally, we also plan to attract senior, internationally accomplished scientists either as permanent or part-time/visiting faculty in the SciLifeLab community within technology- or data-driven themes.

Building attractive research and training environments

Considerable effort will be placed on developing attractive research and training environments at the main SciLifeLab sites in Solna and Uppsala as well as nationally. This will involve building an engaging research community, seminar series, mentoring programs and other activities, as well as ensuring access to equipment and infrastructure to young PIs and fellows. This has already started in the Campus Solna site, where a dedicated Campus Solna Director position will be established in 2020. The Campus Solna Director will focus on improving the research environment and interactions within the SciLifeLab site in Stockholm.

Launching a program on advanced training and education in technology- and data-driven life science

SciLifeLab platforms have been very active in organizing national courses in technology and data-centered topics for the user community. Over the past decade, 100s of events have been organized and 1000s of researchers have gained insights on recent technology developments in life science, promoting continued and life-long learning for scientists in Sweden. These activities will continue, linking up and highlighting the latest technologies. We will also build a new training program in data-driven life science.

Launching postdoc & PhD student programs

SciLifeLab host universities have operated their own SFO-funded postdoctoral programs aiming to e.g. unite researchers within their university with technology facilities. As part of the plan for the data-driven life science focus, we plan to launch a postdoctoral program as well as a graduate student programs and educational initiatives. Here, in order to focus on training of next-generation scientists, we will consider a national program with extensive course work and multi-disciplinary training initiatives involving both life science and computational topics. The postdoc and PhD programs may also involve systematic international recruitment, rotations and exchange as well as joint supervision across universities and disciplines.

Spreading knowledge beyond academia

Increasing the knowledge of SciLifeLab's capabilities is important to industry, healthcare and other sectors of society, which are not as connected with the latest developments within the global academic community. We will increase the dissemination of new technology applications and scientific areas to the broader community and the public in order to increase national awareness of life science and promote STEM research to a new generation of students in Sweden.
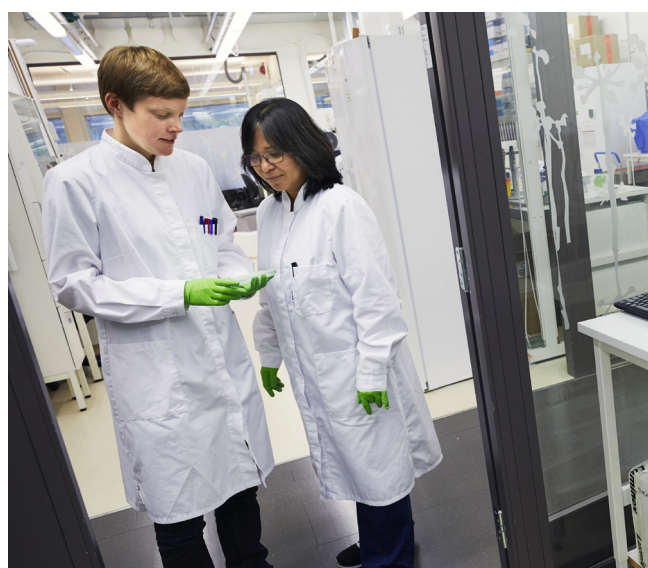
Promote Collaborations Across Sectors and Borders

Addressing the grand challenges of life science demands the collective effort of the entire life science community, including increased collaboration between disciplines and different sectors in society. SciLifeLab's role is to promote new paradigms for collaboration and interdisciplinary research that would not otherwise happen, such as across universities and across disciplines. For example, utilizing multi-omics research and data and continuous monitoring of health transition in medicine, utilization of machine learning and artificial intelligence in data-driven research on biodiversity and environment, or linking genetic markers of tree populations to advances in materials science and forestry. National research infrastructures present an ideal environment for serving as a hub for interdisciplinary collaboration, as well as partnerships between academia, industry, healthcare and the global research community.

Increase coordination with other national infrastructures and associated initiatives

SciLifeLab technologies are complementary to university core facilities, other national research infrastructures and strategic research initiatives in life science. Examples include structural biology and imaging facilities (e.g. MAX-IV, ESS), healthcare infrastructures (e.g. Genome Medicine Sweden, biobanks, quality registries), environmental infrastructure initiatives (Swedish Biodiversity Infrastructure and Swedish Infrastructure for Ecosystems Science), protein production and purification centers (e.g. GE Testa Center) and initiatives within artificial intelligence (e.g. WASP, AIDA and AI Innovation of Sweden). SciLifeLab will complement and collaborate with these strategic research initiatives, launch joint research efforts, promoting interdisciplinary science and thereby leverage Sweden's combined national infrastructure.

Promoting access of SciLifeLab infrastructure to industry, healthcare and environmental research

We will increase awareness of SciLifeLab's infrastructure and associated research community to sectors outside of academia. SciLifeLab will, together with our host universities, engage with the government and other public entities to improve industrial collaborations with academia, interactions with healthcare and environmental research, as well as increased focus on open data and its utilization. SciLifeLab will focus on creating the best possible prerequisites for cross-sector collaboration, particularly in areas that are currently underrepresented in the SciLifeLab community.

Creating an ideal multi-university environment for collaborative technology development and testing

As a technology-centric organization connected to several universities, SciLifeLab provides an attractive collaborative environment for technology development and early testing and adaptation, both within academia and between academia and industry. Many of our facilities embark on long-term collaborations in technology development with companies, including development of test-bed environments and designation as reference laboratories for industry partners. These opportunities will be further exploited, thereby attracting international visibility, investment, innovation, knowledge, and competitive edge to our infrastructure.

Promoting international collaboration

As a national organization, SciLifeLab can act as a collaborative platform between the Swedish life science sector and international organizations and collaborative networks in life science. This will allow for Swedish researchers to pool resources for maximum impact on the international arena and for attracting international funding. The access of SciLifeLab infrastructure for international users and reciprocal links with Nordic and European infrastructure networks will be explored to place SciLifeLab infrastructure and could build the ideal combination and synergistic interaction between national and international infrastructures. SciLifeLab today also acts as a site for other countries, research communities and funders to explore and compare how Sweden has set up its research infrastructure and how it engages in national initiatives. SciLifeLab often exists as a window to the Swedish life science ecosystem for such visitors.

Expressing a unified voice for the life science community

We will support and promote the entire life science community in Sweden. Together with other stakeholders in the public and private sector organizations such as the Swedish Research Council (VR), SwedenBio, Vinnova, the Läkemedelsindustriföreningen (LIF), Business Sweden, international partners and collaborators, embassies and chambers of commerce, we will support the communication and branding of Sweden as a strong life science nation internationally.

Strategic objective 6

Build Translational and Innovation Capabilities

SciLifeLab is a major sustainable source of innovation, exemplified by the considerable number of spin-off companies that have their origin from the SciLifeLab research environment, translational initiatives that have reached clinical application (e.g. Genomic Medicine Sweden), many lead drug molecules that have been licensed for commercial development, as well as numerous public-private initiatives that have been started (e.g. the Human Secretome Initiative and Center for Translational Microbiome Research). The Diagnostics Development (DD) and Drug Discovery & Development (DDD) platforms have played a major role in such interactions, and while we expect similar activities in other fields of research in the future, the description below focusses on DD and DDD.

Translating advanced diagnostics from research to healthcare and precision medicine

SciLifeLab will continue to provide service and expertise in the development, validation and implementation of genomic sequencing in translational and clinical research, clinical trials and new diagnostics through DD platform and the Genomic Medicine Sweden. The DD platform is established through dedicated technology and clinical genomics expertise at universities and university hospitals in Stockholm, Uppsala, Gothenburg and starting 2019, also in Umeå, Linköping and Örebro, reaching full national coverage. Together with DD and GMS, healthcare regions and biobanks, we will continue to transition genomics and other cutting-edge molecular technologies towards clinical application. The data-driven individual health research program will provide entirely new opportunities for translational research as well as for healthcare innovations.

Translating academic drug discovery projects to industry

The DDD platform makes use of fundamental academic research discoveries across the country and validates these as drug discovery targets and creates lead molecules that would provide attractive future investment and development opportunities within the private sector. In recent years, many pharmaceutical companies have scaled down their internal R&D initiatives in and are increasingly dependent on research collaboration with academic research. Over the past 4 years, DDD has successfully developed therapeutic discoveries with numerous academic groups across the country. Several projects have been out-licensing to industry or established as new spin-off companies. DDD will continue to promote academic discoveries towards industrial drug discovery, and will engage in joint drug discovery programs with SMEs and large pharma companies. Increasingly, new drugs being developed are biological therapies (proteins, peptides, antibodies) or new modalities (gene therapies, cell therapies, therapeutic vaccines etc.) and it is essential that DDD as a national platform has access to these technologies and expertise, ideally from within the national research community in Sweden.

Moving towards a national innovation system in drug discovery

The "valley of death" between early academic drug discovery and successful commercial drug development remains broad and deep. DDD will work with the national innovation system to promote effective licensing and transfer of early drug leads to the private sector. This requires close collaboration between the DDD research infrastructure,

academic scientists, innovation funders (Vinnova, The Swedish Foundation for Strategic Research (SSF), Novo Seeds), innovation actors (innovation offices, Testa Center and RISE AB etc.), healthcare and industry. We see major opportunities for creating a joint plan for a new innovation ecosystem for Swedish drug discovery. ■

Final remarks

The SciLifeLab 10-year strategy described above is centered on leveraging the investments made into national life science infrastructure to enable collaborative research, recruitment, training, translation, innovation and data-driven strategies that provide synergistic benefits for the entire life science ecosystem. We hope to develop SciLifeLab from a technology-driven infrastructure organization towards an integrated and collaborating community in both technology- and data-driven life-science research. We believe this will benefit Sweden as a whole with the aim to position the country as a leading life science nation within fundamental research, but also in addressing challenges from the industry, healthcare and society at large. This is a collaborative research strategy where we work together with all the stakeholders in the broad life science sector towards these goals.

Acknowledgements

Abbreviations

AI	Artificial intelligence
AIDA	Analytic Imaging Diagnostic Arena
Chalmers	Chalmers University of Technology
DD	Diagnostics Development (Platform at SciLifeLab)
DDD	Drug Discovery and Development (Platform at SciLifeLab)
DDBE	Data-driven biodiversity and evolution
DDCB	Data-driven cell biology
DDIH	Data-driven individualized health
DDLS	Data-driven life science
EBI	European Bioinformatics Institute
ELIXIR	European Life Science Infrastructure Initiative
ELSI	Ethical, Legal and Social Implications
EMBL-EBI	The European Bioinformatics institute
EOSC	European Open Science Cloud
ERC	European Research Council
ESS	European Spallation Source
Euro HPC	High-Performance Computing in Europe
FAIR	Findable, Accessible, Interoperable and Reusable
GA4GH	Global Alliance for Genomics and Health
GDPR	General data protection regulation
GMS	Genomics Medicine Sweden
GU	University of Gothenburg
KAW	Knut and Alice Wallenberg Foundation
KI	Karolinska Institutet
KTH	KTH Royal Institute of Technology (Kungliga Tekniska Högskolan)
LIF	Läkemedelsindustriföreningen
LiU	Linköping University
LU	Lund University
NBIS	National Bioinformatics Infrastructure (SciLifeLab Bioinformatics, VR funded network name)
NCBI	National Center for Biotechnology Information
NMMP	National Molecular Medicine Fellows Program (with the WCMM, see below)
PI	Principal investigator

RCP	Research Community Program at SciLifeLab
RDA	Research Data Alliance
SFO	Strategic research area funding (support from the government) to Universities for their SciLifeLab collaboration
SIB	Swiss institute of Bioinformatics
SLU	Swedish University of Agricultural Sciences
SMEs	Small and medium sized enterprises
SND	Swedish National Data Service
SNIC	Swedish National Infrastructure for Computing
SSF	The Swedish Foundation for Strategic Research
STEM research	Research within Science, Technology, Engineering, Mathematics
SU	Stockholm University
SUNET	Swedish University Computer Network
TDP	Technology Development Project
UmU	Umeå University
URFI	The Universities' Reference Group for Research Infrastructures
UU	Uppsala University
VR	Vetenskapsrådet (Swedish Research Council)
VR-RFI	The Swedish Research Council's Council for Research infrastructure
WASP	the Wallenberg Artificial Intelligence, Autonomous Systems and Software Program
WCMM	Wallenberg Centers for Molecular Medicine (at the GU, LU, LiU and UmU)
ÖRU	Örebro University