The BIOTEK2021 programme is the Research Council of Norway’s most comprehensive research initiative in the field of biotechnology. The programme will run from 2012 through 2021. The BIOTEK21 programme succeeds the Programme on Functional Genomics in Norway (FUGE), which was concluded in 2011. The FUGE programme heralded a new era in biotechnological research in Norway and led to the development of new work forms focusing on national cooperation and task distribution and highly focused research activities. The BIOTEK2021 programme will take this concept to a new level, where Norwegian biotechnological research is to become more international, more industry-oriented and more at the forefront in selected areas.
During the past year, the Research Council of Norway’s programme on Biotechnology for Innovation (BIOTEK2021) has been working to design an ambitious strategic initiative. This initiative expands the foundation established by the previous Programme on Functional Genomics in Norway (FUGE), incorporating significantly greater focus on innovation and value creation. The FUGE programme marked a turning point in Norwegian biotechnology, and helped to establish national cooperation on infrastructure and competencies. Likewise, the launch of the targeted strategic initiative “Digital Life – Convergence for Innovation” is part of the BIOTEK2021 programme’s stated ambition to strengthen Norway’s innovation capacity.

The new initiative reflects the BIOTEK2021 programme’s high aspirations and willingness to take a calculated risk. The Digital Life initiative will be the programme’s most comprehensive and integrated effort. The aim is to promote responsible innovation and value creation by encouraging more extensive and closer cooperation between biotechnological research groups and researchers in other disciplines and technology areas. We also believe that the initiative will open up a host of new opportunities for Norwegian trade and industry in the future.

The term “digital life” triggers a wide array of interpretations and reactions, which is precisely why it has been chosen. Our aim is to generate attention and to engage, as well as to promote collaboration across disciplines and fields of interest. Dialogue between and involvement from a wide variety of stakeholders during the activities is an important component of Responsible Research and Innovation (RRI), part of the base on which the pillars of the initiative rest.

Biotechnology is advancing at a rapid pace, and cooperation with researchers in other subjects and disciplines is growing increasingly important. While many countries have already established dedicated initiatives in interdisciplinary fields such as bioinformatics, systems biology, synthetic biology and the like, only a few have designed activities in line with the vision of the Digital Life initiative. Our objective is to support the integrated development of biotechnology based on disciplinary convergence rather than the development of new, stringently delimited disciplines. We have set the bar high, and achieving our ambitions will be dependent on scientifically rigorous, cooperation-oriented leadership.

Many R&D institutions in Norway are already underway with independent strategic initiatives closely aligned with our new effort. This provides us with a sound foundation and reinforces movement in the desired direction. The mission of the Digital Life initiative is to foster effective national cooperation that in turn attracts international attention to Norway as a hotbed for biotechnological research and innovation within selected areas.

Jostein Chr. Dalland
Chair of the BIOTEK2021 programme board
The Research Council of Norway’s programme on Biotechnology for Innovation (BIOTEK2021) has decided to pursue a strategic initiative, entitled “Digital Life – Convergence for Innovation”, as the flagship of the programme in its remaining period.

This document is intended to describe for stakeholders the framework of the Digital Life initiative, outlining its background and aims, and providing some direction as to its implementation.

The aim of the Digital Life initiative is to create economic, societal and environmental value in Norway from biotechnological research and innovation, by encouraging transdisciplinary research. Digital Life was framed as a strategic initiative, based on the ambition that Norwegian research and innovation should take full advantage of the transformative technological and methodological opportunities offered by ongoing advances in digitalisation and the emerging potential for convergence across a range of disciplines.

It is expected that the competencies and skills developed through a portfolio of ambitious projects funded under this initiative will have a long-lasting effect on how Norwegian biotechnological research is pursued in the coming decades. This will, however, require substantial conceptual and methodological change in the way research and innovation are performed and perceived.

The decision to go forward with the Digital Life initiative has been based on a series of board meetings, a workshop with an International Advisory Group and several discussions with major stakeholders. The first step in operationalising the initiative will be to establish a national hub-node centre structure that will create a vibrant, networked, transdisciplinary digital life community in Norway that supports science, technology and innovation and strives for global recognition of excellence in key strategic areas for Norway.

Future funding announcements under the Digital Life strategic initiative will be planned and adjusted during the course of the BIOTEK2021 programme, based on experience gained in the initial phase and close dialogue with stakeholders.
Background

The BIOTEK2021 programme is a strategic, long-term initiative designed to further develop biotechnological research in Norway and shift its focus towards responsible innovation. The programme is run by the Research Council of Norway and is the main instrument for implementing the Government’s National Strategy for Biotechnology.

The BIOTEK2021 programme has a distinct innovation-oriented profile. The objective is to generate biotechnology that contributes to innovation and subsequent value creation in order to solve societal challenges in a responsible manner.

The work programme for the BIOTEK2021 programme points to biotechnology as an area of expertise that shares an interface with a number of subject areas within the life sciences, mathematical sciences and engineering. To make practical use of biotechnology, understand its social context and support its responsible development and governance, contributions from the social sciences, the humanities and law are also needed.

The development of biotechnology for responsible innovation therefore requires a high level of diverse competencies and knowledge that are merged together through extensive inter- and transdisciplinary activity.

In early 2013, the BIOTEK2021 programme board discussed the need to launch a forward-looking strategic effort with the potential to have a transformative and long-lasting effect on biotechnological research and innovation in Norway. Inspired by international developments and building on the foundation established by the previous Programme on Functional Genomics in Norway (FUGE), a proposal for a strategic initiative on digital life was developed by a group selected from the programme board. A basic motivation for the initiative was for Norwegian research and innovation to take full advantage of the transformative technological and methodological opportunities currently shaping biotechnology within the framework of engineering science.

In October 2013, the BIOTEK2021 programme invited an International Advisory Group comprised of high-level international academics and industry experts to advise on the initiative.

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1 Work Programme for the BIOTEK2021 programme (2012–2021)
2 National Strategy for Biotechnology 2011–2020
representatives to Oslo to discuss how such a strategic effort could be realised in Norway. The initial advice was to undertake a stakeholder engagement process to identify gaps and opportunities and to ensure that the Digital Life initiative would be aligned with the interests of major stakeholders in Norway. During spring 2014, the Digital Life initiative was discussed with a number of academic and industry leaders and was in general met with strong support.

At a meeting in June 2014, the BIOTEK2021 programme board decided to launch “Digital Life – Convergence for Innovation” as its major strategic effort (Figure 1).

FIGURE 1: Illustration of the Digital Life – Convergence for Innovation initiative as the strategic flagship of the BIOTEK2021 programme.

The figure illustrates the hierarchy of the activities under the programme according to strategic importance and visibility. The Digital Life initiative rests on already established programme activities. The “Large projects” category refers to large-scale industry-relevant Researcher Projects, of which there are currently five. “Proof-of-principle” refers to projects granted funding under a call for proof-of-principle studies, and “Internal joint calls” refer to calls issued by the BIOTEK2021 programme in collaboration with other programmes at the Research Council.
Digital Life – Convergence for Innovation

As a consequence of several technological and methodological engineering breakthroughs over the past 20 years, biological research is currently generating data at an unprecedented rate. Due to the immense complexity of biological systems, our capacity to translate this data into an understanding of integrated biological functions has not developed at the same pace. Biotechnological innovation is severely hampered by this inability to understand and control highly complex biological systems, which calls for other conceptual and methodological approaches than those normally employed within the life sciences.

As a response to this challenge, a number of interdisciplinary areas have emerged during recent decades that have significantly influenced the way biotechnological research is being performed. Examples of such areas include bioinformatics, bionanotechnology, systems biology, bioengineering and synthetic biology. There is considerable overlap between these areas, and it is necessary to employ an integrated, overarching perspective to promote their future progress and enhance their capacity to contribute to biotechnological innovation. The current thinking in leading international institutions is moving in the direction of transdisciplinary integration. Integrating knowledge that transcends established subjects, disciplines and experts allows new opportunities for research and innovation to emerge. In this context, convergence refers to the integration of the life sciences with the physical sciences, mathematical sciences, engineering sciences, social sciences and beyond.3

For biotechnology, the convergence framework provides novel opportunities to foster innovation e.g. by introducing engineering approaches such as design based on quantitative understanding of the subject matter into biotechnological methodology. The strategic effort Digital Life – Convergence for Innovation of the BIOTEK2021 programme aspires to promote transdisciplinary convergence in Norwegian biotechnological research and innovation (Figure 2).

3 Note the different approaches to convergence in the US and the EU, respectively, as exemplified by “The Convergence of the Life Sciences, Physical Sciences, and Engineering” (MIT 2011) and “Converging Technologies – Shaping the Future of European Societies” (EC 2004).
The aim of this effort is to create economic, societal and environmental value for Norway, in part by helping existing bioindustries to gain further competitive advantages and by providing incentives for the emergence of new innovative companies.

Most notably, the mission of Digital Life – Convergence for innovation is to facilitate a major shift towards a concerted use of conceptual, methodological and technological elements from the life sciences, mathematical sciences and engineering throughout the whole biotechnological innovation process. One important implication will be that the development of novel and sustainable biotechnological innovations, with significant societal utility and value, to a greater extent become guided by the design principles and methods characterizing mature engineering disciplines.

Biotechnological innovation results from the complex co-production of technological advances, politics and societal values. Thus, the societal context represents a pivotal dimension of the Digital Life initiative.
Strategic elements

The Digital Life – Convergence for Innovation initiative builds on existing competencies and infrastructure in Norwegian research communities. Some key elements were developed as part of the FUGE programme, such as technology platforms on genome sequencing, bioinformatics and proteomics. However, the initiative will need to involve a large number of knowledge communities in academia and industry in the fields of applied mathematics, informatics, biology, medicine and beyond.

The success of the Digital Life initiative rests on the seven pillars illustrated in Figure 3. These are critical areas that must be given sufficient attention and support over time in order to realise the ambitions of the strategic effort. The pillars are described in more detail below.

**Lighthouse:** The first pillar deals with creating a vibrant, networked digital life community in Norway. It is essential to obtain critical mass in order to foster transdisciplinarity. Activities under this pillar will support science, technology and innovation and be targeted towards achieving global recognition of excellence in key strategic areas. The emerging transdisciplinary community together with leading international communities will develop new models of collaboration transcending established conceptual and methodological approaches. Merging academic cultures across and beyond disciplines to tackle extraordinary biotechnological challenges requires development of a common language in the
broader sense. This represents a massive challenge. Well connected to its international counterparts, the new community will function as a national “lighthouse”, guiding the way in transforming biotechnology research and innovation in Norway.

A first step in the realisation of this pillar will be to establish a national hub-node centre structure as described in Section 4.

**Talent:** The second pillar deals with promoting recruitment of talented young researchers to the Digital Life mission. Performing science based on convergence in line with the Digital Life mission is extremely challenging, intellectually as well as culturally. It requires giving talented researchers opportunities to explore new horizons and embark on difficult scientific and societal problems, perhaps at the risk of failure. In addition, the researchers will meet the intellectual challenge of integrating knowledge across boundaries. This kind of transdisciplinary research also challenges existing funding and publishing traditions, creating disincentives. Thus, the Digital Life initiative must invest in talented, creative and risk-willing individuals to ensure recruitment of the next generation of research leaders who will set the agenda in coming decades. Education and training comprise a critical criterion for the success of the Digital Life initiative. Undergraduate education is handled by the universities, and is not part of the initiative itself. However, post-graduate education through ongoing professional development programmes will be a key function, both at the Ph.D. level and at the level of established researchers. Ph.D. training is expected to be coordinated with existing and emerging graduate-level researcher schools.

**Future:** This pillar deals with taking the “unknown” into consideration when developing the Digital Life initiative. To a large extent, we lack best practice and experience to guide implementation of efforts such as the Digital Life initiative. It is therefore important to be open to testing activities, learning from experience and adjusting the plan during the course of the programme. Regular assessment by and dialogue with stakeholders are key elements of this process. Most notably, diagnostic and prospective competencies and capacities need to be developed through mutual and adaptive learning processes. Activities under this pillar will give necessary flexibility to development and enable inclusion of new promising initiatives.

**Growth:** This pillar deals with fostering innovation and creating societal and financial value in Norway with a solid foundation in biotechnology. A core rationale behind the Digital Life initiative is to integrate competencies and technologies to solve specific and emerging challeng-
es. This should lead to the development of novel and internationally competitive biotechnological innovations based on rational design and the capacity to better control biotechnological processes.

The stakeholder involvement process has revealed that the various Norwegian industries are in different positions with regard to establishing ties to, and taking advantage of, the Digital Life initiative. Building further on the salmon genome project, and with considerable need for innovation relating to e.g. feed and fish health, the aquaculture industry appears to be in a good position to be a dedicated partner from the start. On the other hand, small biotech spin-off companies (i.e. the majority of Norwegian biotech companies) may need incentives to commit to the long-term activities under the Digital Life initiative.

In order to promote industry involvement and growth under the Digital Life initiative, several measures are being discussed with the aim of promoting interaction between industry, academia and society, including the establishment of a dedicated industry engagement and technology transfer group, as well as industry networks. More specifically, the use of existing funding instruments such as Innovation Projects for the Industrial Sector and doctoral and post-doctoral research fellowships targeting industry are being discussed.

**Brand:** This pillar deals with communication and marketing tasks, with three important aims: fostering convergence in the Norwegian system for biotechnological research and innovation; promoting efforts to engage in dialogue with important stakeholder groups such as the general public; and attracting the attention and subsequent participation of the international research community. Sharing of information is central to the integrated model of the Digital Life initiative. This is a huge task as it requires a transformation of the current academic culture gravitating around faculties and disciplines. Development of a new culture of information-sharing and collaboration across established subjects and disciplines, between academia and industry, and involving broad stakeholder representation and engagement will require collective and continuous experimentation in communication.

To reach the right audience, the development of a good communication strategy will need to encompass internal, national and international strategies. The strategy will need to include plans for incorporating recent developments and future advances into communication platforms and media.

**Responsible Research and Innovation (RRI):**
All activities under the Digital Life initiative must be underpinned by the principle and practice of Responsible Research and
Innovation (RRI). It is critical that the biotechnology community is mindful of its societal context and develops anticipatory competence regarding its impacts. What kind of future do we collectively want science, technology and innovation to bring into the world? RRI is a new approach to governance that challenges us all to think about our responsibilities for the future, as scientists, funders, innovators and citizens, and to act upon these.

RRI is a cross-cutting action under Horizon 2020. As the first research council in Europe, the Research Council UK/Engineering and Physical Sciences Research Council (EPSRC) made a formal commitment to a framework for responsible innovation4 in October 2013. Importantly, EPSRC recognises that RRI itself must be a deliberative and responsive process in its own development, shaped by the research community and the stakeholders. The RRI approach of the Digital Life initiative will therefore to a large extent evolve in tandem with the framework for RRI currently being developed within the Research Council of Norway.

**International perspective:**
International cooperation will be a core cross-cutting activity under the Digital Life initiative, promoting knowledge exchange, fostering mobility and facilitating the use of common platforms and infrastructures. Competence building in Norway on digital life must be closely linked with international initiatives. An integrated workstream under the Digital Life initiative will involve activities such as:

- A strategic approach to national competence building in an international context;
- Recruitment of leading international researchers to Norway in key areas of competence;
- Mobility programmes (doctoral/post-doctoral exchange, short term/long term);
- Active use of international infrastructures such as ELIXIR, ISBE and others;
- Collaboration with international research projects;
- Participation in international/joint calls (Horizon 2020, ERA-NETs, NIH, NSF, etc.).

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4 [http://www.epsrc.ac.uk/index.cfm/research/framework/]
Implementation

The Digital Life initiative will be implemented in three phases:

> **Phase I**: Preparatory/dialogue phase (completed June 2014);
> **Phase II**: Establishment of a hub-node centre structure for digital life (2014–2015);

**Phase I** involved a number of meetings and discussions between the BIOTEK2021 programme and national research institutions and industry representatives, as well as with a high-level International Advisory Group. This phase culminated in the decision of the BIOTEK2021 programme board in June 2014 to move forward to Phase II.

**Phase II** in the implementation of the Digital Life — Convergence for Innovation initiative will be the establishment of a National Centre for Digital Life. The call for mandatory outlines (expression of interest) to host the centre was announced in August 2014.

The centre will facilitate and support science, technology and innovation and strive for global recognition of excellence in key strategic areas for Norway. The mission of the centre will be to serve as a flagship in creating a vibrant, transdisciplinary digital life community. It will be organised according to a hub and spokes model in which core competencies are co-localised in the central hub with spokes to distributed specialist nodes. The hub will be hosted by one institution on behalf of the centre. Both the hub and the nodes will be responsible for a varied transdisciplinary research project portfolio. The schematic structure of the National Centre for Digital Life is illustrated in Figure 4.

In addition to performing research and innovation projects, the centre will execute vital tasks relating to i) data management, standardisation and methodological rigour, ii) industry engagement and technology transfer, iii) education and training programmes (including ongoing professional development), iv) international cooperation, and v) development of governance based on principles of Responsible Research and Innovation. This will be organised as a networking project.

The ambition is for the centre to create a dynamic environment where academics, industry and interested publics are invited to collaborate. Frequent mobility and communication between participating
groups will be the key to fostering such a dynamic environment.

**Phase III:** Future calls under the Digital Life initiative will be planned during the course of the BIOTEK2021 programme, based on experience and dialogue with stakeholders following the establishment of the virtual centre. Calls may involve the use of existing funding instruments such as Innovation Projects for the Industrial Sector and doctoral and post-doctoral research fellowships targeting industry.

**FIGURE 4: Schematic structure of the National Centre for Digital Life consisting of a hub with associated nodes.**

Both the hub and nodes will be responsible for a varied transdisciplinary research project portfolio in collaboration with national and international partners (examples of such projects are illustrated by red frames). The hub will take a leading role in performing the national leadership (lighthouse) function with support from the nodes. In addition to doing cutting-edge science, the centre will take on important responsibilities in coordination and provision of infrastructure and competence at a national level.