



European Research Council
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ERC Frontier Research on Biotechnology From discovery to innovation

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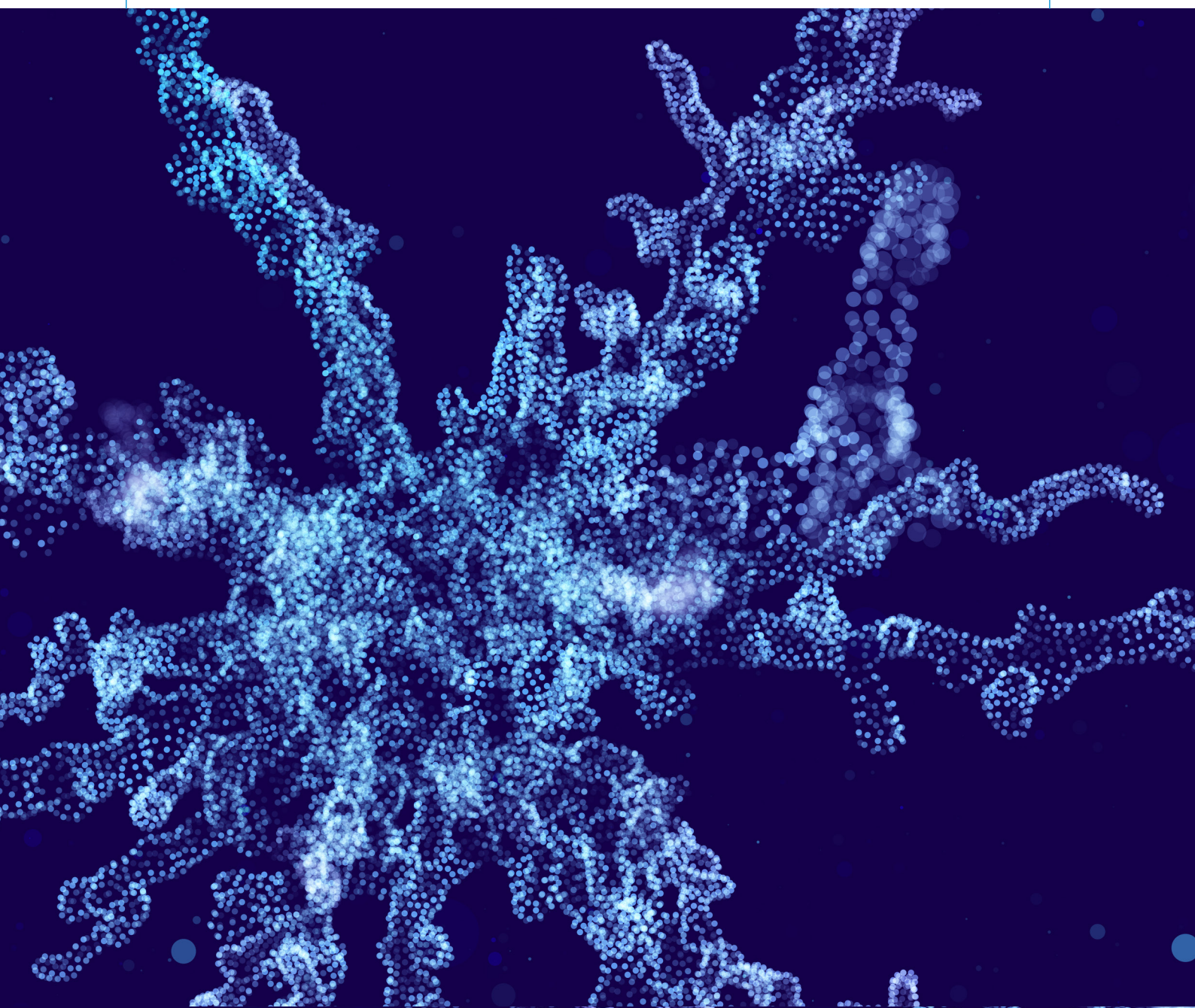


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Foreword

Biological processes have long been used to improve health, produce food and enhance quality of life. Bread, cheese and other fermented foods show an early, intuitive understanding of how the biology of living organisms can benefit people. Modern biotechnology built on this foundation from the 1960s and 1970s, as advances in molecular and cellular biology – including genetic engineering – enabled the production of therapeutic proteins and other medicines. It laid the groundwork for an industry that can improve health, strengthen food systems and support cleaner industry.

In recent decades, progress in fundamental research, scientific instruments and data analysis has driven rapid advances in the field of biotechnology. What has changed is the scale, speed and precision with which biological systems can now be read, designed and engineered.

This matters for Europe as the European Union works to strengthen research and innovation in biotechnology. The European Research Council supports this effort by funding curiosity-driven frontier research across disciplines. Between 2014 and 2023, it funded 2 416 biotechnology projects with EUR 4.09 billion – 21% of its total portfolio over that period.

This report looks closely at these projects and the results they have produced. What emerges is a portfolio far more applied than its ‘fundamental research’ label might suggest: 78% of projects contributed to one or more biotechnology areas, generating new platforms, methods, products and spin-off companies. The ERC Proof of Concept scheme played a key role in this transition, helping grantees test the innovation potential of their discoveries – support that many biotechnology grantees have drawn on, with some going on to secure European Innovation Council Transition grants to carry their work even closer to market.

Together, these findings show how frontier research underpins Europe’s scientific leadership and underline the importance of supporting the full path from curiosity-driven discovery to technological development and scale-up.

Having spent much of our careers at the interface of fundamental biology and its translation into real-world impact, we have seen first-hand how unpredictable – and how essential – that journey from discovery to application can be. Few of the technologies now transforming health, agriculture and industry could have been foreseen at the time the underlying research began. Frontier research is where this future takes shape long before it is visible elsewhere: today’s investigator-driven exploration of living systems is tomorrow’s therapy, crop, material or industrial process.

Sustained support for open-ended, curiosity-driven science is therefore inseparable from Europe’s biotechnology ambitions – it is its foundation. As biotechnology continues to accelerate in scope and significance, it is this type of research that will extend what is possible and keep Europe at the forefront of new discoveries.



Geneviève Almouzni
Former member of the ERC Scientific Council



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Executive Summary

Biotechnology is a strategic technology for Europe and a driver of a fast-growing industrial sector. It is essential for advancing knowledge and innovation across the life sciences, thus strengthening Europe's competitiveness, while contributing to better health, quality of life and citizen's well-being.

Biotechnology supports a wide range of applications, from pharmaceuticals, diagnostics and sustainable food production to innovative chemicals, bio-based products and biomanufacturing. Recognising its strategic importance and the need to accelerate the translation of Europe's strong research base into market-ready innovation, the European Union (EU) has launched several policy initiatives to strengthen biotechnology and biomanufacturing and reinforce its global leadership. These include the [European Biotech Act](#), proposed by the European Commission in December 2025.

In this evolving policy landscape, this report examines the contribution of European Research Council (ERC)-funded frontier research to biotechnology. It explores how it advances scientific knowledge, drives technological breakthroughs and supports innovation across the sector.

The ERC funds a **substantial portfolio of biotechnology projects**, selected solely on the basis of scientific excellence. While medical biotechnology represents the largest share of the ERC portfolio, the funded projects also span industrial, agrifood, environmental and blue biotechnology. The report analyses ERC funding, its geographical distribution and the scientific disciplines involved. It also presents an overview of scientific performance and results, illustrated with examples from various applications areas. (Chapter 2; project examples in Chapters 5-12)

- Between 2014 and 2023, the ERC funded **2 416 biotechnology projects with EUR 4.09 billion**, involving researchers in 28 countries.
- These projects account for **21% of all ERC projects funded during that period**, which underlines the significance of biotechnology in the ERC portfolio.
- The report highlights the **broad range of disciplines** covered by ERC-funded biotechnology research, across the Life Sciences (66.8%), Physical Sciences and Engineering (32.7%), and Social Sciences and Humanities domains (0.5%). The strongest representation is found in areas including prevention, diagnosis and treatment of human diseases, biotechnology and biosystems engineering, products and processes engineering; cell biology, development, stem cells and regeneration; and synthetic chemistry and materials and material engineering.
- It shows that 22% of projects focus on research that could shape the future of biotechnology including through the development of new techniques and methods. Most of the remaining projects (78%) focus on **medical biotechnology** (1 448 projects). Other projects relate to **industrial biotechnology** (245) or to **cross-sector or non-specific applications**, for example through platform technologies or research methods (227). Smaller groups of projects may lead to applications in **agriculture and food** (139), **environmental** (69) and **blue biotechnology** (23).
- Analysis of the projects' scientific publications points to the strong visibility and influence of the portfolio. Publications stemming from ERC-funded biotechnology research receive, on average, **2.46 times more citations than the global baseline** for comparable publications, according to SciVal's field-weighted citation impact (FWCI). In addition, 27% of publications in this portfolio rank among the top 10% most cited worldwide in their field.

To better understand how ERC frontier research may lead to innovation, Chapter 3 takes a **technological perspective**. It classifies ERC projects using the European Innovation Council (EIC) deep tech taxonomy for portfolio reporting and Feedback to Policy, developed in collaboration with the European Investment Bank.

- This classification confirms a strong **concentration on health**, including therapeutic drugs and biologics, regenerative medicine and diagnostics.
- It also shows significant contributions to synthetic biology; biomass, bio-based and engineered living materials; nanotechnology and miniaturisation; and environmental monitoring and intelligence.

The report also looks ahead. In a survey sent in May 2026 to all ERC grantees in the biotechnology portfolio (388 respondents, 19.6% response rate), grantees were asked which **emerging technologies are most likely to reshape biotechnology by 2030**.

- Respondents found **life sciences data mining by artificial intelligence** as the emerging technology most likely to affect the sector
- Other highly ranked technologies include mRNA vaccines (82%), omics technologies (78%), tissue engineering (77%), CRISPR-Cas gene editing (76%), CAR-based therapies (74%), engineered living materials and synthetic cells (72%), and pluripotent stem cells (68%).

The report also identifies **evidence that research results are being valorised, from discovery to application**. Chapter 4 draws on project reported data together with the results of the May 2026 survey and shows how ERC grantees secured follow-on funding to explore the innovation potential of their findings as well as clear signs of technological uptake.

- **531 ERC Proof of Concept (PoC) grants** are included in the biotechnology portfolio, representing 30% of all PoC grants awarded between 2014 and 2023. ERC grantees can apply for PoC grants to explore the commercial or societal potential of the results obtained during their research.
- ERC PoC grants led to **25 EIC Transition grants**, which support the next development steps for promising discoveries.
- Around 14% of publications linked to the biotechnology projects (3 946 in total) have been cited in at least one patent. (Section 4.1)
- At least **211 researchers have filed one or more patents**, some of which have been licensed to companies.
- Researchers have contributed to the creation of at least **72 spin-off companies**.

Taken together, these results show that ERC-funded frontier research does more than expand the knowledge base underpinning biotechnology. It also builds the technological foundations for future products, services and industrial capabilities in the EU. Projects' impact can go beyond scientific publications and directly supports innovation through new scientific methods, proofs of concept, demonstrators, and contributions to practice and policy, as well as through patents and spin-off companies.

At the same time, the report identifies persistent **challenges that limit Europe's ability to scale up biotechnology innovation, as well as opportunities that could be seized at European level**. Drawing on the survey responses collected in May 2026, the report outlines challenges and possible actions in five main areas: support for (frontier) biotechnology research; funding gaps between early-stage discovery and proofs of concept; support for commercialisation and scale-up; stronger innovation ecosystems; and more effective governance and policy frameworks.

Overall, the report's findings show that **curiosity-driven research funded by the ERC is a foundational pillar of Europe's biotechnology ecosystem**. By giving researchers the freedom to pursue creative and ambitious ideas, and to explore uncharted scientific territory, ERC funding generates the knowledge, methods and technological breakthroughs that underpin future waves of innovation.

The results also show that ERC-funded biotechnology research is already leading to tangible innovation outcomes and follow-on investment. At the same time, the evidence highlights the importance of a strong innovation continuum that combines excellence in frontier research with effective mechanisms for translation, scale-up and market deployment.

As global competition in biotechnology intensifies, sustained investment in frontier science, combined with robust innovation ecosystems, will be essential if Europe is to turn scientific leadership into technological sovereignty, industrial competitiveness and long-term economic growth.



1. Introduction and policy context

Biotechnology is a **strategic technology for Europe's** long-term competitiveness. It underpins some of the European Union (EU)'s fastest-growing innovative industries and contributes nearly EUR 40 billion each year to the EU's economy. Health biotechnology alone accounts for more than 80% of this value¹.

Biotechnology is also essential for advancing knowledge in the **life sciences**². It supports a wide range of sectors, including health and medicine, agriculture, food production and safety, industrial manufacturing and environmental applications.

Recent policy documents including the [EU Competitiveness compass](#), [Strategic Technologies for Europe Platform](#) and the Commission Recommendation on [Critical Technology Areas for the EU's Economic Security](#) highlight the need to support biotechnology as a key driver of the **EU's economic security and global competitiveness**. Biotechnology also affects EU citizens' daily lives and concerns.

For these reasons, the European Commission aims to position the EU as a global leader in biotechnology by advancing research and development (R&D), fostering an ecosystem in which biotechnology innovation can thrive and increasing the growth potential of biotechnology companies in the EU³.

EU initiatives for biotechnology

In December 2025, the Commission adopted a proposal for a Regulation establishing a framework of measures to strengthen the EU's biotechnology and biomanufacturing sectors, the [European Biotech Act](#). The proposal focuses on the area of health and would amend biotechnology-related Regulations. In a second step, a European Biotech Act II is expected in the fourth quarter of 2026.

The Biotech Act responds directly to a well-documented competitiveness gap⁴. In the health sector, for example, the EU only holds 7% of global venture capital investment in health biotechnology, compared to 63% for the USA and 14% for China. Structural weaknesses are further diagnosed in the [Draghi Report on the Future of EU Competitiveness](#).

The objectives of the Biotech Act include boosting industrial ecosystem connectivity and R&D, improving access to funding for start-ups and small and medium-sized enterprises (SMEs), facilitating the uptake of artificial intelligence (AI) and digital solutions, reducing time to market through regulatory simplification and introducing biosecurity safeguards to prevent the misuse of biotechnology. The Act also builds on existing strategies and initiatives that support research and innovation in biotechnology and biomanufacturing, including the **EU Life Sciences strategy** and the new **EU Bioeconomy strategy**. More broadly, the sector is governed by EU legislation covering food safety, including recently adopted legislation on new genomic techniques (NGTs), genetically modified organisms (GMOs), advanced therapy medicinal products (ATMPs), chemicals, clinical trials, intellectual property rights and market authorisations.

At research funding level, **Horizon Europe** provides the framework for EU investment in biotechnology research and innovation from frontier research to funding health, food, bioeconomy and digital clusters. Under Horizon Europe pillar three, the **European Innovation Council (EIC)** supports the scale-up of deep-tech biotechnology ventures through its Transition and Accelerator (grants), and EIC fund (equity) instruments.

¹ [European Commission, Overview, Health biotechnology in the EU – figures](#)

² [COM\(2025\) 525 final](#)

³ [European Commission, Overview, Health biotechnology in the EU – figures](#)

⁴ [European Commission, Overview, Health biotechnology in the EU – figures](#)

ERC Frontier research contribution

The European Research Council (ERC) plays a key role in the EU research ecosystem by funding frontier research across all scientific fields, including a substantial **biotechnology portfolio**. ERC grants enable scientific excellence and intellectual freedom and generate breakthrough knowledge that underpins Europe's future technological leadership. The Proof of Concept (PoC) scheme further supports ERC grantees to explore the commercial or societal potential of early-stage discoveries.

Since 2007, ERC-funded projects have delivered **major advances** in gene editing, mRNA vaccines and therapeutic molecules such as proteolysis targeting chimeras (PROTACs), among other areas. ERC-funded biotechnology research contributes to several overarching EU policy priorities. In the context of the **European Green Deal**, frontier research in biosystems, synthetic biology and metabolic engineering supports decarbonisation by enabling the development of bio-based alternatives to fossil-derived materials and processes. ERC research also advances the knowledge and methods needed to support healthy food production, resilient agriculture, food safety and sustainable food systems. In the context of the **EU's digital agenda**, convergence between biotechnology and AI, notably in protein structure prediction, genomic data analysis and automated laboratory platforms, is opening new frontiers in drug discovery and precision medicine. Cross-cutting EU priorities, including **open strategic autonomy**, biosecurity and responsible research and innovation, are also becoming increasingly important in the governance of biotechnology at EU level.

ERC-funded biotechnology research supports **innovation pathways** that contribute to the broader EU objectives of health security, food sovereignty, industrial competitiveness and environmental sustainability. The EIC Transition instrument has also enabled a number of ERC biotechnology grantees to bridge the gap between early-stage discovery and market-ready applications.

This report analyses ERC-funded biotechnology research and its outcomes.

Chapter 2 maps **ERC funding for biotechnology**, the disciplines involved, the geographic distribution of ERC biotechnology projects, and indicators of their scientific performance.

Chapter 3 takes a **technological perspective**. It maps ERC projects using the deep-tech classification developed by the EIC to show where ERC frontier research has the greatest potential for technological innovation. Looking ahead, the report also presents the results of a survey showing how ERC grantees ranked the emerging biotechnologies most likely to transform the sector by 2030. Finally, based on a small sample of projects, the chapter provides initial insights into how AI supports biotechnology in ERC-funded research.

Chapter 4 examines how findings from ERC frontier research translate into potential innovation, patents and spin-off companies, based on data reported by ERC grantees and their survey responses. It also discusses the main challenges and enabling factors along the pathway **from curiosity-driven research to innovation**.

Chapters 5 to 11 focus on the **applications areas of ERC projects and present examples** of projects and their results, covering topics from novel therapies and sustainable industrial processes to disease-resistant and climate-resilient crops and food systems. These chapters address medical, industrial, agrifood, environmental and blue biotechnology, as well as projects with biotechnology applications that do not fall into these categories (non-specific applications). Chapter 11 highlights projects, the results of which may support future biotechnology advances, although their original research proposals were relatively distant from direct biotechnology applications.

Finally, Chapter 12 provides **perspectives from the social sciences and humanities** on developments in biotechnology and their impact on the regulatory, ethical and legal frameworks that shape innovation ecosystems and society. It highlights relevant ERC-funded projects in this domain.

2. ERC Frontier research on biotechnology

The ERC, established by the EU in 2007, is the premier European funding organisation for excellent frontier research. By giving researchers the freedom to pursue ambitious ideas, the ERC enables groundbreaking research with impact beyond science. It provides knowledge and innovation that can inform and shape EU policies, from design to implementation.

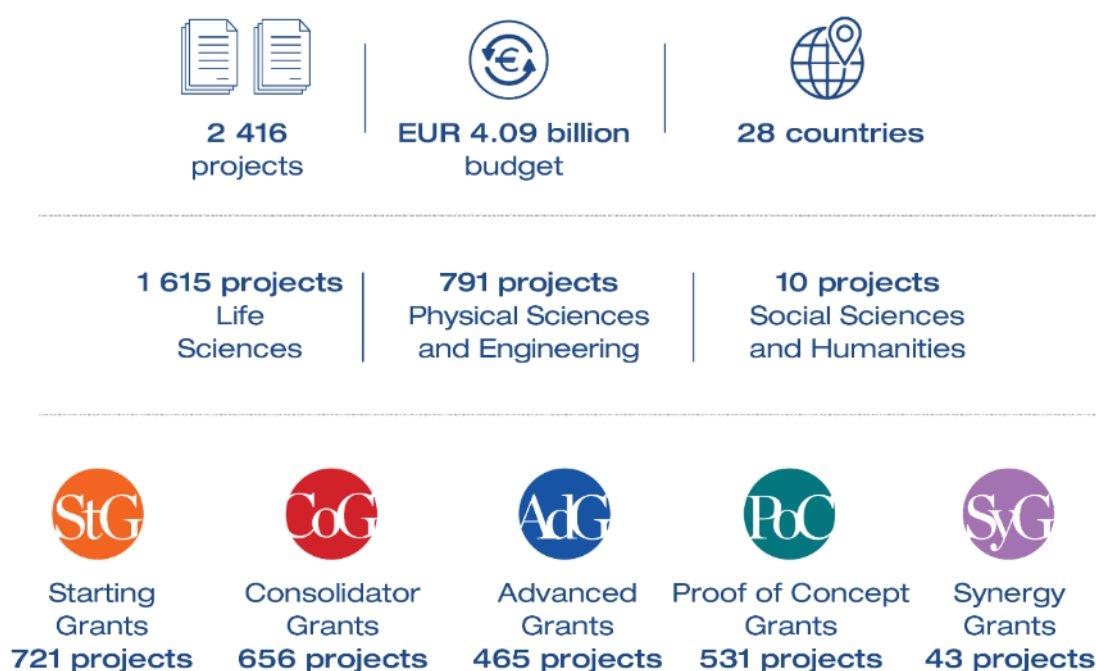
This chapter gives an overview of ERC funding in biotechnology. Projects included in this portfolio align with the Organisation for Economic Co-operation and Development (OECD) [definition](#) of biotechnology: “the application of science and technology to living organisms, as well as parts, products and models of them, to alter living or non-living materials for the production of knowledge, goods and services.” Given the large number of projects using gene editing, sequencing or other omics techniques, the report only included those with the potential to advance future biotechnology research or applications, as well as those relevant to issues addressed by the European Biotech Act.

The chapter also examines ERC projects geographical distribution, their scientific landscape, and their areas of application. Finally, it provides indicators of the scientific performance of the project portfolio.

2.1. At a glance

Without setting predetermined priorities, the ERC funded 2 416 projects in the field of biotechnology in ERC calls from 2014 to 2023. They represent a total ERC investment of over EUR 4.09 billion and 21% of ERC projects funded during that period.

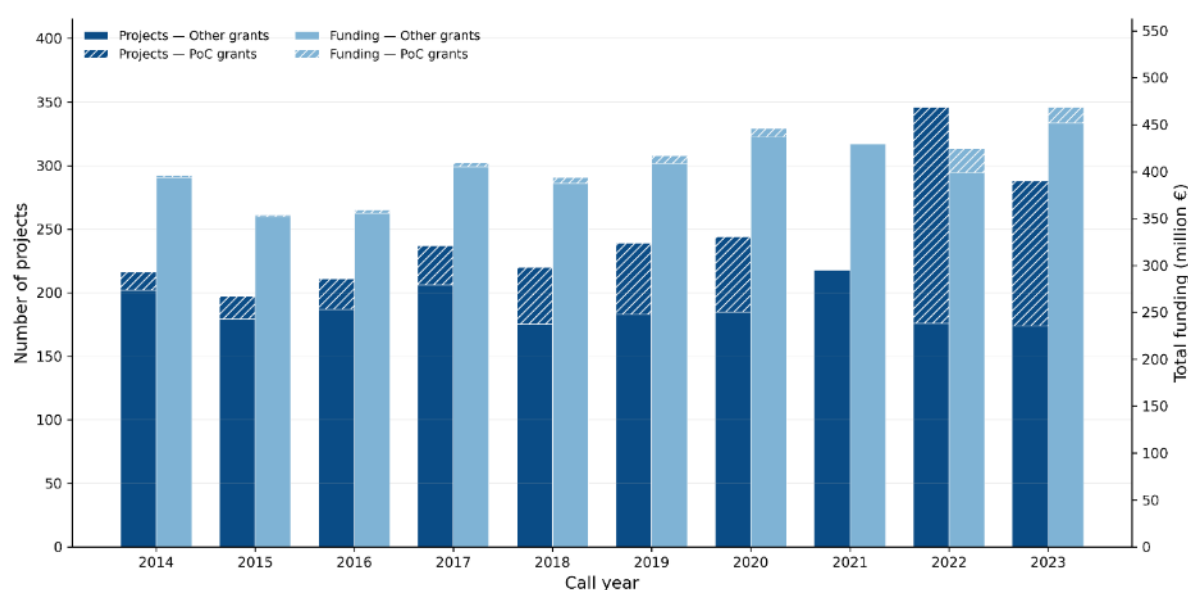
The portfolio includes projects across all main funding schemes, Starting Grants (StG), Consolidator Grants (CoG), Advanced Grants (AdG) and Synergy Grants (SyG). 531 PoC projects are also included, which allow ERC grantees to explore the innovation or commercialisation potential of their results.



In addition to a limited number of projects from the Social Sciences and Humanities (SH) domain in the field of biotechnology (10 projects), 45 projects from this domain address a variety of research topics related to biotechnology in society, and, more broadly, the role and impact of life sciences and health research. They provide perspectives on innovation but also on the impact of biotechnology on society, including from a legal and ethical point of view. These 45 projects are not included in the statistics presented above but their research is presented in Chapter 12.

Biotechnology projects are funded consistently year after year (Figure 1). The pronounced increase in project numbers in 2022 corresponds to the funding of two PoC calls for projects in that year following the absence of a PoC grants in 2021.

Figure 1: ERC biotechnology projects by call year (2014-2023)



Geographical distribution

In terms of geographical distribution, projects are hosted in **28 countries** across EU Member States and associated countries. The four countries hosting the highest number of biotechnology grants are Germany, France, the Netherlands and the United Kingdom (UK), which represent close to 50% of the projects in this portfolio (52% of the funding) (Figure 2).

The **top 10 institutions** hosting ERC biotechnology grants concentrate around 21% of the projects and ERC funding in biotechnology (Figure 3). They include research organisations and universities in the aforementioned four countries, such as CNRS and INSERM in France, the Max Planck Society and the Ludwig Maximilian University Munich in Germany, and the University of Cambridge in the UK. Institutions in Belgium, Israel and Sweden also complete this top 10 list.

Figure 2: ERC biotechnology projects by country (2014-2023, top 20 countries)

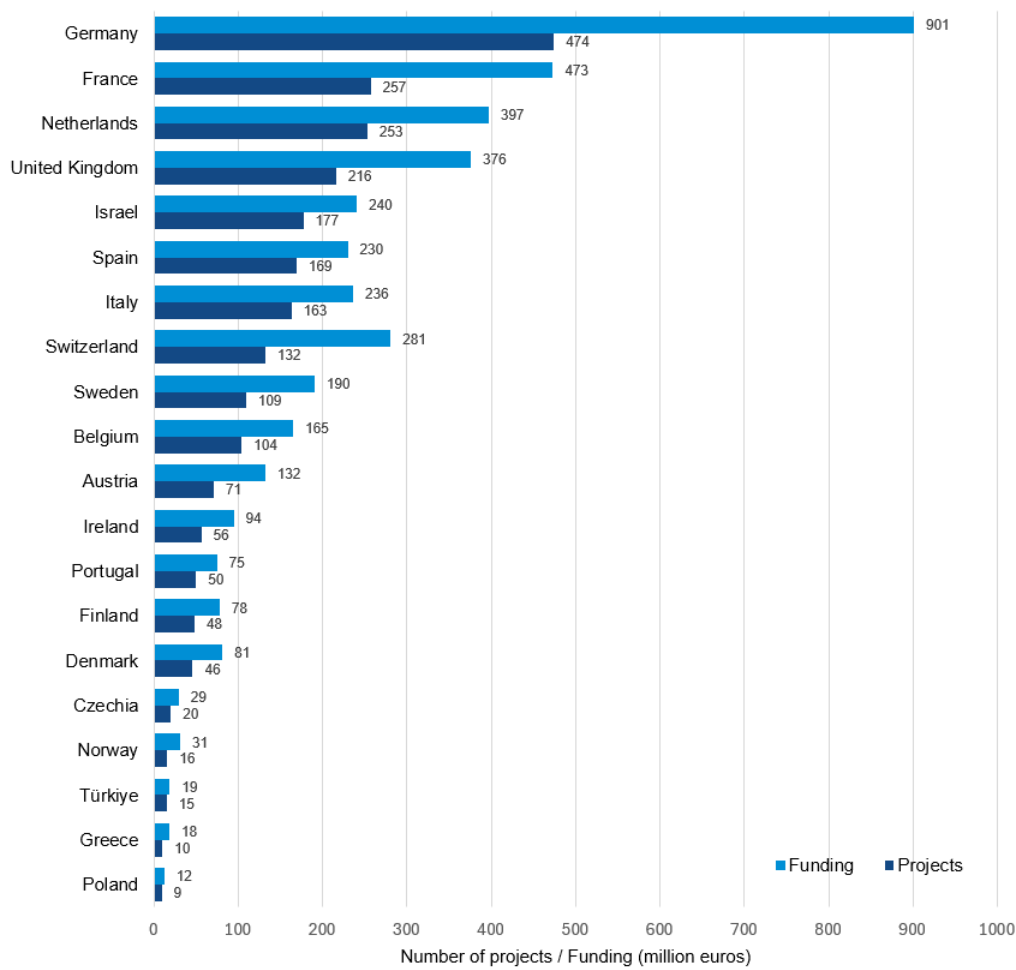
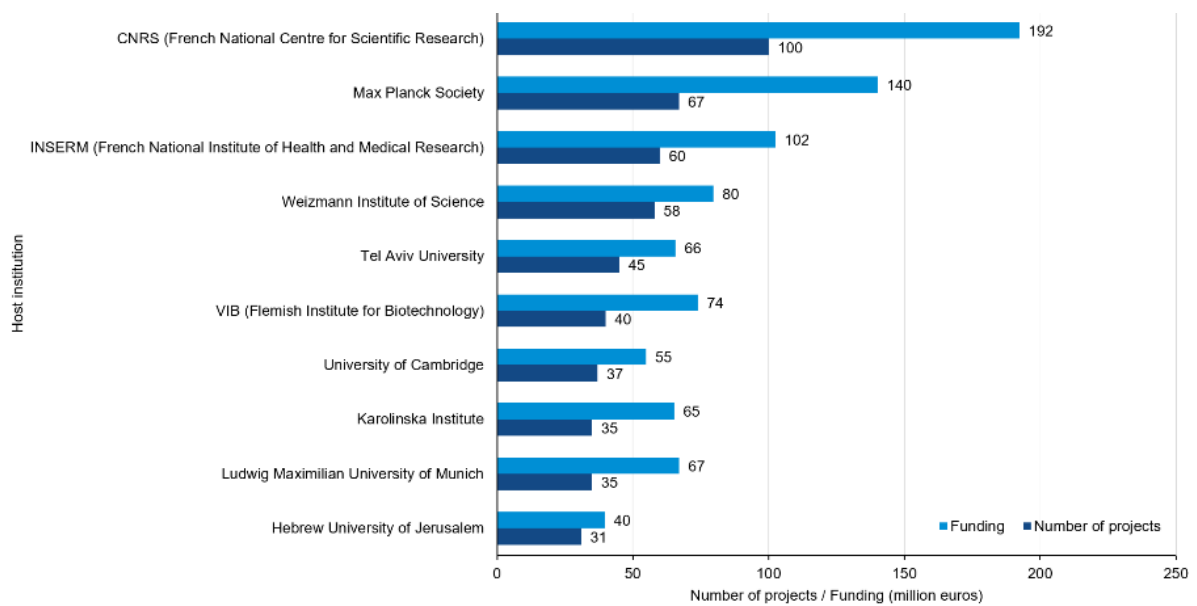


Figure 3: Top 10 institutions hosting ERC biotechnology projects (2014-2023)



These figures show the distribution of projects per country and host institutions. They do not reflect the success rate of individual researchers or institutions.

2.2. Scientific landscape

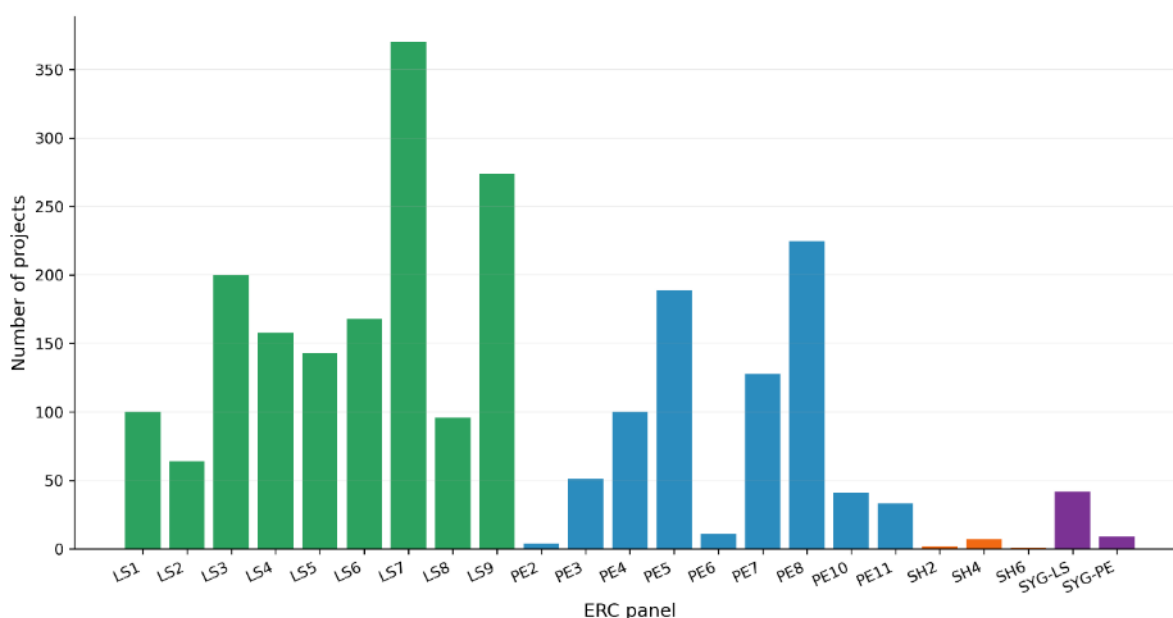
Most projects in the portfolio are funded by ERC panels in the Life Sciences (LS) scientific domain. Together with SyG grants predominately from the Life Sciences, they account for two thirds (66.8%) of the projects, while Physical Sciences and Engineering (PE) panels (including SyG grants predominately from the PE domain) account for one third (32.7%), reflecting the disciplinary convergence that characterises frontier biotechnology research.

Figure 4 shows the distribution of projects across the ERC evaluation panels in the LS, PE, SH domains as well as SyG projects. PoC grants are distributed according to the panel of their parent grant, while SyG grants are represented separately in two bars to reflect their disciplinary grounding as SyG-LS or SyG-PE.

Projects are mainly funded in the following panels: LS7 (Prevention, Diagnosis and Treatment of Human Diseases), LS9 (Biotechnology and Biosystems Engineering), PE8 (Products and Processes Engineering); LS3 (Cell Biology, Development, Stem Cells and Regeneration) and PE5 (Synthetic Chemistry and Materials). Some projects were also funded in the PE11 panel (Materials Engineering), although to a lesser extent in this figure as the panel was only created in 2021.

A small number of grants are funded in the SH domain (0.5%), mainly in the SH4 panel (The Human Mind and Its Complexity). Contributions from other SH panels (SH2, SH6) consider, from an interdisciplinary perspective, design and historical contributions to inform biotechnological solutions for sustainable architecture and agriculture. These projects correspond to research funded in the SH7 panel (Human Mobility, Environment, and Space) that was created in 2021.

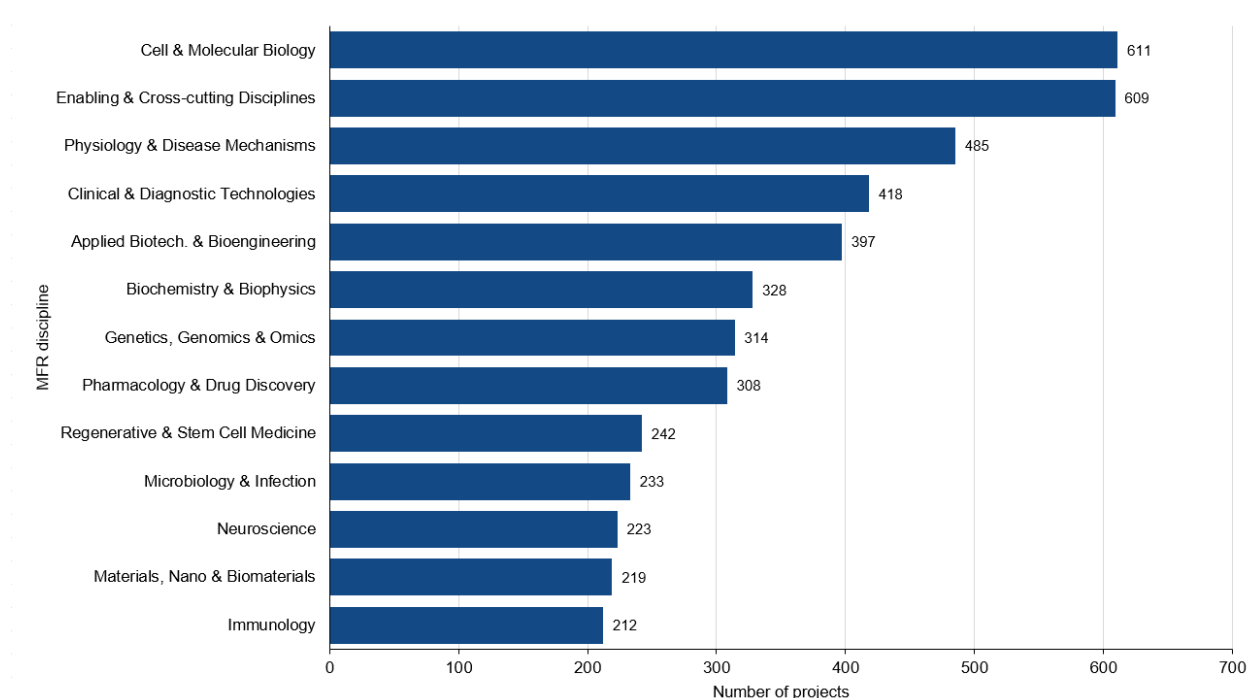
Figure 4: ERC biotechnology projects by evaluation panel (2014-2023)



The ERC panel structure can be found in [ERC Work Programme 2027](#), pp. 55-58.

Mapping Frontier Research ([MFR](#)), an internal ERC classification initiative (see the Methodology chapter), provides a complementary view of the scientific disciplines in the biotechnology portfolio. The overview presented in Figure 5 confirms the strong anchoring in cell and molecular biology (611 projects), and medical research including physiology and disease mechanisms, clinical and diagnostic technologies, pharmacology and drug discovery, and regenerative and stem cell medicine. It also highlights the important contribution of enabling and cross-cutting disciplines supporting biotechnology research (609 projects), including projects in engineering, AI, physics, agriculture and ecology. Strong contributions are also observed in projects focused on applied biotechnology & bioengineering, biochemistry & biophysics, and genetics, genomics & omics, each accounting for more than 300 projects.

Figure 5: Main scientific disciplines in the ERC biotechnology portfolio



PoC grants are not included in this figure. A detailed analysis of ERC PoC grants from 2014 to 2023 can be found in the report [ERC Proof of Concept grants: Exploring the innovation potential of ERC-funded research](#). The analysis shows that biomedical engineering and biotechnology are among the top ten scientific disciplines of all ERC PoC projects with a main grant funded in this period.

Interdisciplinarity

The ERC biotechnology portfolio tends to show a high degree of interdisciplinarity compared to ERC-funded research more broadly. Considering projects from 2014 to 2023 and excluding PoC grants, a large majority of projects (82%) was associated with multiple ERC scientific descriptors by the principal investigators when they applied, compared with around 76% ERC-wide. 17% of the biotechnology projects are described as cross-domain, mainly combining descriptors from the LS and PE domain, almost twice the share observed across the overall ERC portfolio (9%).

Moreover 43 SyG are included in the biotechnology portfolio, representing 23% of the SyG grants funded in 2014-2023. While interdisciplinarity is not a requirement for SyG grants, several projects also bridge several disciplines.

Taken together, this analysis points to a large portfolio of biotechnology projects, anchored in life sciences and medical research with an extensive contribution of physical sciences and engineering, and interdisciplinary research.



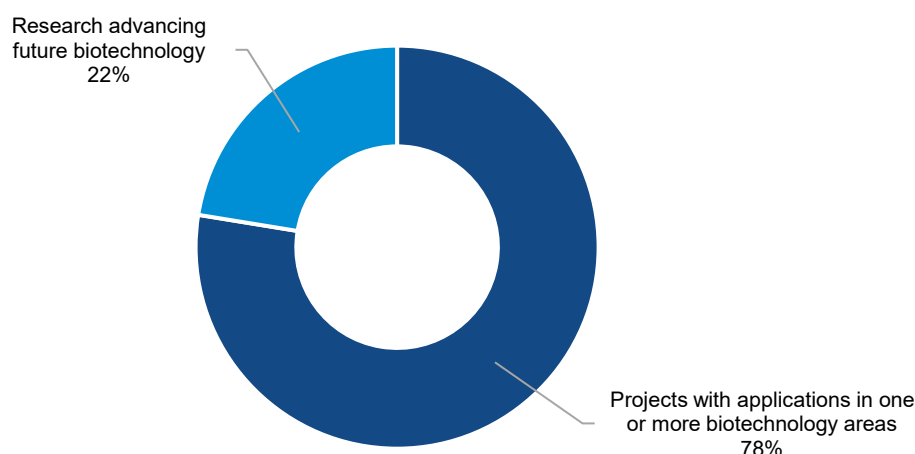
2.3. Projects by biotechnology application area

Many biotechnology projects combine fundamental research (which advances knowledge and methods for future biotechnology developments) and research programmes that have the potential for applications in the short to medium term, such as for clinical practice, advanced manufacturing or environmental monitoring.

Projects in the biotechnology portfolio were first classified according to the number of areas of application (Figure 6).

- 78% of the projects (1 874) have a potential for **application in one or more biotechnology areas**.
- 22% of the projects (542) developed “**research advancing future biotechnology**” but may not have immediate application in biotechnology sector. Examples of these projects are featured in Chapter 11.

Figure 6: ERC projects advancing knowledge for future biotechnology versus projects with applications



The OECD defines eight areas of applications in biotechnology⁵, which were grouped into six categories for the purpose of this analysis. This classification provides an overview of the application areas of ERC projects in this analysis (Figure 7):

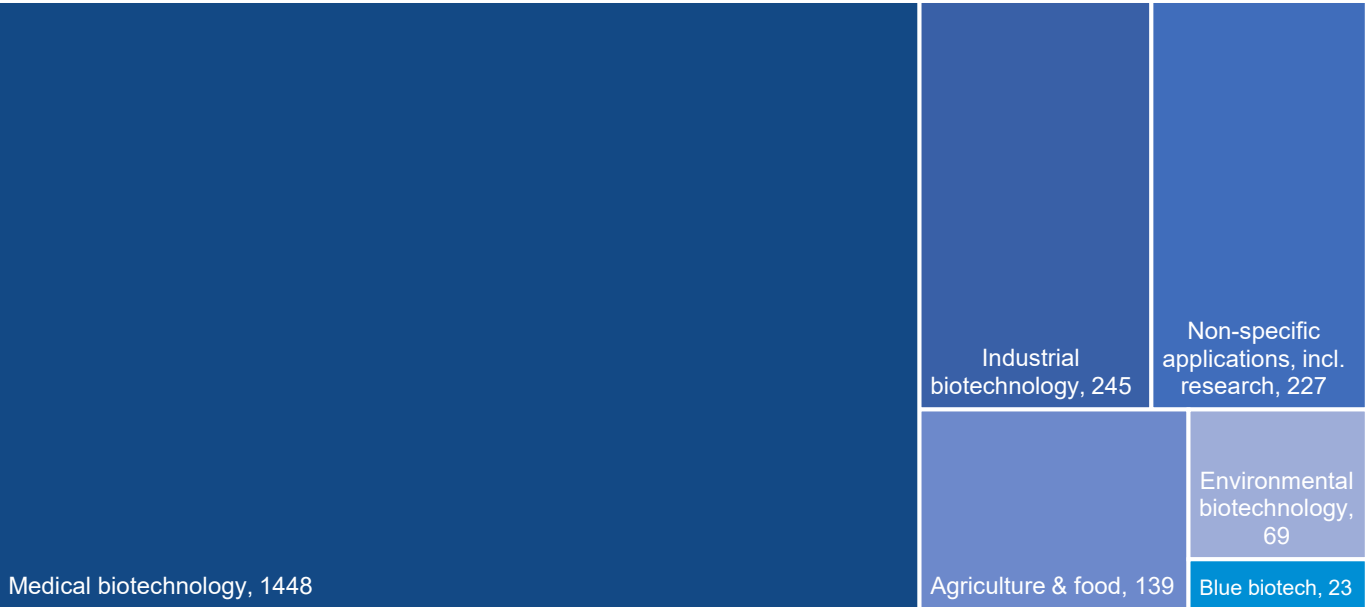
- **Medical biotechnology** covers the OECD ‘human health applications’ area. A large majority of ERC projects contribute to medical and pharmaceutical biotechnology (1 448 projects).
- **Industrial biotechnology** covers projects in ‘industrial processing’ (245 projects).
- **The agriculture and food** category covers biotechnology for ‘agriculture’, and ‘food and beverages processing’ (139 projects).
- **Environmental biotechnology** includes projects with applications for ‘natural resources’ and the ‘environment’ (69 projects).
- **Blue biotechnology** corresponds to projects using marine or freshwater materials or with marine applications (23 projects).

⁵ [Revised proposal for the revision of the statistical definitions of biotechnology and nanotechnology.](#)

Table 2. Proposed classification for biotechnology applications, 2016 update. <https://dx.doi.org/10.1787/085e0151-en>

- **Non-specific applications** in this portfolio include projects with methods for research or research that could have applications for several sectors, e.g. through synthetic biology or technology platforms (227 projects).

Figure 7: ERC projects across biotechnology application areas

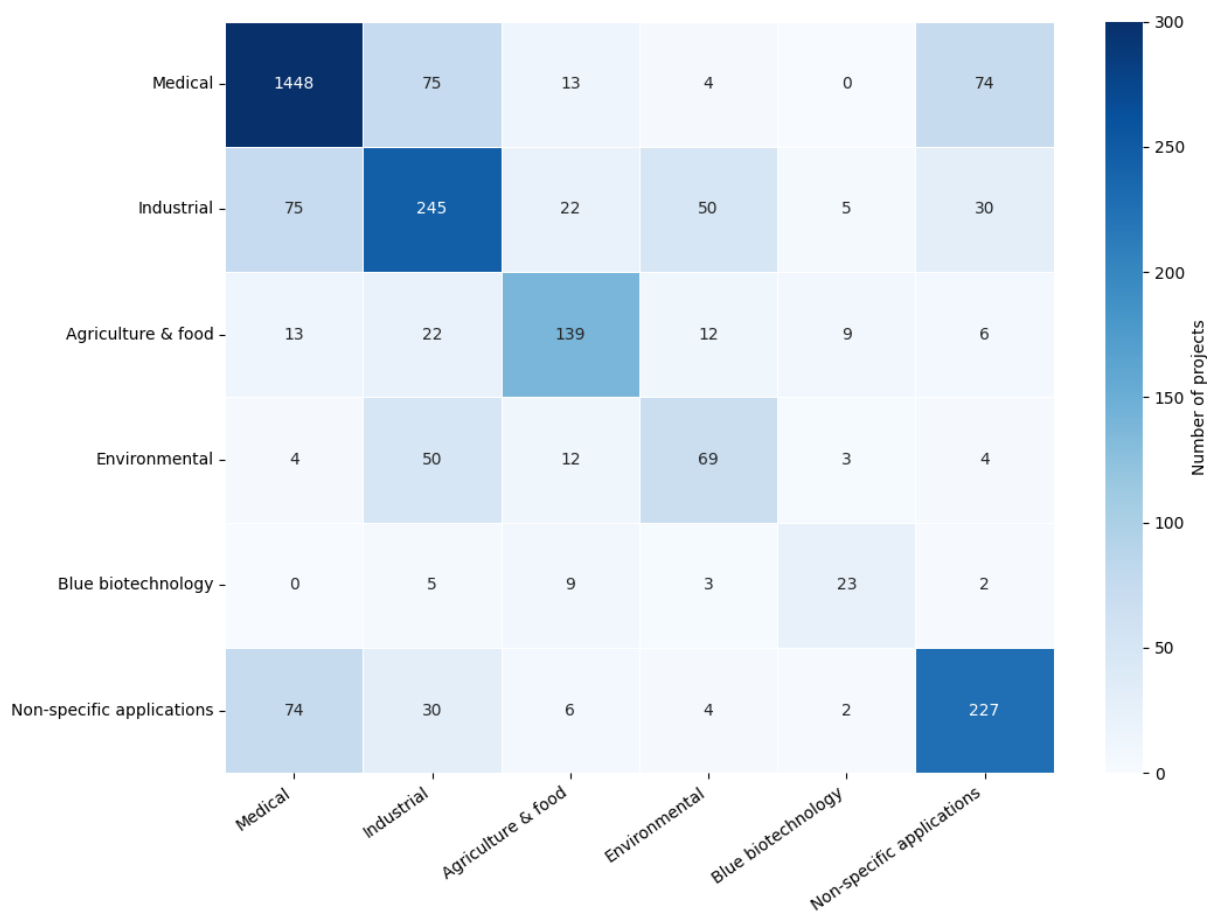


Only projects contributing to one or more biotechnology application areas are represented in this figure (78% of the ERC portfolio).

Projects can fall into several categories of application and have been counted in all categories in which they are relevant. There are significant overlaps, for example between health and industrial applications, and between industrial and environmental biotechnology projects (Figure 8).

Recent biotechnology classifications propose other types of biotechnology application, such as those in nutrition, crop resilience or biotechnology supported by computational science. They are not represented separately here, but examples of projects are provided in the thematic chapters of this report (Chapters 5-12).

Figure 8: ERC biotechnology projects with applications in several areas



2.4. Scientific publications and citations in policy documents

This chapter focuses on the scientific publications resulting from the ERC-funded biotechnology projects included in this portfolio. The analysis was conducted through [SciVal](#), which provides analytics to help evaluate research performance and understand broader research impact. The analysis is based on a dataset that includes both publications reported by researchers in their reports to the ERC and those identified through [OpenAIRE](#). The dataset includes project publications up to February 2026 – 28 438 publications.

Citation performance

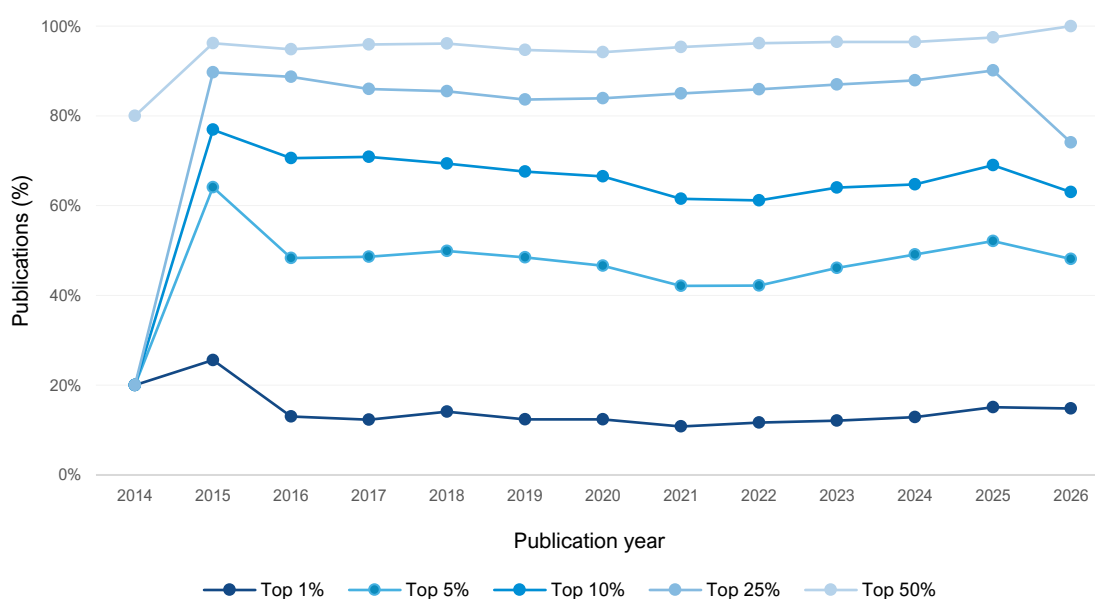
The publications from the projects in this portfolio have broad visibility and influence, as shown by three metrics. First, the field-weighted citation impact ([FWCI](#)), as defined by SciVal, shows that ERC-funded biotechnology research receives **2.46 times more citations than the global baseline** for similar publications, i.e. those in the Scopus database with the same publication year, type and discipline. Regarding the citation volume and reach, these projects had been cited 1 468 009 times at the time of this analysis, with a high average of **51.6 citations per publication**. Remarkably, **27% of publications in this portfolio rank in the top 10%** of the most cited works worldwide within their field.

Publications in top journals

An additional indicator of scientific influence is the frequency with which research outputs appear in leading journals. These journals were identified according to their CiteScore ranking, a journal metric in Scopus and SciVal, which measures number of citations of documents by a journal divided by number of publications, over a four-year period.

The analysis of publications linked to ERC biotechnology research in top-journals shows a consistently high prominence of ERC-funded research outputs. Around **65% of the publications were featured in the top 10% of journals**, while nearly 86% of publications were placed in the top 25% of journals (Figure 9).

Figure 9: Percentage of biotechnology project publications in top journals by year of publication

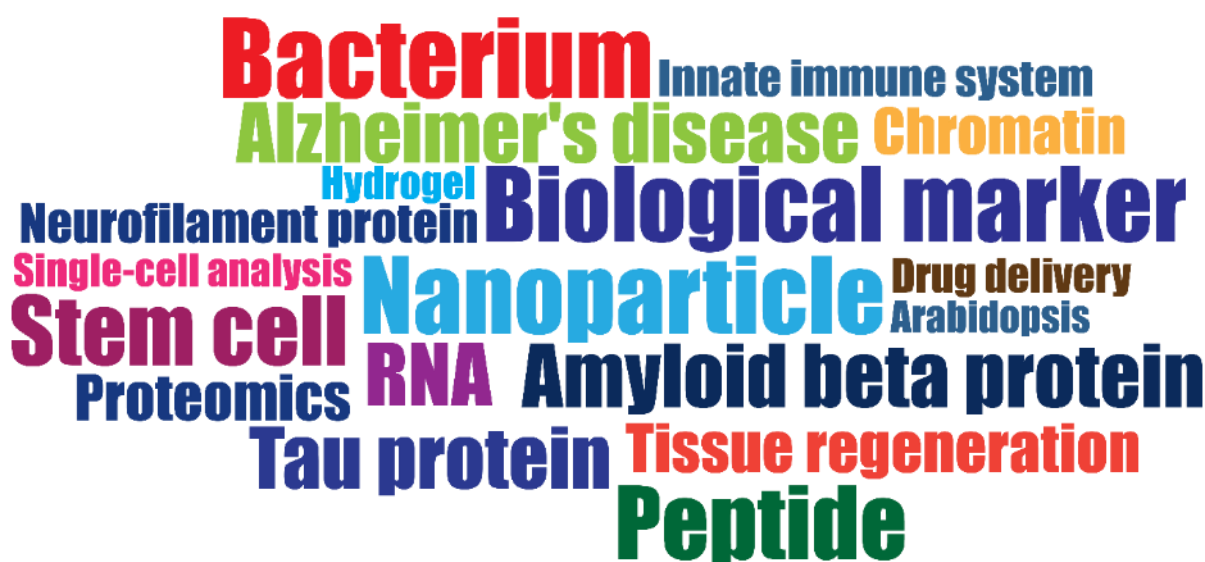


Source: SciVal, adapted by the authors.

Key themes in scientific publications

A thematic analysis of publications within this portfolio, using SciVal key themes, the most frequent topics across all publications, showed key themes such as gene editing and the CRISPR-Cas system, single cell analysis, synthetic biology and the microbiome, as well as more health and biomedical themes including tau proteins, organoids, nanomedicine and optogenetics.

Figure 10: Key themes in ERC biotechnology project publications



Source: SciVal, for publications from 2015-2024, adapted by the authors.

Citations in policy documents

In addition to its scientific impact, ERC-funded research has also informed policy. More than 1 200 publications linked to biotechnology projects within this portfolio have been cited in policy documents produced by intergovernmental organisations, national and local governments, and think-tanks. Notably, one in five projects in this portfolio has generated publications cited in such policy documents.

While such citations provide only an indirect indicator of potential policy influence, several projects and associated publications nevertheless emerge as examples of research contributing to policy-relevant debates and evidence-informed decision-making.

- One example is the [NOVCARBFIX](#) project, led by Ron Milo from the Weizmann Institute of Science in Israel, which explores methods to enhance carbon fixation rates for improved agricultural productivity and renewable energy storage. Research from this project has been referenced in a United Nations Development Programme [report](#) on human security, in a United Nations Environmental Programme (UNEP) [report](#) on planetary climate, biodiversity and pollution emergencies, and in multiple publications from the Food and Agriculture Organization of the United Nations (FAO), addressing [the intersection of land use and climate change](#), [global fisheries and aquaculture](#), and [livestock-related emerging infectious diseases](#). Additionally, the project findings appear in two separate [World Bank](#) and [World Economic Forum](#) reports on the economic costs of nature loss, as well as in an OECD [publication](#) examining environmental risks associated with certain pesticides.

- Another notable example is the [INVADIS](#) project, led by Marc Lecuit at the Pasteur Institute in France, which examined the molecular mechanisms underlying tissue invasion, dissemination and host responses during *Listeria monocytogenes* infection. The project's research outputs were cited in various policy-relevant reports on the topic, including an FAO [report](#) and a [joint report](#) from the World Health Organization (WHO) and the FAO. Additionally, the research was referenced in a [joint study](#) by the European Centre for Disease Prevention and Control, the European Food Safety Authority, and the European Union Reference Laboratory. National public health agencies also drew from this work: the Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu) cited the research findings in two separate reports, available [here](#) and [here](#), and France's Agence Nationale de Sécurité Sanitaire Alimentation, Environnement, Travail of France referenced the project in multiple policy documents (such as [1](#) and [2](#)).
- The [DeMMYR](#) project led by Diane Saunders from the John Innes Centre in the UK focused on developing new wheat varieties with enhanced resistance to a globally threatening disease affecting cereal crops and grasses. The findings were included in relevant policy documents, including a United Nations Conference on Trade and Development [report](#) on promoting food security through non-tariff measures, and two FAO reports: [on climate-change impacts on plant pests](#) and [on sustainable plant production](#).

Projects from the SH domain, described in Chapter 12, are further examples of ERC-funded research that informed policies relevant to biotechnology.



3. Technological landscape

This chapter takes a technological perspective on the ERC frontier research in biotechnology.

- Firstly, it maps ERC projects using the deep-tech classification developed by the EIC to show where ERC frontier research has the greatest potential for technological innovation.
- Looking ahead to 2030, the chapter presents the results of a survey showing which emerging biotechnologies are most likely to transform the sector, according to ERC grantees' responses.
- Finally, based on a reduced sample of projects, the chapter provides preliminary insights into how AI supports biotechnology in ERC-funded research.

3.1. Sectors and technologies across the ERC biotechnology portfolio

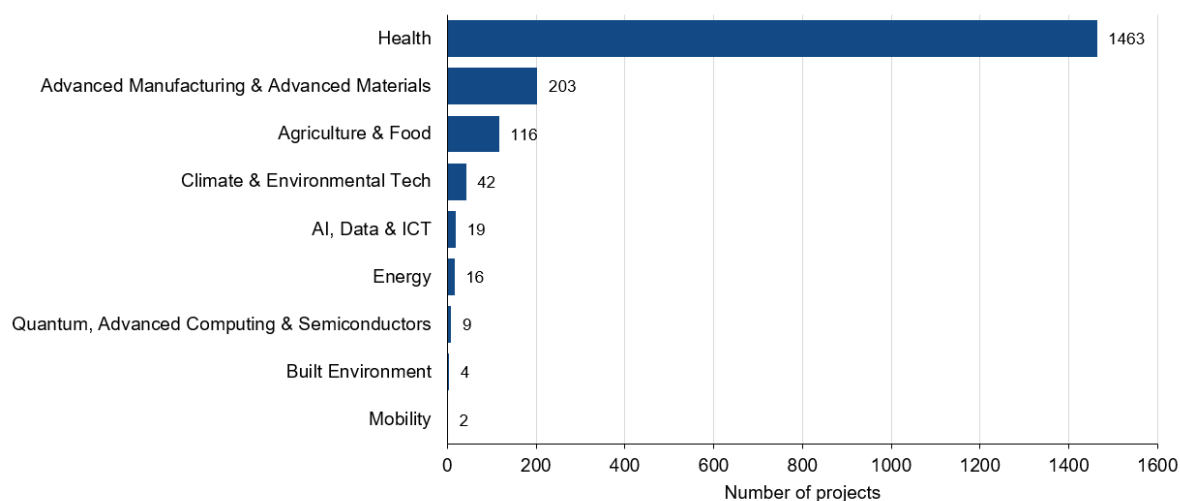
The EIC deep-tech taxonomy highlights where ERC-funded biotechnology projects could drive innovation. The taxonomy is a technology-oriented classification system that includes 11 primary categories, 64 secondary categories and 161 tertiary categories, all corresponding to underlying technologies, applications and sectors, and has been used to report on the impact of the EIC with coverage at Technology Readiness Levels (TRLs) from 1 to 9.

The taxonomy is used in this report to describe the application areas and technologies addressed by biotechnology projects to complement the MFR scientific classification and biotechnology application detailed in previous chapters.

ERC projects that aligned with at least one of the application areas of the OECD classification (see Section 2.3) were classified with the EIC taxonomy – 1 874 projects, covering 78% of the total ERC biotechnology portfolio.

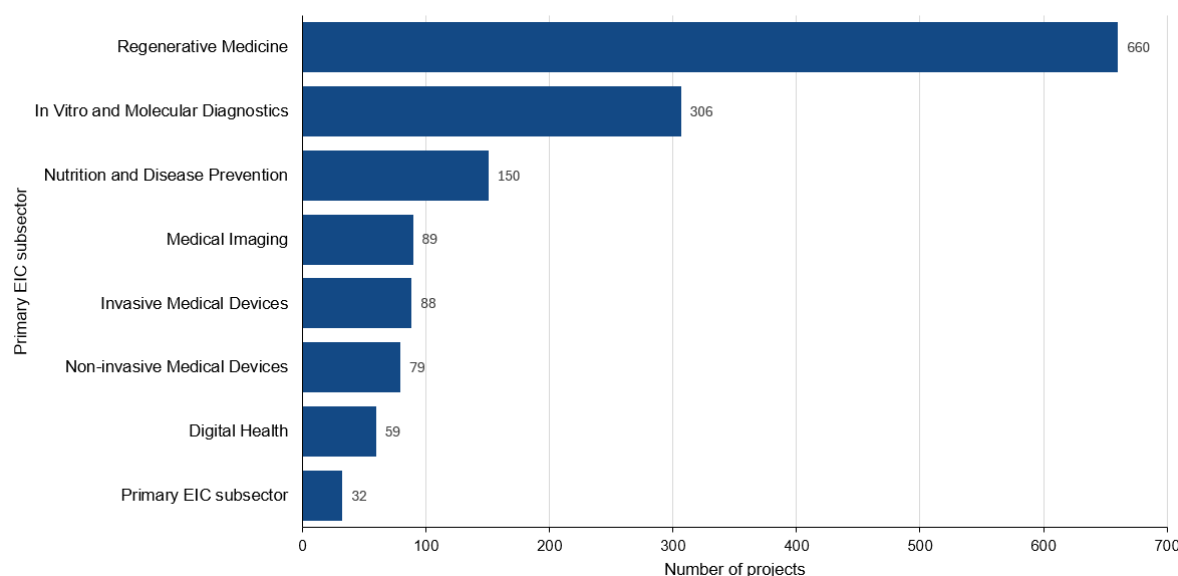
The distribution of projects across **EIC main sectors** (primary categories in the taxonomy; Figure 11) shows most of the classified projects are in the **health** sector (78%). This category combines the projects classified as 'medical technology' and 'health biotechnology' in the EIC classification. The **advanced manufacturing and advanced materials** sector that covers projects with applications in industrial biotechnology including synthetic biology and biomaterials, and the **agricultural and food** sector follow. Together these three sectors represent 95% of the projects. 'Climate and environmental tech' represents a small share of projects, with 41 projects identified in this sector.

Figure 11: ERC biotechnology projects across the main sectors of application



Given the **dominance of health** in the portfolio, Figure 12 focuses on projects in this field with a break down by **main subsector** (secondary categories in the taxonomy), providing a more detailed view of their **application areas**.

Figure 12: ERC biotechnology projects in the health sector across subsectors



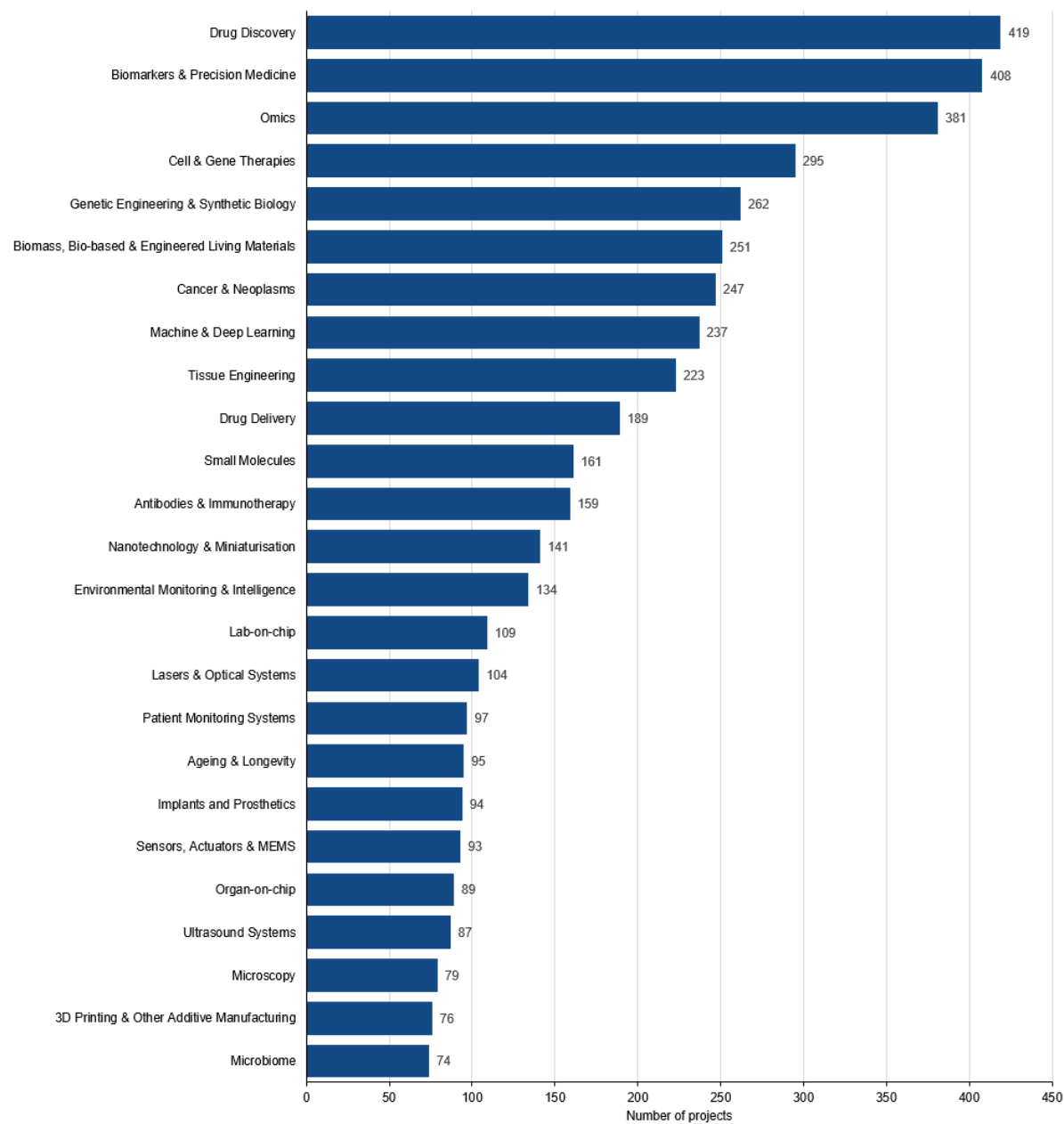
ERC projects were finally classified by **technologies** and **focus areas** (EIC taxonomy tertiary categories; Figure 13) to further describe the research conducted by projects in the portfolio, their applications, methods used and, for projects in the health category, the targeted diseases.

Technologies most deployed by ERC projects include **drug discovery** (419 projects), **biomarkers & precision medicine** (408 projects) and **omics techniques** (381 projects). They are closely followed by **cell & gene therapies** and **genetic engineering & synthetic biology**, with more than 250 projects each.

Beyond the health and medical sector, **biomass, bio-based & engineered living materials** (251 projects) stand out, followed by **machine & deep learning** (237 projects). A smaller but significant number of projects develop research relevant to **nanotechnology & miniaturisation** (141 projects) and **environmental monitoring & intelligence** (134). Machine & deep learning appears in 237 projects, which is considerably higher than the 19 projects classified in the AI, Data & ICT sector. This could reflect that AI is often embedded as an enabling tool in projects whose primary classification is in another sector – typically the health sector.

In terms of focus areas, **cancer and neoplasms** is the only area ranked in the top 15, corresponding to a large pool of cancer research projects developing diagnostic tools and therapies. Examples of projects are available in Chapter 5. **Ageing & longevity** appears lower in the list.

Figure 13: ERC biotechnology projects across technologies and focus areas



ERC projects distribution across the main 25 technologies and sector areas.

3.2. Biotechnology outlook to 2030: emerging technologies

In May 2026, a survey invited ERC grantees leading biotechnology projects to reflect beyond their current research and identify which emerging technologies they consider most likely to change biotechnology and its applications by 2030. 388 answers were collected for the survey (19.6% response rate). More information on the survey is available in the Methodology chapter.

The survey listed 30 emerging technologies grouped under seven thematic categories, with respondent asked to rate each one on a five-point scale (very likely, likely, unlikely, highly unlikely, too uncertain to assess). A free text 'other' field allowed respondents to flag any additional technologies that were not part of the list.

The options proposed in the survey focused on recent technologies emerging in weak signals analyses or identified as promising novelties that could have an impact on the biotechnology sector. They were extracted from OECD and European Commission reports.⁶

Although the question was optional, it received a high response rate with each of the 30 individual items rated by 86-95% of the respondents across the list. The respondent pool comprises two thirds LS and one third PE grantees, which matches the composition of the wider ERC biotechnology portfolio. The majority of respondents work on projects with applications in health, which is consistent with the broader composition of the portfolio described in the previous chapter.

Emerging technologies most likely to change biotechnology by 2030

Eight technologies were rated 'very likely' or 'likely' by >65% of respondents, and most of them sit within life sciences and medical biotechnology (Figure 14).

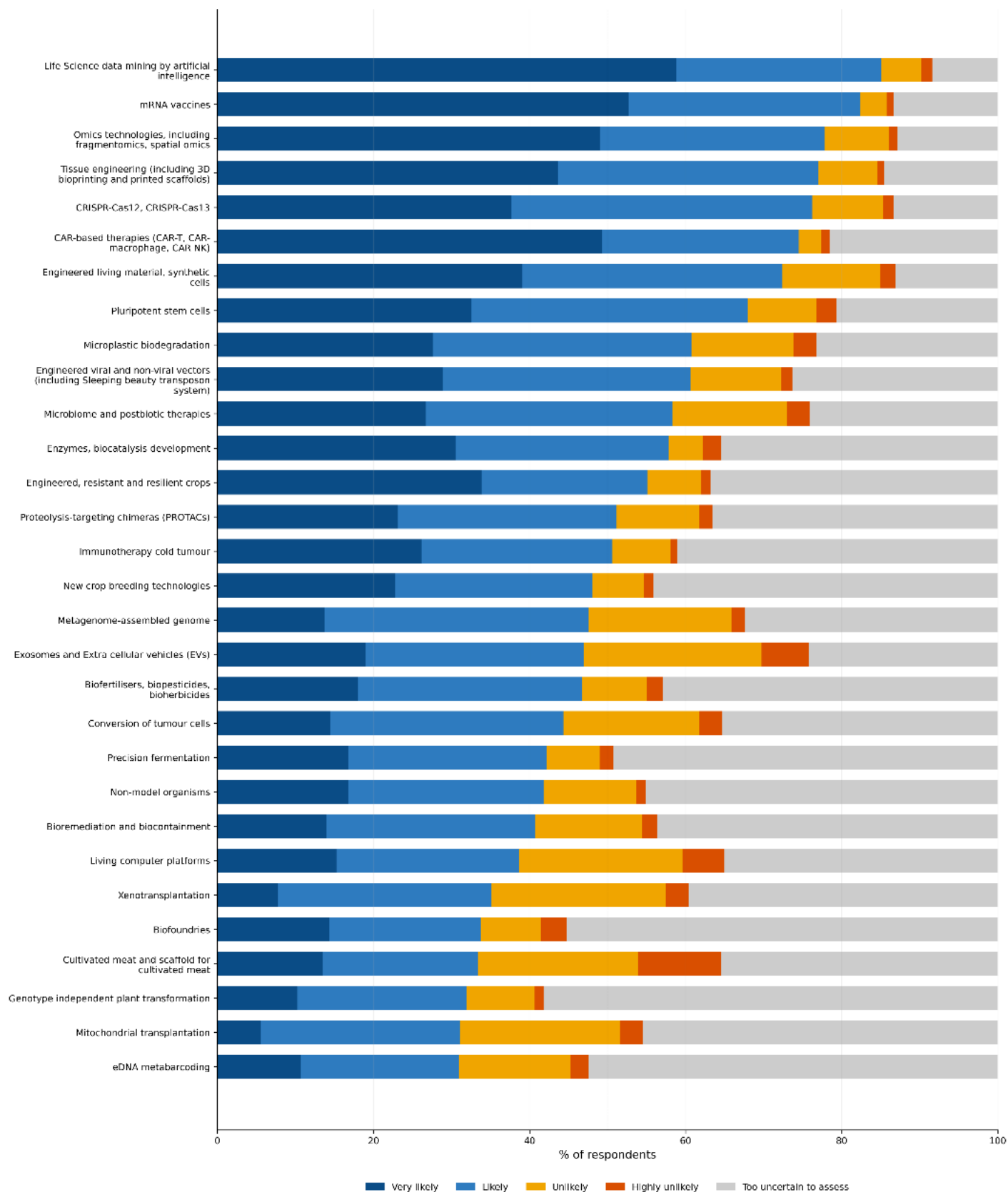
Life Sciences data mining by AI stood out as the most consensual emerging technology in the survey, rated 'very likely' or 'likely' by 85% of respondents (with 59% selecting 'very likely' alone).

It was followed by **mRNA vaccines** (82%), **omics technologies** (78%), **tissue engineering**, including 3D bioprinting (77%), **CRISPR-Cas12 and CRISPR-Cas13** (76%), **chimeric antigen receptor (CAR)-based therapies**, including CAR-T, CAR-macrophage and CAR NK (74%), **engineered living material and synthetic cells** (72%), and **pluripotent stem cells** (68%).

The potential of AI methods to impact biotechnologies and accelerate discoveries was also highlighted by respondents as an important driver for European biotechnology by 2030 (see Section 4.2). In the free text 'other' field, 20 respondents independently raised AI methods or use of AI as promising areas, citing AI-driven biological design, foundation models, AI-driven drug discovery, closed-loop protein engineering combining protein language models with directed evolution, and the convergence between AI and synthetic biology.

⁶ For example, the OECD's [Synthetic biology in focus: Policy issues and opportunities in engineering life](#), the European Commission's Joint Research Council [Weak signals in Science and Technologies — 2024](#), and [Healing the Future — Horizon scanning for emerging technologies and breakthrough innovations in the field of cell and gene therapies](#).

Figure 14: Looking ahead to 2030, which emerging technologies do you believe are most likely to significantly transform biotechnology and its applications?



Source: ERC biotechnology survey responses, May 2026

Among the emerging therapies listed, **CAR-based therapies** emerge as the most highly rated after **mRNA vaccines**, which reflects the visibility of cellular immunotherapies among ERC grantees working at the frontier of immunology and oncology.

Several of the technologies most highly rated by respondents are already actively pursued by ERC grantees, as shown by the EIC technology classification (Figure 13). Gene editing techniques are embedded in the 262 projects classified under 'Genetic Engineering & Synthetic Biology'; omics technologies are used in 381 projects; and tissue engineering corresponds to a group of 223 projects across the portfolio.

Beyond medical applications

Several emerging technologies with applications beyond health also featured prominently among the results: **microplastic biodegradation**, rated 'very likely' or 'likely' by 61% of respondents, **enzymes and biocatalysis development** (58%), and **engineered, resistant and resilient crops** (55%).

Engineered living material and synthetic cells, already mentioned above (72%), also span industrial and environmental biotechnology applications, including for manufacturing, environmental protection, energy and agriculture.

Emerging technologies captured in open responses

The technologies proposed in the survey were complemented by respondents' free-text responses (117 responses). While some answers specified available options, several technologies not covered by the list were also proposed. The most frequently mentioned technologies were the following:

- AI-driven biological design (20 times);
- Advanced protein engineering and *de novo* design (12 times);
- RNA therapeutics beyond mRNA vaccines, including siRNA, circular RNA and antisense oligonucleotides (9 times);
- Organoids and organ-on-chip systems (9 times);
- Neurotechnology and bioelectronic medicine, encompassing brain-computer interfaces and closed-loop neuromodulation (9 times);
- Nanomedicine and targeted drug delivery (8 times);
- Advanced imaging and biosensing (8 times).

Some of these topics are also prominent among the most frequent technologies in the ERC biotechnology portfolio (Figure 13), e.g. organs-on-a-chip and microbiome research, when considered beyond strictly therapeutic applications.

Potential of combined emerging technologies

Around 12 respondents suggested that the **combination of multiple emerging technologies**, rather than any single technology in isolation, could be the most transformative factor for biotechnology by 2030. Several combinations were specified in these responses:

- AI with organoids and advanced human model systems, leveraging AI to design and interpret experiments in increasingly sophisticated *in vitro* human systems;
- RNA and gene editing technologies combined with advanced imaging, enabling real-time monitoring of therapeutic interventions at cellular and subcellular resolution;
- AI integrated with protein design and directed evolution, accelerating the design-build-test cycle for novel proteins and biologic;

- AI applied to multi-omics and clinical data, supporting biomarker discovery, patient stratification, and the translation of molecular insights into clinical decisions;
- AI integrated with synthetic biology, moving from descriptive modelling to predictive design of biological systems.

The recurrence of AI across nearly all these pairings reflects a broader signal in the free-text responses: AI is seen not only as an emerging technology but also as a connective enabler that amplifies the impact of other emerging fields.

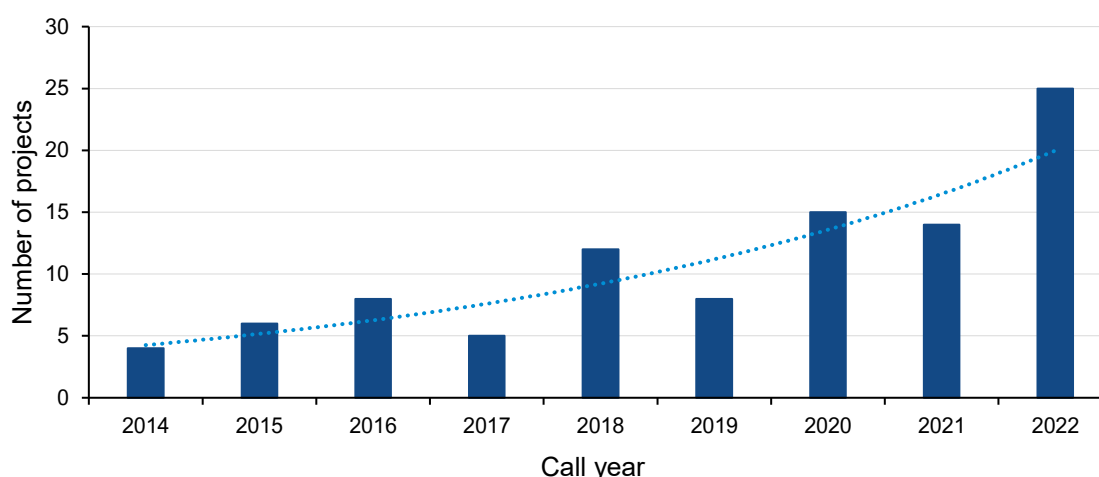


3.3. Artificial intelligence in ERC biotechnology research: overview

This chapter presents a snapshot of the use of AI in the ERC biotechnology portfolio. It is based on a small dataset of 97 projects that are included in both the ERC biotechnology and the AI portfolio analysed in the report [Mapping ERC frontier research artificial intelligence](#). The sample covers only grants awarded between 2014 to 2022 that used AI in their research. Although limited in scope, this set of projects provides a high-level overview of how AI can support ERC biotechnology research.

Of the 97 projects, around half fall within the LS domain and the other half within the PE domain. One project belongs to the SH domain. The distribution of projects by call year suggests that the use of AI increased steadily over this period (Figure 15). This trend is consistent with the overall growth in AI-related projects identified in the AI report mentioned above.

Figure 15: ERC Projects in the AI and biotechnology portfolios by call year (2014-2022)



The AI methods and technologies employed by these 97 projects, as described in project abstracts and keywords, were reviewed along with those used by a set of projects funded in ERC 2023 calls.

Machine learning and deep learning emerge as the most widely utilised AI methods in these projects. [Machine learning](#) refers to a set of techniques that enable systems to learn from data, identifying patterns and regularities without explicit human instructions. This process allows systems to improve their performance and generate models. [Deep learning](#), a subset of machine learning, focuses on training artificial neural networks – inspired by the human brain’s structure and functions. This approach extracts features from raw data through multiple layers of abstraction and processes large-scale datasets with high-dimensional inputs. Other AI methods used by ERC grantees include **digital twins**, **neural networks**, large scale **data mining, analysis and integration** and **embodied AI**.

Two thirds of the projects using AI methods have applications in the medical and health-related domains, e.g., clinical decision support and precision medicine, drug discovery, regenerative medicine and neuroscience. Others have applications in industrial biotechnology including advanced materials. Below are examples of how AI is used, highlighting specific methods and applications.

Clinical decision support and precision medicine

- [OUTSMART-infection](#) uses **machine learning to analyse phenotypic and genomic data from patients' gut microbiomes**, developing a model that designs treatments for recurrent urinary tract infections and helps prevent antibiotic resistance.
- [CURE](#) develops a high-fidelity computational framework using **deep reinforcement learning to optimise flow-diverting stents for the treatment of intracranial aneurysms**, to reduce risks of haemorrhage, support doctors' decision-making and guide new implant design – contributing to the convergence of biotechnology, AI, computational science, and clinical medicine.

Therapies and drug design

- [Precision Lethality](#) constructs a **deep learning model to predict drug sensitivity of individual cells**, based on a cell barcode strategy that monitors the survival of cell populations under specific drugs and identifies additional drugs to target resistant populations. This allows the identification of a combination of drug treatments to effectively target all cells, given the heterogeneous nature of many tumours – including neuroblastoma, the focus of this project.
- [JuvenTwin](#) will leverage **digital twins** to simulate and screen rejuvenation treatments to combat the mechanobiological effects of vascular ageing.
- [AMADEUS](#) uses **machine learning** among other methods **to engineer a comprehensive technology platform** capable of autonomously synthesising thousands of small molecules per day. This platform **will optimise the drug discovery process** for unmet medical needs, reducing drug costs for patients and lowering the environmental footprint.
- [AB-AG-INTERACT](#) uses **machine-learning techniques to predict binding rules between antibodies and antigens**, which will allow for in silico design of therapeutics and vaccines.

Regenerative medicine

- [EvOoc](#) applies **machine learning-based algorithms** to adjust mechanical forces based on tissue responses within organ-on-a-chip platforms, enabling controlled in vitro development of adult tissues.

Advanced manufacturing and biomaterials

- [FASTEN](#) uses **deep learning** combined with a computational approach **to enable fast and accurate routine design of highly efficient enzymes** that are relevant for industrial uses and could boost chemical manufacturing competitiveness.
- [NEUROMETA](#) aims to develop mechanical bio-based metamaterials with adaptive behaviours that mimic **artificial neural networks**.

More examples of medical biotechnology projects using AI are available in Chapter 5. More broadly, the use of AI in ERC-funded health research is examined in the report [ERC Frontier Research for Artificial Intelligence in Health, from disease prevention to diagnosis and treatment](#).

4. From curiosity-driven research to innovation

Biotechnology is one of the fastest-growing economic sectors in the EU and one of the critical technologies the EU aims to support. It is increasingly important not only for health and medical innovation but also for industrial and agrifood applications, as well as for the EU's competitiveness in these markets. The proposed European Biotech Act aims to strengthen the biotechnology and biomanufacturing sectors, from early-stage research to innovation scale-up and commercialisation, reinforcing the EU's global competitiveness and leadership in this field.

This chapter explores how ERC grantees are bringing their findings closer to markets, as well as challenges and opportunities in moving from frontier research to innovation, based on a survey of grantees leading ERC projects in this portfolio.

4.1. Indicators of innovation

This report examines several key metrics to characterise the innovation potential of ERC-funded biotechnology projects and the valorisation pathways pursued by grantees. It combines information on projects included in the portfolio and on their follow-on grants, research outcomes reported by ERC grantees at the end of their projects, and responses collected in May 2026 in the survey mentioned in Section 3.2 (338 responses, 19.6% response rate, see the Methodology chapter for more information on the survey).

The analysis identified:

- **531 PoC grants included the biotechnology portfolio.** They represent 30% of the PoC projects funded in the same period (2014-2023).⁷ ERC grantees can apply for PoC grants to explore the commercial or societal potential of the results obtained during their research.
- **25 EIC Transition grants** were awarded to ERC biotechnology grantees, signalling successful advancement from early-stage innovation in their PoC grant towards market readiness. These grants represent over EUR 59 million in follow-up support.
- **At least 211 researchers have filed one or more patents.**
- **At least 72 spin-offs** were launched, reflecting active commercialisation steps.

These indicators underscore the portfolio's role in translating frontier research into innovation beyond academic research. Some survey respondents also mentioned that they secured follow-up funding from national funders, EIC Pathfinder grants or collaborative projects funded by the Horizon programme.

ERC projects in biotechnology outputs

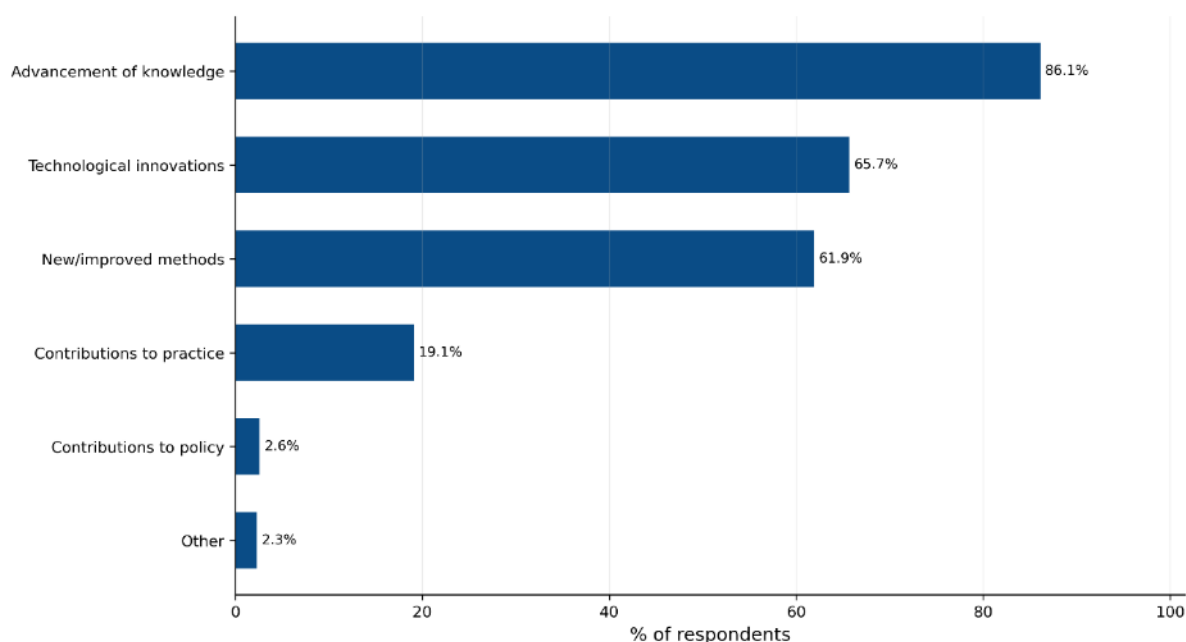
The survey also provided further detail on project outcomes and innovation pathways.

When asked about their outputs (Figure 16), respondents mainly reported **advancements in knowledge** (86.1%), which is expected for frontier research projects. Nonetheless, most respondents also reported **technological innovations** (65.7%) and **new/improved methods** (61.9%). A smaller share of respondents mentioned contributions to practice or policy.

Over 76% of respondents plan to **exploit or commercialise results within five years**, including through technology transfer, patenting, spinoff creation, or input to guidelines or policy (Figure 17).

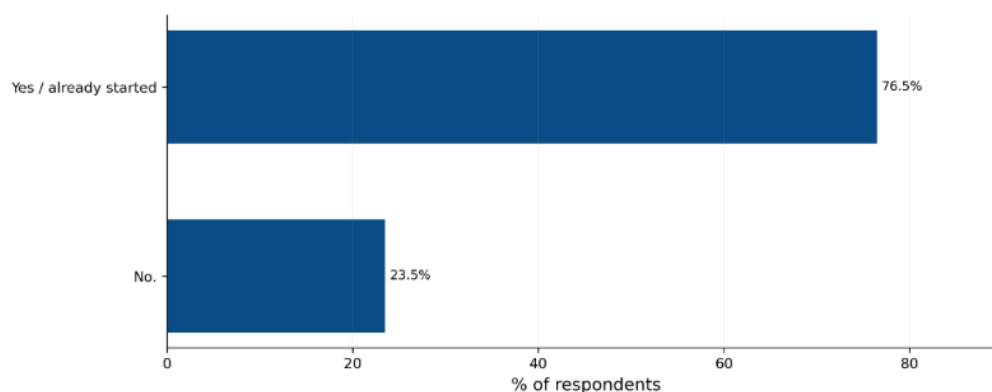
⁷ Since the completion of this analysis, an additional 186 PoC grants have been identified that support ERC grantees in exploring the innovation potential of results from projects in the biotechnology portfolio. These grants are not included in the statistics presented in this report.

Figure 16: Which types of output have resulted from your ERC project so far?



Source: ERC survey responses, May 2026

Figure 17: Do you plan to have your research innovation/results exploited or commercialised in the coming five years?

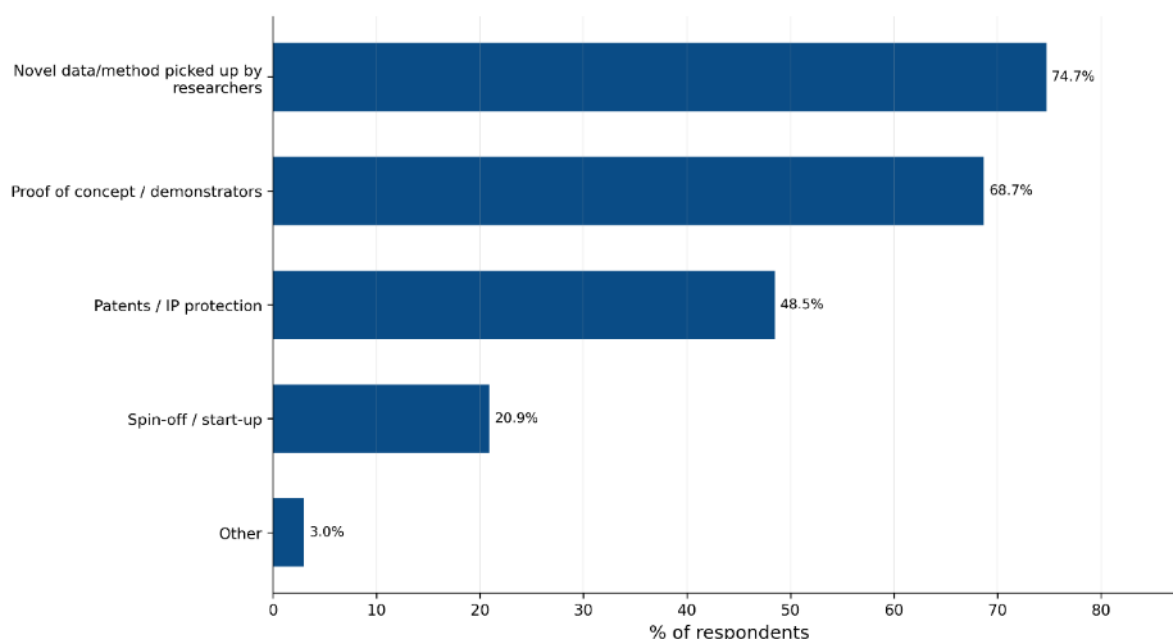


Source: ERC survey responses, May 2026

Grantees who confirmed they aimed at transferring their results reported their **main innovation outcomes** (Figure 18) relatively early in the path to innovation, with **novel data or methods** (74.7% of respondents) and **proofs of concept/demonstrators** (68.7%) as the most cited options. **Intellectual property protection** (e.g. patents) is planned by 48.5%, while **spin-off creation** is under consideration by 20.9% of respondents.

Other strategies (3%) include market identification, stakeholders or industry partnerships (including through stakeholder groups and training in their area of research), and securing follow-up funding from programmes supporting innovators, public or private funders.

Figure 18: What outcomes have your ERC project(s) achieved?



Source: ERC survey responses, May 2026. This question was asked to respondents who declared that they planned to exploit or commercialise their research innovation/results in the coming five years (or who had already done so).

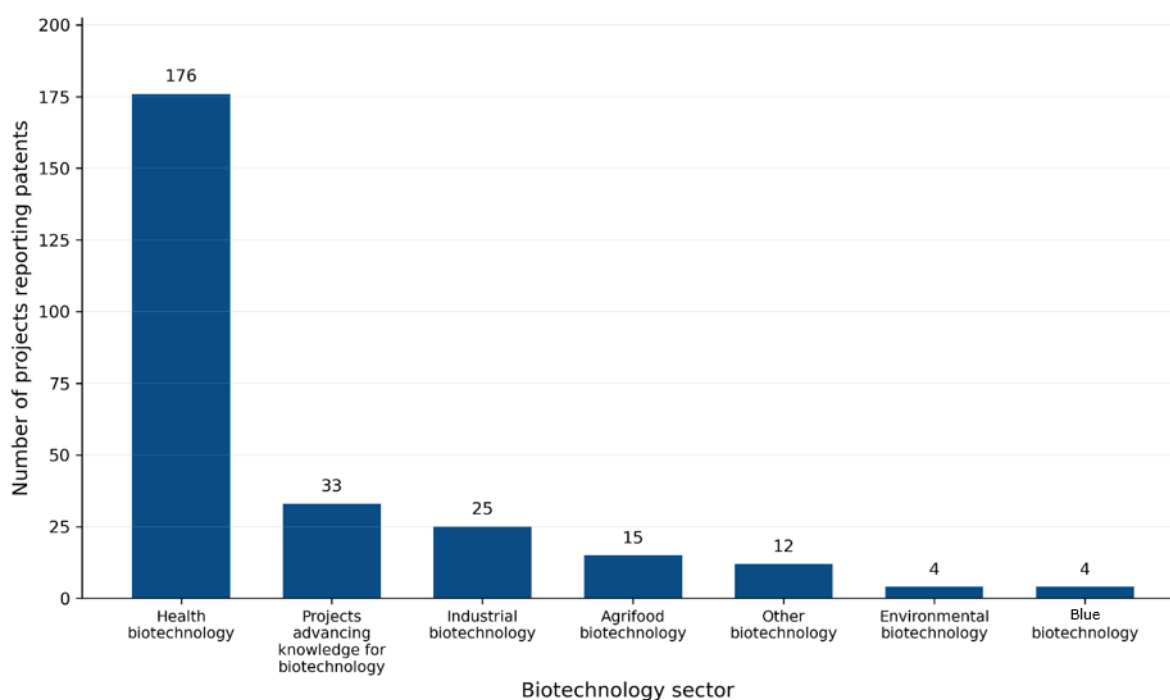
Patents and citations in patents

Within this portfolio, and up to the date of this analysis, 211 researchers have declared one patent application or more, whether through the survey or in their project reports. These applications are at various stages: some recently submitted, others granted but not yet exploited, and others licensed to spin-offs or established biotechnology companies. More than 80 of these researchers hold PoC grants, confirming the important role these grants play in helping ERC-funded researchers both advance innovative technologies and secure the protection and valorisation of their findings.

Regarding host institution countries, Germany (38 projects), the UK (24), Spain (23), the Netherlands (22) and France (19) represent more than half of all patent-filing projects. Israel (18), Italy (17), Switzerland (14), and Belgium (11) follow.

The sectoral analysis (Figure 19) shows patent activity in both projects with biotechnology applications and those undertaking more fundamental research. Health biotechnology dominates with 176 projects reporting one or more patents filed, followed by projects advancing knowledge for biotechnology (33), industrial biotechnology (25), and agrifood biotechnology (15).

Figure 19: Number of ERC projects reporting patents by biotechnology sector



In this graph, a project can be relevant and counted in more than one sector.

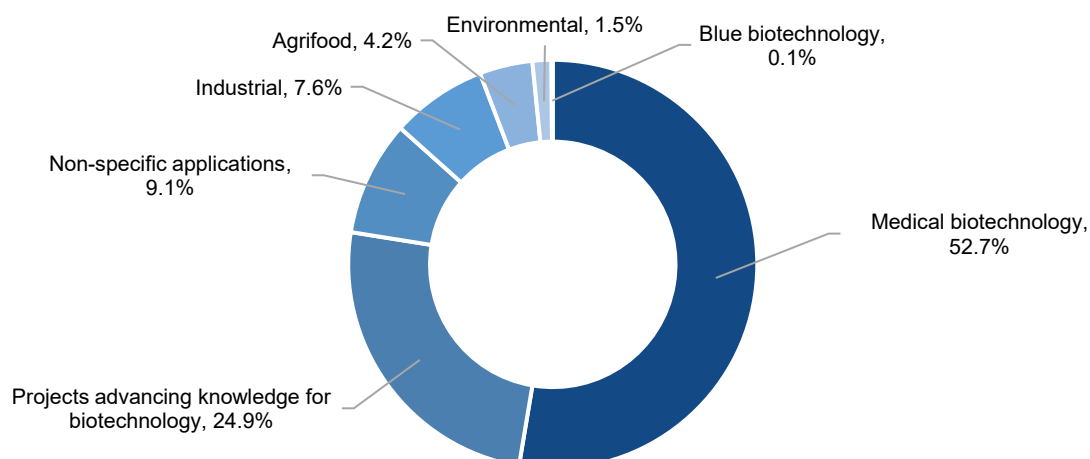
Analysing **citations of ERC-funded publications in patents** reveals how this research translates into technological and innovation advancements. This analysis was conducted through [SciVal](#), using the same set of publications as in Section 2.4 (28 438 project publications up to the cut-off date in February 2026).

Around 14% of all publications (3 946 in total) linked to projects in this portfolio have been **cited in at least one patent**.

This compares with a finding from the ERC 2022 report [Assessing the influence of ERC-funded research on patented inventions](#), which studied ERC-funded projects from all scientific domains that started from 2007 to 2016. The study concluded that, on average, 7.45% of the publications produced by ERC projects are cited by subsequent patent applications, with significant variation across scientific fields in the patent-to-paper citation percentages (for the LS domain, around 12%). This report also analysed citations in patent at project level and found that more than 40% of ERC grants generated research that was subsequently cited by patents.

Across the various biotechnology sectors (Figure 20), the highest proportion of projects cited in patents falls within health biotechnology (52.7%). Smaller shares are evident in projects advancing knowledge for biotechnology (24.9%), projects with non-specific or cross-sector biotechnology applications (9.1%), and industrial biotechnology (7.6%).

Figure 20: Percentage of project publications cited in patents by biotechnology sector



Source: SciVal

Geographically, institutions in Germany record the highest number of patent-cited publications (716 publications, 18%), followed by institutions in the UK (534 publications, 13.5%) and the Netherlands (458 publications, 12%). Closely following them are Switzerland (10%), France (7%), Sweden (6.5%), Spain (6%), Italy (6%), and Israel (6%). Most publications cited in patents originate from leading European research institutions, such as the University of Cambridge (UK), ETH Zurich (Switzerland), University of Gothenburg (Sweden), the Max Planck Society and Ludwig Maximilian University Munich (Germany), the Flemish Institute for Biotechnology (VIB, Belgium), and the Federal Polytechnic School of Lausanne (EPFL, Switzerland).

Spin-off and start-ups companies

ERC grantees have launched at least **72 spin-off or start-up companies** building on their ERC-funded research.

Their research projects are mainly hosted in the Netherlands (11 companies), the UK (11), Israel (10), Germany (7), France (7) and Switzerland (6). Regarding sectors of application, projects leading to companies mainly have applications in **medical biotechnology** (59), mirroring the overall portfolio of projects, followed by projects **advancing knowledge for biotechnology** (10), and projects with **industrial and non-specific applications**. A few projects have applications in the agrifood and blue biotechnology fields.

In terms of **support mechanisms** for company creation, half of the survey respondents who launched a company (63) reported they secured follow-up funding (including ERC PoC and EIC Transition grants). More than a quarter have benefited from interdisciplinary collaboration or strategic partnerships (industrial, clinical or other stakeholders).

As for patents, the development stages of these companies vary: some are in early stages (e.g. with no online presence yet), some exploit a licensed patent from the project, some are well-established and have attracted investments. Finally, a few companies ceased operations for various reasons (lack of funding or companies closed as staff moved to other positions). Examples of spin-offs and start-ups are available in the Chapters 5 to 11.

4.2. Drivers, enablers and challenges

Accelerating the translation of research into innovation and market uptake is a central objective of the European Biotech Act. This chapter examines the challenges encountered along this pathway, drawing on the perspectives of ERC grantees leading projects within this portfolio.

Survey responses from ERC grantees highlight both barriers and enabling factors, as well as possible actions to support biotechnology researchers and innovators across five main areas:

- Facilitating biotechnology research and frontier research.
- Addressing funding gaps between curiosity-driven research and proof of concept.
- Supporting commercialisation and scale-up;
- Strengthening Europe's innovation ecosystems;
- Governance and policy frameworks.

The analysis presented in this chapter is based on responses to four questions of the survey circulated in May 2026. Grantees who indicated that they intended to exploit or commercialise their results within the following five years, or had already done so, were asked about their experience in assessing and developing the innovation potential of their research results (297 replies, corresponding to 76.5% of all respondents).

From a predefined list, they were asked to identify the **three main factors that had supported progress** (Figure 21) and the **three main challenges** encountered in moving from frontier research to innovation (Figure 22). Respondents reported that the flexibility of ERC funding and their unique result or novelty were key enablers to progress towards innovation. The top three main challenges reported by respondents were a lack of follow-up funding; scientific or technological challenges, or unclear demand; and regulatory or legal complexity.

All respondents were invited to consider the outlook to 2030. They were asked to assess which **drivers and enablers** were most likely to strengthen Europe's biotechnology sector (367 replies, Figure 23). In addition, they were invited to suggest **policy measures**, whether already in place or currently missing, that the EU could prioritise in order to strengthen the European biotechnology sector by 2030. This final question received 318 replies.

Figure 21: Which factors have been most important in enabling your frontier research to progress towards innovation?

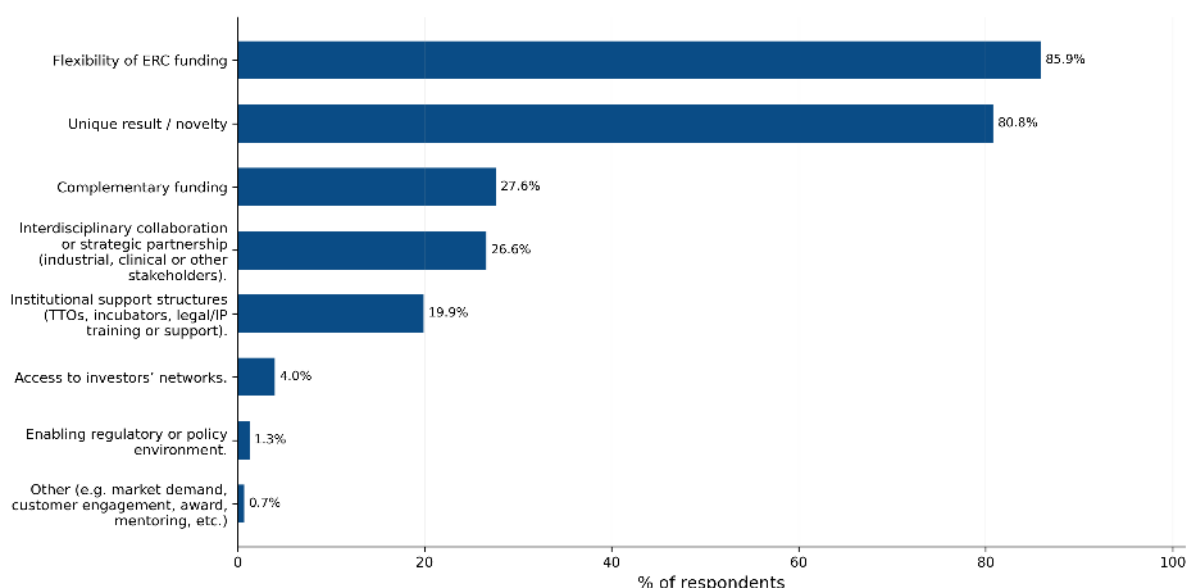


Figure 22: Which challenges did you encounter when moving from frontier research towards innovation?

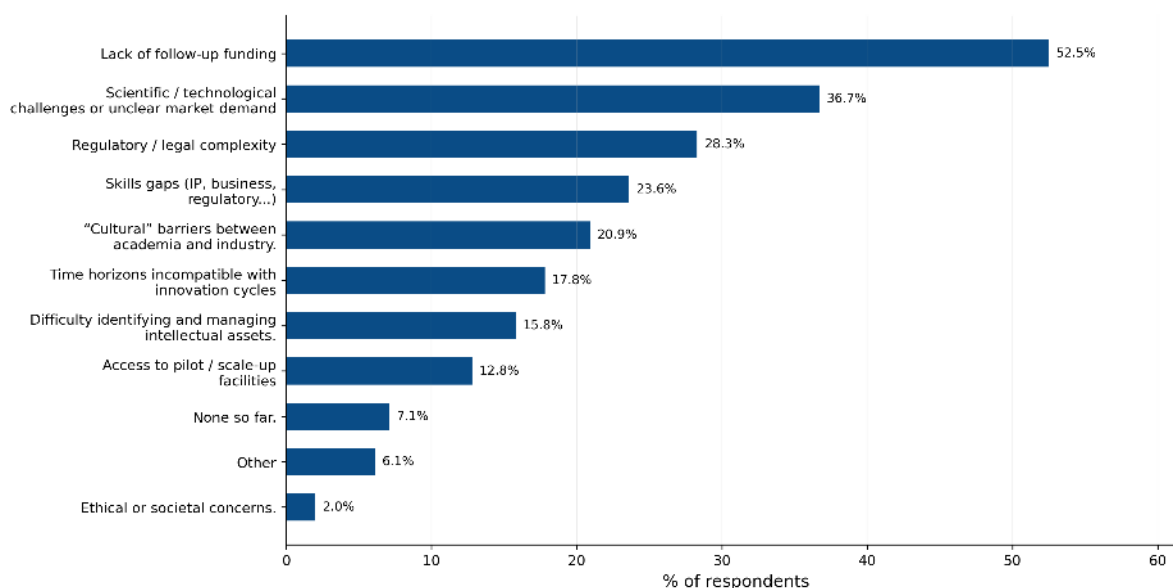
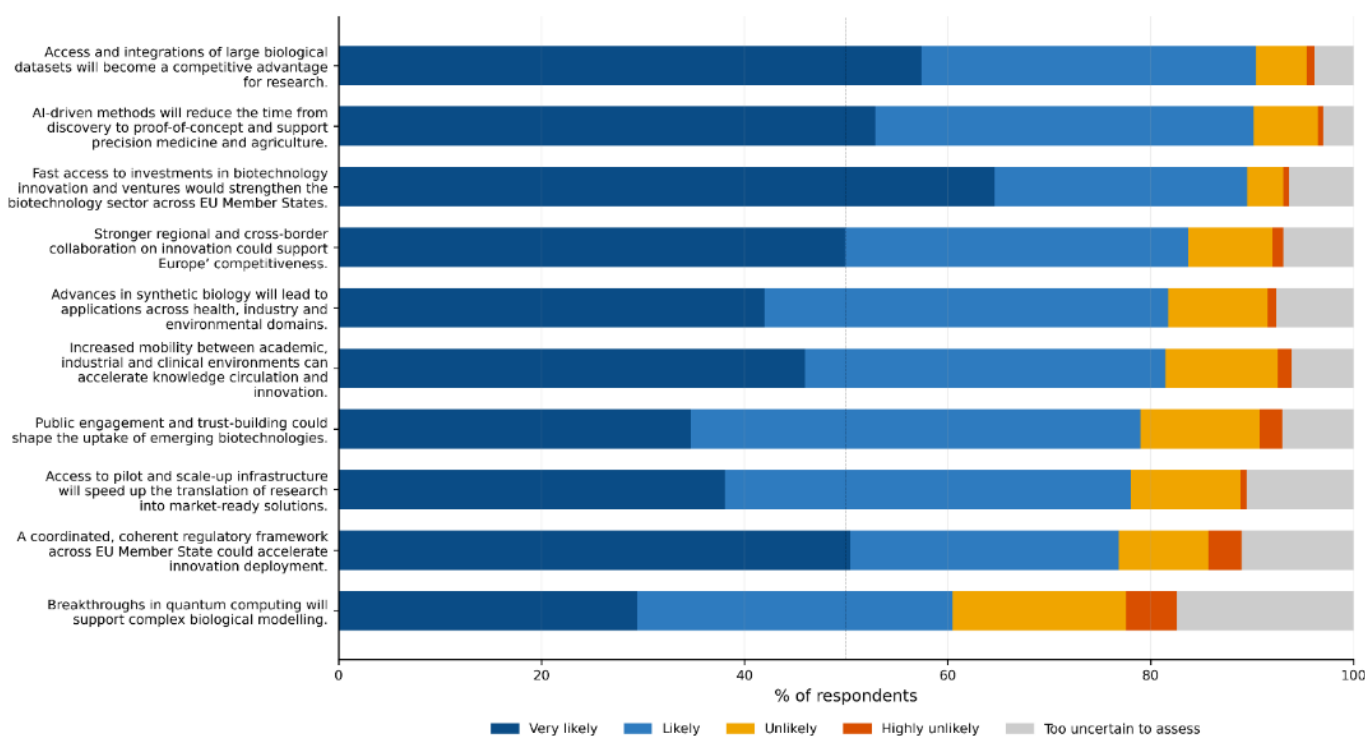


Figure 23: Looking ahead to 2030, which of the following drivers and enablers are most likely to strengthen biotechnology in Europe?



Facilitating biotechnology research

The ERC provides long-term flexible, portable funding, and independence for grantees and their teams to pursue high-risk research. Survey responses rank the **flexibility of ERC funding** as the **main factor helping grantees** in advancing along innovation pathways; 85.9% indicated this (Figure 21). The second main factor is the **uniqueness or novelty of their result**, cited by 80.8% of the respondents (Figure 21). These answers are consistent with the second main challenge respondents reported, namely scientific/technological challenges or unclear market demand (Figure 22).

Survey responses to the last free-text question also underline the importance of sustaining scientific excellence and broadening the knowledge base for future biotechnology innovation. In this context, respondents frequently referred to data, AI and support for frontier research. Many respondents called for stronger support for **interdisciplinary and independent curiosity-driven research**, including the work in marginalised or less mainstream areas. They also emphasised the importance of maintaining and expanding bottom-up, investigator-driven funding for **high-risk research**, while reinforcing support mechanisms that connect excellent fundamental science towards proof of concept, validation and eventual innovation pathways. **Frontier research** was repeatedly described as a key foundation for future advances in biotechnology.

“The strength of ERC is the belief in excellence. No ‘designed’ programme will allow for such bottom-up excellence (that may be hard to measure immediately ...but will be the core of innovation in the future).”
Sebastian Jessberger, STEMBAR project

“I am deeply concerned by narratives around a ‘science economy’ that seek to align scientific progress with political cycles lasting only a few years. Such expectations fundamentally misunderstand how science works and how the path from discovery to translation unfolds.”
Noel de Miranda, RARITY project

Access and integration of large biological datasets was seen as the most likely driver for biotechnology by 2030, bringing a competitive advantage for research. On **knowledge and data sharing**, respondents stressed the need for frameworks and more coherent and interoperable infrastructures that enable **responsible access to, and sharing of data**, across academia (but also industry). Some referred to the value of a European open-access strategy and open-source initiatives, while others noted that better communication of scientific practices to the public could also strengthen trust.

Another recurring theme was the **use of AI** in biotechnology. Researchers highlighted the need to promote AI uptake to unlock its potential for both research and applications across domains. Respondents also called for clearer **governance frameworks** that ensures its safe use. AI was mentioned in the context of agrifood, drug development, diagnostics, AI application-specific integrated circuits, surgical robotics, AI-driven medical devices, and brain-computer interfaces.

“AI for food bridging across biology, chemistry, physics, engineering, nutrition science, and policy.”
Ellen Kuhl, DISCOVER project

“Currently, innovation is hindered by massive regulation and unclear interpretation of the GDPR and AI acts, etc.”
Jan Hasenauer, INTEGRATE project

Funding the translation from research to innovation

Survey results identify **lack of follow-up funding** as the main challenge for ERC grantees seeking to translate research into innovation. More than half of respondents cited this challenge. Funding was also a recurring topic in their suggestions, with particular emphasis on **ERC PoC** and **EIC funding instruments** as important mechanisms for advancing breakthrough findings towards innovation and start-up creation.

Taken together, respondents called for stronger and more strategic support across the full biotechnology pipeline. Several respondents also suggested strengthening links between existing ERC and EIC funding schemes.

Funding across the biotechnology pipeline: suggested actions

- Increase public funding and the number of calls for collaborative, inclusive, interdisciplinary, and thematically-diverse fundamental and translational research. This should cover both academic research and academia-industry partnerships, support the translation of academic technologies into start-ups and SMEs, and encourage stronger participation from widening countries.
- Expand early-stage, seed and later-stage funding to address financing gaps between innovation, spin-off creation, scale-up and commercialisation.
- Reinforce dedicated risk financing and scale-up support for high-risk but promising start-ups, including through EU funding instruments.
- Develop long-term public investment strategies to mobilise EU assets, attract and complement private capital, and provide alternative funding routes for start-ups.

“Flexible translation-enabling support for validation studies, human model systems, advanced technology platforms, and early intellectual property guidance could help overcome barriers to translating fundamental discoveries into applications, while preserving the central role of curiosity-driven research as the foundation of future biotechnology innovation.”

Alexander Walter, PlasticSite project

ERC PoC and EIC grants: suggested actions

- Expand the number, duration and budget of ERC PoC grants to strengthen support for early-stage validation and help projects cross the innovation ‘valley of death’.
- Facilitate the progression from ERC to EIC funding schemes, particularly for smaller teams and first-time innovators, in order to improve their access to EIC funding.
- Increase overall EIC funding, particularly for EIC Pathfinder, to address funding gaps between research and start-up funding, and accelerate biotechnology innovation.
- Make EIC grants more flexible and allow longer application timeframes, especially for EIC Transition grants.

“Increase the funding and the duration for the ERC Proof of Concept. 12 to 18 months is too short for many life sciences-biotech validation efforts.”

Markus Weingarh, champANTIBIOTICS project

“Major changes are not required, but tweaking of existing programmes to improve problem areas. For drug development, I see that EIC Accelerator (...) is extremely competitive, so many good companies do not apply because their time invested to raise EUR 2.5 million from private capital has a much higher probability of success. These young companies have limited bandwidth to apply everywhere, so decisions are made about time invested versus outcome. If the maximum contribution was reduced to EUR 1 million more companies could be supported. It is the EUR 500 000 - EUR 1.5 million seed funding space that is feeling an incredible crunch right now.”

Dennis Gillingham, ExploDProteins project

Strengthening Europe's biotechnology innovation ecosystems

Survey responses highlighted the need to strengthen biotechnology translation and innovation in Europe across several interconnected areas: **talent and career development, ecosystem support, intellectual property and shared infrastructures**. Respondents also identified **collaboration and partnerships, and institutional support structures** such as technology transfer offices, incubators or training programmes, as important enablers. Around 20% of respondents cited these factors as key to supporting them. In parallel, a similar share identified skills gaps and cultural barriers between academia and industry as obstacles to translating research into innovation.

On **talent and career development**, respondents emphasised the need to strengthen skills, provide better support for translational and entrepreneurial careers, and improve conditions to attract, retain and circulate talent across Europe. Some also called for more inclusive environments that address barriers related to gender, disability and geographic disparities.

Respondents further stressed the importance of a stronger **biotechnology innovation ecosystem** to support translation and uptake. Priorities included more flexible university support for spin-offs, faster and more effective technology transfer, closer collaboration across sectors and countries, and coordinated hubs and networks to reinforce Europe's competitiveness. They also suggested stronger EU-level support for such structures.

On **intellectual property** protection, respondents pointed to challenges related to licensing, the need for stronger EU-level support and greater harmonisation.

Finally, survey responses highlighted the need to improve access to **biotechnology infrastructures**. Respondents linked this to the ability of start-ups to scale up, accelerate the translation of research into commercial production and strengthen Europe's biotechnology capacity.

Talent and career development: suggested actions

- Strengthen **interdisciplinary, translational and entrepreneurial training** for biotechnology researchers, including support for spin-off creation, patenting, legal, regulatory, and intellectual property issues; collaboration with industry, and the development of clinical and industrial applications.
- Improve researchers' **career pathways and talent retention** by attracting and retaining talent across Europe, including in widening countries, supporting mobility between academia and industry, and easing transitions into entrepreneurship.
- Provide **targeted support for specialised and high-risk research careers**, including senior scientists, and explore dedicated institutional models that could strengthen Europe's biotechnology knowledge base and implementation capacity.

*"Introduce biotech talent visas and/or tax incentives for PhD supervision in EU-widening countries ...to address brain drain."
Cristina Silva Pereira, SNAIL project*

Ecosystem and collaborations: suggested actions

- Encourage **universities to provide more direct and flexible support to early-stage companies and spin-offs.**
- Improve the **speed and conditions of technology transfer processes** and provide **EU-level support** to help innovators move technologies from early-stage research to higher technology readiness levels.
- Strengthen **collaboration** among academia, hospitals, industry, investors and public authorities through staff exchanges, dedicated collaboration spaces and networking forums.
- Promote collaboration in biotechnology **across Member States** and with key partners, such as the UK and Switzerland, by fostering openness and a shared vision.
- Develop **pan-European and regional biotechnology centres, hubs and clusters** to improve coordination and reduce fragmentation
- Support **long-term ecosystem development** to retain competitiveness in Europe.

*"One possible solution would be to allow universities to support early-stage companies more directly. For example, a rule could be introduced that start-ups in their first three years, and with fewer than ten employees, can be hosted by a university for a modest fee and granted access to infrastructure. This would provide a strong boost, as many startups emerge directly from academic environments."
Timo Betz, PolarizeMe project*

*"I would suggest prioritising the creation of strong/regional 'hub and spoke' biotech entities – clusters of biotech companies and angel investors working in a tight and synergistic environment with clear routes to scale-up and commercialisation (look at the fast-growing Zhangjiang Biotech Base in Shanghai or Science Creates in Bristol)."
Fabrizio Scarpa, NEUROMETA project*

Infrastructure: suggested actions

- Invest in, and improve access to, shared EU biotechnology pilot and scale-up infrastructures. Respondents provided examples, such as biofoundries, large-scale omics facilities, AI-enabled biological data platforms and computational resources, to support start-up development and anchor production capacity in Europe.
- Establish integrated science innovation parks that bring together the expertise needed for upscaling.

*"Innovators in biotech funded by EU grants would benefit from being given free access to an EU-funded incubator for their startups. Finding an affordable place to grow my start-up ...has been my greatest struggle in these years."
Manuela Raimondi, NICHILD project*

Commercialisation and scale-up

Survey findings highlighted barriers in converting research into innovation that can scale commercially, with a large share of respondents suggesting measures to improve access to finance. Respondents also mentioned intellectual property, although less often. Looking ahead to 2030, >60% of respondents saw fast access to investments in biotechnology and ventures as one of the key factors necessary to strengthen the sector in Europe.

In free-text answers, respondents described **access to risk capital** as a major bottleneck. They called for a stronger European venture capital ecosystem, better incentives for private and long-term investors, and more predictable demand to help attract private capital to strategic biotechnology areas.

“A stronger EU biotech investment vehicle. A European Investment Bank/ European Investment Fund-backed fund specifically for deep biotech, with longer investment horizons and greater risk tolerance to support the translation of breakthrough research into clinical and commercial applications.”
Joost Sluijter, EVICARE project

Private and external investment: suggested actions

- Create **incentives to increase and accelerate private investment** in European biotechnology and start-ups. Proposed actions include tax measures and initiatives that encourage private and venture capital to invest in Europe; advance market commitments and green public procurement to create more predictable markets for biotechnology solutions.
- Develop mechanisms that **connect private investment** more closely to innovation and align venture-building with EU long-term goals, such as climate action and neglected diseases, rather than relying only on venture capital priorities.

“The EU should urgently implement the Draghi report recommendations, especially completing the Capital Markets Union and creating a true EU-wide capital market. Europe has savings and talent, but too little risk capital reaches deep-tech ventures. Unlocking private capital for high-risk biotechnology is essential if Europe wants to compete with the US and China.”
Johannes Binting, Time2SWITCH project

Free-text answers also pointed to **intellectual property** as a related challenge in commercialisation. Respondents called for stronger EU support, guidance and training on intellectual property for researchers, so that they can better protect, manage and translate academic discoveries into commercial applications.

“I would recommend that the EU prioritise policies that help bridge the gap between excellent academic biotechnology research and practical applications. In particular, increased training and education opportunities on legal, regulatory and intellectual property aspects would help researchers better navigate the path from academic discovery to biotechnology innovation.”
Irma Querques, BROADCAST project

Governance, regulation and policy framework

Governance was another key theme in the survey free-text responses. Many respondents called for a more enabling framework in Europe, which is consistent with their answers that rank regulatory and legal complexity as the third most common challenge in moving from research to innovation, cited by 28.3% of respondents (Figure 22). Their suggestions are grouped below around three themes: simpler administrative procedures; a coherent and predictable EU regulatory framework; and actions to address gaps or weaknesses in existing regulations affecting specific biotechnologies or application areas, from GMOs to clinical trials.

A small number of grantees also raised broader concerns about the EU's geopolitical position and long-term competitiveness in biotechnology. They argued that Europe needs to strengthen its biotechnology ecosystem to retain talent, preserve innovation capacity and remain industrially competitive. Some called for more targeted investment and dedicated funding for breakthrough, first-in-class and other paradigm-shifting therapies. They pointed to limited EU innovation in this field and warned of further disinvestment by major pharmaceutical companies. Others stressed the need to strengthen strategic sovereignty in biotechnology by reducing critical dependencies, while avoiding protectionist measures that could undermine openness and collaboration.

Administrative and regulatory simplification: suggested actions

- Reduce and simplify regulatory and administrative procedures for biotechnology research.
- Streamline start-up requirements (regulations on funding, taxation, sales and human resources)
- Improve public procurement processes.
- Develop a coordinated, innovation-friendly EU regulatory framework that safeguards EU values, ensures a high level of human health and environmental protection, and provides fair opportunities for SMEs and start-ups.
- Harmonise regulation across EU Member States for new and advanced biotechnologies, with faster and clearer regulation and approval processes and regulatory sandboxes for, for example, gene and cell therapy, GMOs, gene editing, ATMPs, clinical translation, animal research and AI-driven biotechnology.

"We have as many, and often better, ideas than the USA, but we undermine them by making implementation so difficult that people give up. Even working with relatively harmless GMOs requires such a large investment of time and money that many startups simply cannot proceed."

Timo Betz, PolarizeMe project

"Like we have a unified regulatory approval process for drugs under EMA, we also critically need a unified reimbursement system for approved drugs and molecular diagnostics. Right now companies have to go to the USA to access a big market that is regulated as one entity and where good prices for innovation are paid. In Europe, everything is fragmented in reimbursement and health economics assessments, making it only attractive as a 2nd-order of priority market. It stymies investments."

Nico Callewaert, GlycoCAR project

Free-text answers brought forward a wide range of sector-specific actions and suggestions, corresponding to existing EU legislation or to biotechnology research and applications areas respondents would like to see supported. These suggestions were put forward by one or more respondents.

Regulation of gene editing techniques	• Continue to harmonise the regulation of genetic safety across EU Member States while aligning the procedures for addressing ethical issues. • Reduce bureaucratic burden regarding genetic engineering in the laboratory. • Develop genomic data infrastructures.
Biotechnology for food, plants	• Enable crop science innovation to address food security issues. • Improve regulation to allow more flexibility in legislation for GMOs and precision technology in plants. • Reassess the potentials and risks of GMOs and new genomic techniques (NGTs). • Prioritise a coherent policy framework for cultivated meat and NGTs that balances scientific rigour with innovation-friendly regulation. • Integrate risk assessment into EU plant health regulation and prioritise food safety over short-term economic gains to sustain consumer trust and market competitiveness. • Update toxicology guidelines to be suited to biologics for food, feed, and bio agriculture applications.
Clinical trials	• Increase funding and incentives for early-stage clinical translation, first-in-human trials and clinical drug development • Simplify regulatory and evidentiary requirements for preclinical and first-in-human testing. • Establish and recognise <i>in silico</i> trials and AI-based clinical development pathways. • Enable high-quality compassionate use trials to generate early clinical data for new therapies. • Strengthen integration across preclinical, clinical and industry settings to accelerate biomarker validation and therapeutic/diagnostic applications.
New therapies including Advanced Therapy Medicinal Products (ATMPs)	• Support advanced therapies and their clinical translation and commercialisation, including those based on gene editing and ATMPs. • Establish a European platform for drug development.
Drug testing, including alternative, new approach methodologies (NAMs)	• Promote, adopt, and advance new approach methodologies (NAMs) and mechanistic biology in Europe's research. • Establish a coordinated EU infrastructure and standardised protocols for organoids, organ-on-a-chip systems to accelerate replacement of animal models in drug development. • Standardise research tools, experimental and analytical standards to improve data translation, reproducibility and reduce drug development errors.
Synthetic biology	• Promote synthetic biology applications including nitrogen fixation, biofuel microbes and engineered soil bacteria.
Blue biotechnology	• Improve regulation to allow more flexibility in legislation for algal genome engineering. • Prioritise marine microbial biodiscovery platforms and culture infrastructure.

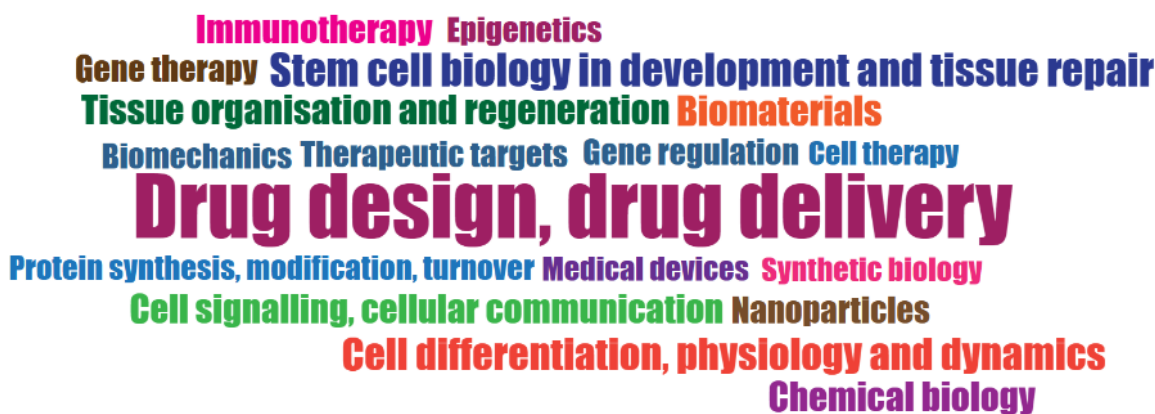
5. Medical biotechnology

Medical biotechnology, also known as health or red biotechnology, enables a better understanding of disease mechanisms and provides prevention, cures or treatments for symptoms by developing biopharmaceuticals such as drugs and vaccines, regenerative medicine or body-integrated prostheses. Medical biotechnology also drives innovation in diagnostic and predictive technologies. These are equally important to correctly identify diseases and the risk of disease development, as well as to decide amongst treatment options and preventive measures. To that end, medical biotechnology relies on multiple scientific disciplines within the life sciences, including molecular biology, genetic and protein engineering, and bioinformatics, while also integrating areas outside the life sciences, such as material science, robotics or AI.

Medical biotechnology provides innovative ways of addressing various non-communicable conditions, from widespread diseases (e.g. cardiovascular diseases or cancer) to rare conditions (e.g. amyotrophic lateral sclerosis). It can also be used to combat infectious diseases caused by viruses (e.g. influenza or SARS-CoV-2), bacteria (e.g. tuberculosis or MRSA), fungi (e.g. candidiasis) and parasites (e.g. malaria). The significance of biotechnology grows as healthcare increasingly moves towards personalised medicine, improving treatment precision while minimising unnecessary or ineffective interventions.

Medical biotechnology is therefore poised to push the boundaries of knowledge in medicine and healthcare, delivering far-reaching benefits. In addition to enhancing the quality of life for patients and their caretakers, effective disease management also reduces the burden on healthcare systems and the economy by decreasing costs and productivity losses.

Figure 24: Main scientific topics in ERC medical biotechnology projects



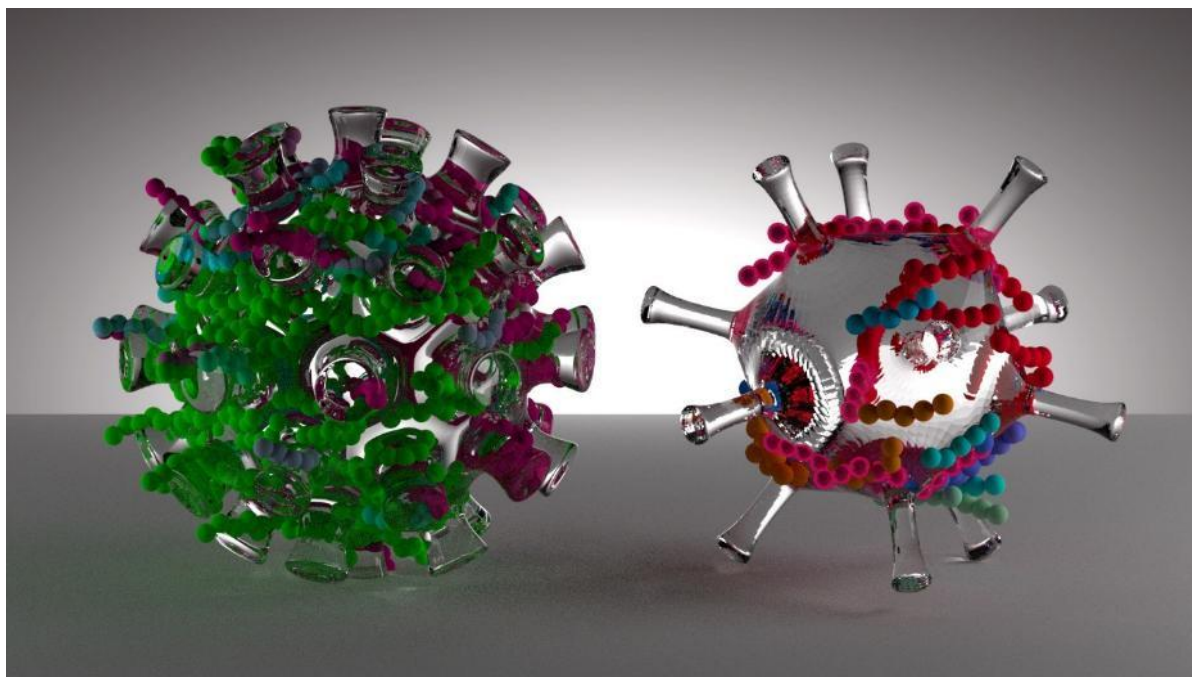
Source: Mapping Frontier Research (MFR)

5.1. Innovative molecular therapies and drug design

To develop new treatments, researchers often start by identifying vulnerabilities (i.e. therapeutic targets) in disease pathways. This can unlock novel targets and offer new avenues to tackle previously untreatable diseases. New tailored medicines, such as small-molecule drugs, vaccines, or antibody-based therapies, are then designed and optimised.

The [TAROX](#) project showed how biotechnology can deliver healthcare solutions through the discovery of new inhibitors, molecules that block or reduce the activity of a specific biological target. Building on evidence that oxidative stress and impaired DNA repair are often key drivers of disease onset and progression, Thomas Helleday based at the Karolinska Institute in Sweden, identified **inhibitors against enzymes** that play critical roles in responding to DNA damage. By blocking these enzymes, for example the OGG1 enzyme, the inhibitors **mitigate excessive DNA damage-induced immune responses**, which can otherwise cause harmful inflammation and tissue scarring. The project resulted in a spin-off company ([Oxcia](#)), an ERC PoC project ([DOIIF](#)) and an EIC Transition grant ([TOPFIBRO](#)), all focused on further inhibitor development.

Vincenzo Cerullo, who led the [PeptiCrad](#) project at the University of Helsinki, Finland, developed an **oncolytic vaccine strategy** that disrupts cancer cells and mobilises the patient's own immune system against the tumour. Therefore, the oncolytic virus was altered to present tumour-derived recognition peptides, including neo-antigens from patients' cancer cells. This way, the immune system recognises the antigens and ensures the cancer is attacked. The research led to two PoC projects: 1) [PeptiCHIP](#), on the **in silico neo-antigen discovery from patient samples** and their purification with a novel microfluidics chip and 2) [GLOBEVAC](#), on improving the **thermostability of vaccine** formulations to allow for their storage and distribution without cooling, increasing global access. The project also resulted in two patents ([1](#), [2](#)), a spin-off company ([Valo Therapeutics](#)) and an EIC Transition grant ([PeptiCHIP](#): Pre-clinical validation and demonstration of PeptiCHIP).



Abstract image of PeptiCRAd and PeptiENV; Source: CORDIS, [PeptiCrad](#) project.

Medical biotechnology has inspired the development of treatments that go beyond targeting a single disease-associated protein. The [PEP-PRO-RNA](#) project approached this by targeting **protein-protein and protein-RNA interactions**. Tom Grossmann and his team at Vrije Universiteit Amsterdam in the Netherlands, designed stabilised macrocycle peptides that can selectively inhibit these formerly intractable targets. The project secured three PoC grants: 1) [INCYPRO](#), on a general approach to **increase enzyme stability** through cross-linkers, 2) [proCOLON](#), aiming at inhibiting a specific protein-protein interaction associated with **colorectal cancer** and 3) [grabRNA](#), developing a novel method for stabilised **delivery and release of short interfering RNA** (siRNA) which can suppress the expression of relevant genes in target cells. These projects led to the filing of two patent applications ([1](#), [2](#)), the creation of a spin-off company ([Incircular](#)) and an EIC Transition grant ([INCYPROnext](#)).

Medical biotechnology leverages cutting-edge computational approaches to accelerate the development of new therapeutics. In the [DeNovoImmunoDesign](#) project, Bruno Correia at the EPFL, Switzerland, created **de novo proteins** (i.e. new-to-nature) using advanced computational design to rationally engineer them for their use in **vaccines and cancer immunotherapy**. The work resulted in the PoC project [RSVTriVax](#) that aimed at the development of a vaccine against the **respiratory syncytial virus** (RSV), using a mix of so-called 'epitope-focused immunogens.' To protect these technological advances, the researchers filed a [patent](#).

A large number of ERC-funded projects worked on **coronaviruses** and addressed the global pandemic. A selection of projects is listed [here](#) and some are highlighted in the brochure [COVID-19: Frontier research in the spotlight](#).

Targeted protein degradation

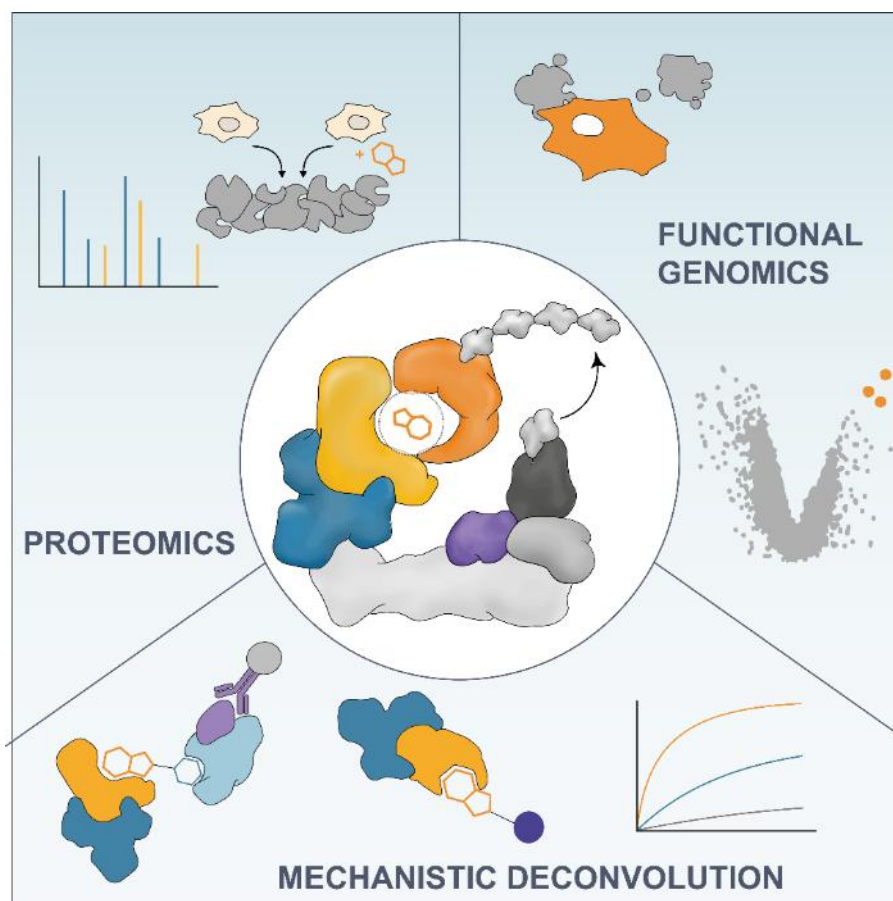
Instead of blocking a disease-causing protein through, for example, inhibitors, proteolysis targeting chimeras (PROTACs) recruit the enzyme E3 ubiquitin ligase to the protein of interest which is in turn marked for subsequent degradation. This method vastly expands the range of treatable targets that are not amenable for small molecule design and were previously regarded as undruggable.

The contribution of ERC-funded research to the development of PROTACs was analysed in a thematic study of ERC impact on scientific progress in highly dynamic fields in which significant discoveries have been made in recent years, referred to as 'hot research areas.' Independent experts identified seminal publications in the area of PROTACs and targeted protein degradation. They assessed the contribution of the ERC to the field as remarkable, with 21% of all seminal publications and 30% of breakthrough seminal papers attributed to ERC-funded research.

ERC-funded research has been instrumental in advancing VHL-based PROTACs, optimising ternary complex formation for improved protein degradation, and exploring structural aspects of PROTACs, molecular glues, and UPS proteins. Additionally, it has expanded proximity-based pharmacology, leading to the discovery of novel degradation principles, including proximity-inducing compounds inspired by PROTACs and molecular glues. More information can be found in the [ERC Annual report 2024](#).

- Based at Kiel University, Germany, Elmar Wolf received two ERC grants ([TarMyc](#) and [PROTAC-PDAC](#)), focused on designing PROTACs for the proteolysis of abnormal transcription factors involved in driving **pancreatic cancer**. To reduce off-target effects, the researchers work on **tissue-specific PROTACs** that are mainly active at their target: cancer cells. The project led to the PoC project [DEGRON](#), on finding the best performing E3 ubiquitin ligases.

- Classic PROTACs contain two binding sites and require the physical engagement with two protein interaction partners. In the [Glue2Degrade](#) project, Georg Winter, based at the Research Center for Molecular Medicine of the Austrian Academy of Sciences, explored new ways to attract E3 ubiquitin ligases to their targets, without the restriction of PROTACs. For this, small molecules, called **molecular glue degraders**, were employed which can bring the ligases close to their target. This advance enlarges the array of targets to include previously '**unligandable**' proteins. These discoveries resulted in a [patent](#) and a spin-off company ([Proxygen](#)).



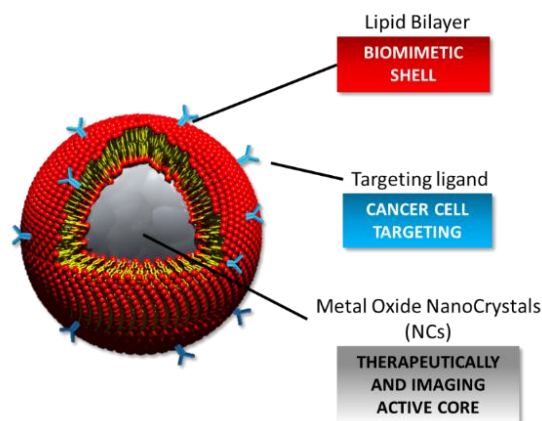
Source: CORDIS: [Glue2Degrade](#) project.

Focus on extracellular vesicle-based therapies

Extracellular vesicles (EVs) are naturally secreted by various cell types in the body, enabling communication between cells. EVs consist of a shell made of lipids and can be used for medical purposes. They can encapsulate and deliver substances of interest to specific sites in the body, such as damaged tissues or tumours. EVs produced by stem or progenitor cells offer particular advantages as they retain beneficial stimulating compounds. Moreover, EVs are not only produced by humans and animals, but also by microbes, offering opportunities for biomedical applications. The following projects use EVs for different therapies:

- [ExocyTher](#) develops an **EV-based therapeutic approach for tissue regeneration** in patients with fistulas. The project focuses on developing a novel temperature-sensitive gel-based delivery platform and an effective EV production process, that uses shear stress to stimulate EV secretion from stem cells. The principal investigator was also involved in the EIC Accelerator grant [ACROBAT](#) that aimed to further scale up the manufacturing technology .
- [TROJANANOHORSE](#) and its PoC projects [XtraUS](#) and [AI CUREs](#) developed novel theranostic approaches for treating cancer patients. This included the use of EV shells obtained from cancer or healthy immune cells as **biomimetic vehicles for the delivery of therapeutic nanoparticles**, which can create reactive oxygen species to eliminate leukaemia cells upon remote ultrasound induction. The project submitted a [patent](#).
- [EVICARE](#) and its PoC projects [TOP-EVICARE](#) and [VIA-EVICARE](#) harnessed **EVs derived from cardiac progenitor cells** to induce heart regeneration. The researchers further focused on optimising EV production, loading and delivery, and filed a [patent](#).
- [NanoBioMade](#) uses stem cells to synthesise new nanomedicines by **repurposing nanoparticle waste** from previous exposure or by supplying them with soluble ionic salts. These therapeutics are then loaded into stem cell-derived EVs and can be applied, for instance, in **photothermal cancer therapy**. With the PoC project [EVoid](#), the researchers developed a sophisticated EV production system using organoids and spheroids combined with hydrodynamic stimulation.
- [MICROBE](#) explores the role of **gut microbiota-derived EVs** for immune system modulation during **cancer** treatment and their potential for **nano-therapeutic applications**.

Beyond treatment, EVs can also be used for **non-invasive diagnostics** via **liquid biopsies** (e.g. blood or urine samples) and biomarker detection. Several ERC projects explore this potential, e.g. [U-Tube](#), [EpiDetect](#) and [IN-THE-KIDNEY](#).

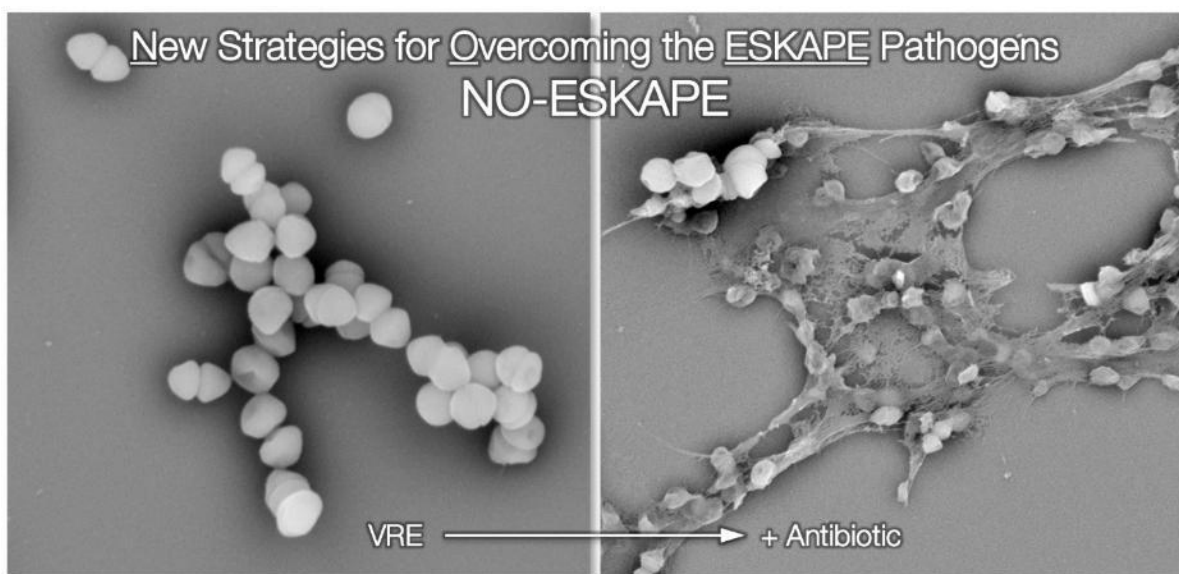


The Trojananohorse concept with a hybrid core-shell and multifunctional nanoparticle.
Source: CORDIS, [TROJANANOHORSE](#) project.

ERC projects developing strategies against antimicrobial resistance

Antimicrobial resistance presents a growing global emergency for public health. Following decades of antibiotic overuse in humans and livestock, pathogenic microbes have developed resistance, and the antibiotics available are increasingly failing to treat infections. Novel ways of fighting microbial pathogens are urgently needed while preventing the emergence of new resistances and preserving beneficial microorganisms in human microbiomes during treatment. Several ERC projects explore innovative ways of tackling this problem from various angles:

- [NO-ESKAPE](#) and its three PoC projects [VOILA](#), [NOVA](#) and [PREVAIL](#) generated new (semi)-synthetic molecules against the most antibiotic-resistant bacterial species, known as ESKAPE pathogens. The researchers explored new ways to target them (e.g. focusing on the cell wall or enzymes conferring resistance) and developed less toxic antibiotic variants, resulting in a [patent](#).
- [BACtheWINNER](#) exploits special bacterially derived proteins with antimicrobial properties, called bacteriocins, with potential for treating human and animal diseases. To find them, the researchers also screen 'unconventional' microbiomes, for example, those of zoo animals.
- [PeptideKillers](#) and its PoC project [FireBacteria](#) engineers *de novo* antimicrobial peptides that target the membrane of pathogens, leading to their disruption and death.
- [vAMRes](#) created human monoclonal antibodies and discovered vaccine targets against resistant bacteria, using an approach called reverse vaccinology.
- [PHARMS](#) employed a high-throughput screening approach for bacteriophages, viruses that can infect and kill bacteria. It identified those that can target resistant bacteria, studied their biological mechanisms and developed a promising phage therapy for treating co-infections of COVID-19 and pneumonia caused by resistant microbes.



Source: CORDIS, [No-Eskape](#) project.

5.2. Drug delivery

Drug design is only the first step towards effective treatment. The drug also needs to reach its target within the body to function at the correct time and place (e.g. specific cells, tissues or organs). Until then, the activity of the drug needs to be protected. Several ERC projects have developed innovative ways to precisely package and deliver drugs:

In the [DYNAP](#) project, Javier Montenegro based at the University of Santiago de Compostela, Spain, developed optimised **cell-penetrating peptides with low toxicity**. By chemically synthesising peptide backbones with functional amphiphilic groups and attaching molecules of interest with reversible chemical bonds, these new vessels can interact with membranes and deliver their therapeutic payload, such as drugs, nucleic acids or nucleases, within the cell. DYNAP submitted a [patent](#) and secured a PoC project ([TraffikGene](#)) and an EIC Transition grant ([TraffikGene-Tx](#)) that focused on further developing **applications for gene and RNA therapy**.

Many orally-administered drugs, particularly therapeutic proteins, face limitations due to degradation, inactivation or poor uptake in the human digestive tract. To address this issue, the [FREJA](#) project, led by Anja Boisen from the Technical University of Denmark develops an **ingestible miniature device**, engineered to open after reaching the gut and then attach to the intestinal lining. This device uses an encapsulated foil made from biodegradable materials that carries the bioactive drug, helping to protect it and improving drug absorption across the intestinal barrier. The project led to a PoC project ([Celloop-CPGoC](#)) that develops an affordable gut-on-a-chip, based on centrifugal forces instead of microfluidic pumping, to test drug absorption.



Foils and foils loaded into gelatine capsules for oral delivery. Source: CORDIS, [FREJA](#) project.

Luis Serrano from the Centre for Genomic Regulation, Spain employed **living microorganisms as vehicles for drug delivery** or to act as vaccines by displaying antigens on their cell surface. In the [MYCOCHASSIS](#) project, a minimal, non-pathogenic version of *Mycoplasma pneumoniae* was designed to serve as a biological chassis. This bacterium was further modified to produce compounds that break down pathogen-formed biofilms in the lung. Unlike conventional therapies, this microbial ‘drug factory’ enables sustained production of tailored treatments, right at the disease location. The project resulted in two PoC projects: 1) [MycoVAP](#), on using ‘living therapeutics’ for **treating ventilator-associated**

pneumonia and 2) [Cytodesign](#), on the development of **immuno-modulatory cytokines**. In subsequent ERC-funded projects ([LUNG-BIOREPAIR](#) and its PoC project [Nanodesign](#)), the researchers extended the scope to non-communicable diseases of the lung. They filed several patents ([1](#), [2](#), [3](#)), founded two start-up companies (Pulmobiotics and [Orikin](#)) and received an EIC Transition grant ([PB LC](#)).

At the Kemijski Institute in Slovenia, Roman Jerala's team uses synthetic biology to design **novel proteins** that have not yet naturally evolved and could have biotechnological or medical applications including the **caging of drugs for their targeted delivery**. With [MaCChines](#), the team designed programmable, modular proteins using so-called coiled-coil building modules and illustrated their versatility in responding to different cellular stimuli and regulating biochemical processes. The project led to three [patents](#) and a follow-on PoC project ([CCedit](#)) which aimed to further improve the efficiency of CRISPR/Cas9 gene editing by colocalising an exonuclease with the Cas9 through coiled-coil building modules while also exploring potential use cases and the commercial potential for biotechnology and health, such as in cancer immuno-, cell or gene therapy. A third project led by Jerala, [PROFI](#), builds on his work to further design proteins that sense and respond to biological, chemical or physical cues to control cellular function, with potential future avenues in advancing therapeutics.

In [BuBble Gun](#), David Fernandez Rivas from the University of Twente in the Netherlands, developed a **needle-free injection technique** using a high-pressure microfluid jet. This method can deliver therapeutics, such as drugs and vaccines, into the human skin or treat skin diseases locally at the site of inflammation. Compared to traditional injections, it causes less pain and discomfort, making it especially suitable for patients who rely on repeated injections for disease treatment as well as those with a fear of needles. At the same time, this innovation reduces waste and infection risks while enabling precise control over dosing and delivery depth in the skin. The project resulted in three PoC projects ([BoldJet](#), [Plant-a-Jet](#) and [Lab-In-Skin](#)), a spin-off company ([FlowBeams](#)) and an EIC Transition grant ([iSENS](#)) to bring the technology closer to market readiness and expand its applications to new fields, such as plant genetic editing.

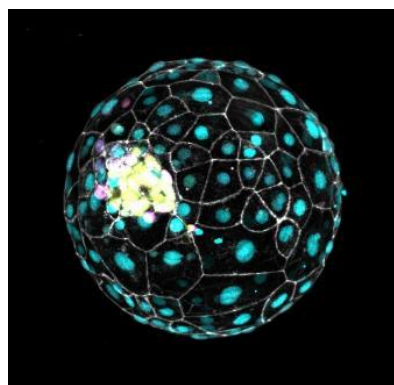
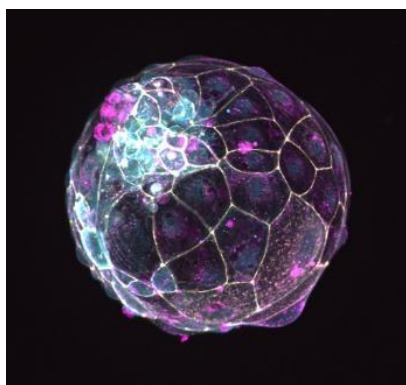
5.3. Novel alternatives for drug testing

Preclinical animal studies often do not accurately reflect the human context, are cost- and time-intensive, and may also raise ethical concerns. On the other hand, simple cell monocultures cannot replicate the complexity of tissues and organs under physiological conditions, so phenomena observed in the petri dish might not translate to the human body. Several ERC projects address this gap by developing different [new approach methodologies](#): animal-free platforms for understanding disease mechanisms, drug development, and toxicity testing. These advanced systems include organoids, organs-on-a-chip, *in silico* models as well as bio-printed tissues and organs (for example, [4DPrintedHeart](#), Section 5.5), with the option to produce patient-specific models for personalised medicine.

Organoids

Organoids, 3D miniature organs, are often made from stem cells that can develop into the relevant cell types and resemble the key morphological and physical features of the organ. Given their ability to mimic some of the key complex functional, structural and biological aspects of native organs and tissues, organoids can be used for studying diseases or testing therapies, such as drug screening or evaluating potential toxicity effects.

- With [BLASTOID](#) and its PoC project, [BLASTOID-DISCOVERY](#), Nicolas Rivron, from the Institute of Molecular Biotechnology in Austria, sought to better understand human embryogenesis and blastocyst implantation by studying embryo models (i.e. blastoids) in combination with uterine organoids. The researcher also worked on identifying drugs that could **promote embryo implantation, survival and growth**, with applications in reproductive medicine such as *in vitro* fertilisation. The project resulted in a start-up company ([dawn-bio](#)). Rivron actively participated in the development of the [ethical framework for using embryo models](#) with his collaboration with the International Society for Stem Cell Research (ISSCR).
- The [Organoid](#) project developed **intestinal organoids** to unravel the complex interplay between the gut's epithelium, its microbiome and host immune responses in both health and disease, including the role of pathogens and the development of a colorectal tumoroid model. With the PoC project [TOXANOID](#), Hans Clevers at the Royal Netherlands Academy of Arts and Sciences in the Netherlands, developed a **drug safety testing** platform using organoids.
- In addition to cerebral organoids, [GPSorganoids](#), led by Mina Gouti Max Delbrück Center for Molecular Medicine in Germany, develops neuro-muscular organoids specific to different locations of the spinal cord to decipher disease mechanisms and enable **drug screening for rare diseases**. Its PoC project [MiniOrgans](#) focused on creating a standardised high-throughput **production platform for organoids** to facilitate their industrial uptake for drug development.



1.

2.

1) Human blastoid, [BLASTOID](#) project. 2) Human blastoid formed from stem cells, picture by Heidar Heidari Khoei, [BLASTOID-DISCOVERY](#) project. Source: CORDIS.

Organs-on-a-chip

Organs-on-a-chip are small microfluidic devices that harbour organ-specific cells in their channels and allow liquids to be pumped through them, mimicking tissue-tissue interfaces, mechanical forces, and chemical gradients found in human tissues and organs. Similarly to organoids, organs-on-a-chip can be used to understand diseases and explore possible treatments. Also, multiple 'organs' can be connected on these chips to study complex physiological interactions, for example, how a drug affects or is affected by various organs.

- [VESCEL](#), led by Albert Van Den Berg at the University of Twente in the Netherlands, created *in vitro* models for researching thrombosis (**blood vessels-on-a-chip**) and neuro-degenerative diseases (**blood-brain-barrier-on-a-chip**), using patient-derived induced pluripotent stem cells (iPSCs). The project led to two PoC grants ([BioREAD](#) and [open-TOP](#)), aimed at improving the commercialisation potential of organ-on-a-chip systems through quality monitoring, standardisation, automation and interoperability, and two EIC Transition grants ([Dypha](#) and [3DCardiacHTS](#)) focusing on cell culture and 3D cardiac tissues for drug discovery screens respectively.
- Amongst other advanced brain metastasis models, [3DBrainStrom](#) created a bio-printed **tumour-on-a-chip**. This model replicates the complex physiological characteristics of the brain metastatic microenvironment to discover disease mechanisms and preclinically test different nanomedicine-based cancer treatment strategies. The project, led by Ronit Satchi-Fainaro at Tel Aviv University in Israel, resulted in a [patent](#), a PoC grant developing a modular targeted nanoplateform for immune cell regulation and therapy ([ImmuNovation](#)) and an EIC Transition grant aiming to identify unique molecular fingerprints associated with gastrointestinal cancers ([TIMNano](#)).
- [MINERVA](#) and its two PoC projects ([DIANA](#) and [PROMETEO](#)) established an interconnected **multi organs-on-a-chip system** that recreates crosstalk along the microbiota-gut-brain axis. In this way, Carmen Giordano from the Polytechnic University of Milan in Italy, studied potential mechanistic connections between the intestinal microbiome and neurodegenerative diseases and advanced drug and probiotics development. The project resulted in two patents ([1](#), [2](#)).

In silico models and digital twins

In silico models and digital twins present another valuable and scalable alternative to animal studies for drug discovery, toxicity testing and determining the best modalities for tissue regeneration in a patient-specific manner.

- One example is the [INSTAnt CARMA](#) project led by Liesbet Geris at the University of Liege in Belgium. It is developing an advanced computational model of osteoarthritis in the knee to enable **in silico trials using virtual patients**. The model integrates complex data sets to predictively test cartilage regeneration treatments, focusing on both drugs and engineered tissue transplantation.

5.4. Molecular diagnostic and predictive tools

For informed treatment decisions, it is crucial to correctly identify the disease source, for example, the pathogen behind an infection or specific cancer subtypes. Additionally, early prediction of an individual's probability of developing a disease is key for taking timely preventive measures. Similarly, prognostic tools can predict disease progression and inform long-term treatment plans. To this end, researchers rely on biomarkers – biological indicators of disease, such as specific genes, molecules, or proteins.

As part of the [PRO-TOOLKITS](#) project, Francesco Ricci, based at the Tor Vergata University of Rome in Italy, established a **cell-free diagnostic platform**, based on synthetically-designed DNA and RNA with high specificity, sensitivity and the ability to detect multiple biomarkers at the same time. Following the binding of specific disease-related biomarkers, such as antibodies or other stimuli of interest, these modules generate detectable visual or electrical signals. The platform was designed to be user-friendly and suitable for **point-of-care applications**. The project resulted in two PoC projects ([IMMUNO-MONITORING](#) and [ELIDIS](#)), which further developed diagnostic immunoassays based on DNA strands modified with antigens or enzymes.

The surface of all cells displays sugar molecules that vary between healthy and cancer cells. In the [SweetAim](#) and [GlycoTherapy](#) projects, Vered Padler-Karavani, based at Tel Aviv University in Israel, exploited these differences and developed **immunotherapeutic strategies** that target these sugar motifs. Three PoC projects followed: 1) [SweetCancerTest](#) developed antibodies capable of detecting cancer-associated sugar variants at the beginning of disease progression; 2) [SugarBiomarker](#), in which the researchers aimed at using **sugar-based risk biomarkers for early diagnosis** of diseases, such as cancer and cardiovascular diseases, while also linking them to eating patterns, and the findings of which paved the way for personalised preventive and therapeutic actions; 3) [SweetCAR](#) which worked on a **CAR-T-cell therapy for solid tumours** based on the recognition of specific cancer-associated sugar patterns.

In the [SCENT](#) project, Cecilia Roque, based at the NOVA University of Lisbon in Portugal, developed a novel method for the **timely detection of pathogenic microbes**, with a focus on antimicrobial-resistant bacteria, to provide early and correct treatment, and inform decisions on the potential isolation of infected individuals. She developed an innovative '**electronic nose**' that can detect volatile metabolites released by pathogens. The device, inspired by biological smell receptors and based on a gelatine gel, produces electrical or optical signals upon detecting these molecules. To interpret these signals, the researchers built a database of microbe-molecule associations and created a machine-learning algorithm to identify pathogenic signatures. The project filed two patents ([1](#), [2](#)) and received two follow-up PoC grants ([ENSURE](#) and [UNMASK](#)) to leverage the technology's non-invasive nature to apply it to other disease areas, such as post-surgical bladder cancer tracking via urine analysis, and for diagnosing Parkinson's disease.

In the [COMPUCELL](#) project, Jerome Bonnet, from the French National Institute of Health and Medical Research (INSERM), used living microbes and synthetic biology to overcome limitations of existing diagnostic tools with a novel system for **single- and multi-biomarker detection**. The researcher and his team introduced sensor modules into bacteria to recognise biomarkers of impaired liver function in liver transplant recipients, providing an easy-to-read colorimetric output. He then extended this approach to microbial communities, creating 'biological computers' for simultaneously identifying several biomarkers. The project resulted in the PoC project [BACTOCONTROL](#), using bioengineering to more precisely control **living therapeutics for cancer treatment**, and a [patent](#).

The [BiomeRiskFactors](#) project, led by Eran Segal at the Weizmann Institute of Science in Israel, uncovered disease risk factors and created a risk prediction algorithm that analyses a person's **microbiome to estimate future pathological risks**, such as developing diabetes or cardiovascular diseases. It led to the PoC project [BiomeDxRx](#) focused on isolating and studying health-promoting strains for possible therapeutic applications.

In the [ModVaccine](#) project, Yang Li, based at the Helmholtz Centre for Infection Research in Germany, used comprehensive omics datasets to pinpoint biomarkers and develop an advanced computational model to **predict immune responses to influenza vaccines**. The researchers studied the underlying mechanisms to develop **personalised vaccination approaches** for non- or less-responsive individuals, including discovering immune response-stimulating molecules. The project also extended its approach to **vaccines against for example, tuberculosis, COVID-19, and mumps, measles and rubella**, and resulted in the PoC project [DiMoVac](#) that aims to design an assay for predicting individual vaccine responses, enabling subsequent patient stratification.

5.5. Regenerative medicine and advanced therapy medicinal products

Rather than merely treating symptoms of diseases, regenerative medicine and [advanced therapy medicinal products](#) (ATMPs) focus on repairing or replacing damaged or diseased cells, tissues, or even entire organs. Given the constraints of organ transplantation, such as limited numbers of matching donors, common immunological complications, and rejection risks, regenerative medicine offers a cutting-edge alternative.

Gene and RNA therapy

Through gene therapy, defective genes can be directly corrected in a patient's own cells with the help of gene editing tools. In contrast, other approaches, such as RNA therapy, temporarily interfere with the regulation of disease-associated genes but do not permanently change the cells' genetic information.

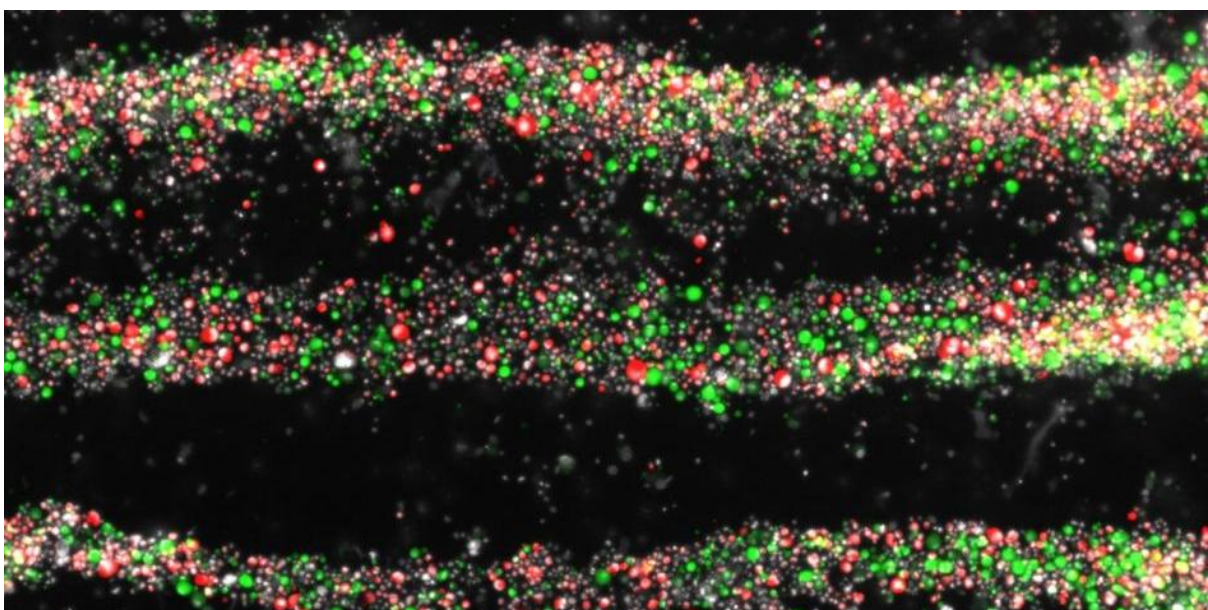
- In the [iHEAR](#) project, Axel Schambach from the Hannover Medical School in Germany developed **gene therapy to restore and prevent hearing loss**. Together with his team, he optimised viral vectors to edit hair cells and spiral ganglion neurons in the inner ear. This included the use of tailored promoters or modified glycoproteins on the virus surface to enhance specificity for the target cells. The project resulted in two PoC projects ([MY-O-SENSES](#) and [EuroVision](#)) on further developing vectors capable of carrying large genetic cargos to treat **Usher syndrome**, a condition that impairs not only hearing but can also lead to vision and balance dysfunction.
- In the [BIORECAR](#) project, Valeria Chiono from the Polytechnic University of Turin in Italy, developed a **regenerative therapy for patients who suffered myocardial infarction**. By combining an injectable hydrogel, novel nanoparticles, and therapeutic microRNAs, the research team laid the groundwork for cardiac fibroblasts-to-cardiomyocytes reprogramming. The project resulted in a spin-off company ([PoliRNA](#)); and two PoC projects: 1) [POLIRNA](#) on nanoparticle-based RNA therapy delivery systems for cardiac and skeletal muscle cells and 2) [EMPATIC](#) focused on an *in vitro* model of heart tissues. The project also led to a [patent](#).

Focus on optogenetics: non-invasive gene control for medical applications

Optogenetics uses external light stimuli to activate gene expression inside cells genetically engineered with light-responsive proteins. Beyond its role in fundamental research, optogenetics has opened new possibilities in medicine, for example, by precisely controlling cellular activity. This technology has been applied in a variety of ERC projects addressing needs in regenerative medicine:

- Building on [Bio-ICD](#), [TransRhythm](#) and the PoC project [Opto-AF-Therapy](#) employ an optogenetic approach to **modulate heart rhythm** by creating electric currents in heart cells, addressing cardiac arrhythmia. The system combines cardiomyocytes that are genetically engineered to express light-sensitive ion channels, light-emitting diode (LED) modules and an arrhythmia-monitoring device. If translated into clinical practice, this technology could offer patients a portable system that responds early and in real-time, replacing current painful electrical shock therapies that require hospitalisation.
- [OptoHear](#) and the PoC project [OptoWave](#) developed optogenetics-based **auditory prosthetics**. In order to activate auditory neurons, they were engineered to express light-responsive ion channels and stimulated via an optical cochlear implant with integrated miniature LEDs. Through a more precise multi-channel approach, this method restores hearing with higher sound frequency resolution compared to traditional electrical cochlear implants. The project resulted in a [patent](#), a start-up company ([OptoGenTech](#)) and an EIC Transition grant ([OptoWavePro](#)).
- [LIGHTHEART](#) applies optogenetics to enable the **precise assembly of bio-printed heart tissues**, making embedding baths redundant and potentially allowing cells to be printed immediately onto damaged hearts during surgery in the future. The project also uses acoustic signals to coordinate spatial cellular patterning, such as for the formation of spheroids.

Similarly, alternative non-invasive stimuli, such as temperature or (ultra-)sound, can be used to modulate gene function for medical purposes (e.g. used to create skin patches for the targeted expression of therapeutic genes or a self-regulating electrogenetic system for insulin dosing ([ElectroGene](#))).



Acoustic manipulation of cell co-culture in fibrin hydrogel. Different cell type labelling at 4X, capture with EVOS M5000. Standing wave patterning with 1.66 MHz frequency. Source: [LIGHTHEART](#) project, © Dr. Oscar G. O'Dwyer Lancaster-Jones

Cell and immune cell therapy

Cell therapy typically involves transferring specific cell types into a patient to treat or prevent diseases. Immune cell therapy, in particular, involves extracting immune cells from the patient's blood, improving them through genetic engineering to recognise specific antigens, expanding their number, and reintroducing them via infusion to destroy the disease-causing cells, for example, to treat many types of cancer and immunological disorder. A prime example is CAR T-cell therapy, where patient-derived T-cells are genetically modified in the laboratory with 'chimeric antigen receptors' to recognise and attack tumour cells.

- In the [INFANTLEUKEMIA](#) project, Pablo Menéndez, from the Josep Carreras Leukaemia Research Institute in Spain, studied the disease mechanisms of a specific and difficult-to-treat **blood cancer subtype in children**. The team also developed a corresponding **CAR T-cell therapy**, which recognises leukemic cells carrying specific tumour-expressed antigens. The project resulted in three PoC projects ([IT4B-ALL](#), [IT4-TALL](#) and [BiTE-CAR](#)), which further developed cell therapies targeting different antigens found on the surface of cancer cells. In BiTE-CAR, the CAR T-cells were additionally modified to release 'bi-specific T-cell engagers' that simultaneously bind antigens on both cancer cells as well as on the patient's own T-cells, thereby recruiting native immune cells to destroy the targeted cancer cells. The researcher secured several patents ([1](#), [2](#)), one of which was licensed to [OneChain Immunotherapeutics](#), a spin-off company co-founded by the researcher, who also obtained an EIC Transition grant ([CARxALL](#)).
- In the [TALE](#) project, Lukas Jeker from the University of Basel in Switzerland, developed an **allele-engineering approach for improved and safer cell therapies**, with a particular focus on blood cancer. The method involves gene editing of haematopoietic stem cells to modify therapeutic binding sites on the surface of healthy immune cells without disrupting their normal function. These engineered haematopoietic stem cells are then transferred into the patient together with therapeutic immune cells. This subtle modification acts as a safeguard, protecting healthy immune cells from unintended destruction by immunotherapy while ensuring that leukemic cells remain targeted. This broadens the spectrum of targets that can be used for cell therapies, extending far beyond those exclusively found on cancer cells. The project led to the creation of a spin-off company, [CIMEIO Therapeutics](#).
- With the [STIMUNO](#) project, Magdalena Winiarska and her team at the Medical University of Warsaw, Poland, studied tumour microenvironments, focusing on previously unknown metabolic pathways that are involved in the suppression of immune cells, thereby limiting their cytotoxic abilities and the effectiveness of immunotherapies. The team developed an innovative platform to study tumour microenvironment metabolites, understand immunosuppressive mechanisms and identify opportunities to increase the efficacy and safety of immunotherapies. Among their key findings, the researchers could pinpoint ammonia and hydrogen peroxide as such immunoinhibitory metabolites. These revealed novel therapeutic opportunities to improve immunotherapies, including NK and CAR-T-cell approaches.

Stem cell therapy

Within the wide spectrum of cell therapies, stem cell therapy harnesses the undifferentiated state of stem cells or re-programmed cells, such as skin cells, known as human-induced pluripotent stem cells (hiPSC). These cells are then activated by a specific cocktail of growth factors and other signalling molecules to differentiate them into the desired cell type *in vitro*. Once implanted into the patient, these cells further mature to replace damaged cells.

- While pacemakers, electronic implants to manage heart rhythm, are invaluable medical devices, they are often associated with complications and technical difficulties. In the [REJUVENATION](#) project, Gerard Boink from the Academic Medical Center of the University of Amsterdam in the Netherlands, used hiPSCs differentiated into specialised heart cells, known as atrioventricular nodal cells. These cells were used to create a **'bypass tract' between the atrial and ventricular heart chambers** to reinstate physiological pace making and conduction of impulses in patients with dysfunctional electrical signalling at this node. This technology could offer a future alternative to electronic pacemakers. The project resulted in two PoC projects ([PACE](#) and [RescuePace](#)) and an EIC Transition grant ([TRACTION](#)) focused on developing gene therapies for cardiac regeneration.

Advanced tissue and organ transplantation

The transplantation of functional cells, tissues, or organs, whether laboratory-grown or genetically-engineered animal organs, known as xenotransplants, represents another cornerstone of regenerative medicine.

- Cells can be grown *in vitro* as organoids, which can more faithfully replicate the physiology of the organ counterparts. A notable example of how organoids can be used to restore functions is the [EYELETS](#) project and its PoC project [SILORGS](#). Led by Per-Olof Berggren from the Karolinska Institute in Sweden, the team used genetic engineering to develop **pancreatic islet organoids for transplantation into the eye**, providing a novel approach to treat diabetic patients by restoring blood sugar homeostasis. The unique accessibility of the eye enables non-invasive clinical follow-up and functional regulation of the transplant. This technology was extended to introduce liver spheroids into the eye to serve as a proxy for tracking metabolic activity in the liver. (See Section 5.3 for more projects on organoids.)
- In the [XenoSim](#) project, Philip Cardiff from University College Dublin in Ireland, is developing an advanced *in silico* model of 'fluid-electro-solid interaction' for **heart xenotransplants** to ensure compatibility in human transplantation. The simulation integrates physiological, electrical, and mechanical parameters, some of which are inaccessible to experimental studies. Beyond compatibility, the researcher and his team also aim to study surgical strategies and xenotransplantation-related pathologies.

In parallel, **bio-printing** provides an innovative platform for fabricating tissues and organs suitable for transplantation.

Focus on bio-printing

Bio-printing is a technology in which living cells are used together with a biocompatible matrix, referred to as bio-ink, to create 3D structures that can develop into functional tissues or even entire organs. While instrumental to studying tissue function and biological mechanisms in both health and disease, bio-printed tissues and organs also have transformative potential for transplantation in regenerative medicine.

- [VesselNet](#) used 3D tissue printing to open new possibilities for **facial transplants and reconstructive surgery**, creating complex vascular networks, necessary to generate integrated tissues of skin, fat, muscle and bone *in vitro* and to sustain them in recipient patients. The PoC project [Print and Grow](#) developed a novel structural support gel which limits tissue mis-shaping after printing while the PoC project [BioForcelnk](#) explored a novel **bio-ink for printing vascularised bone implants** with greater mechanical durability. The project resulted in three patents ([1](#), [2](#), [3](#)).
- [ENABLE](#) addressed existing constraints for developing sizable and functionally-stable tissues, focusing on bone implants. To ensure maturation and survival, the project engineered **tissues capable of generating their own short-term oxygen supply**, which promotes bone formation and vascularisation. They also created a new approach to printing complex branching vasculature to perfuse tissues. The PoC project [NutriBone](#) focuses on establishing a '**self-feeding**' bone implant, based on glucose delivery from glycogen.
- [4DPrintedHeart](#) and the PoC project [SPARE HEART](#) are creating a novel **4D-bioprinting approach**, combining patient-derived cells and a smart hydrogel to make **cardiac patches and functional hearts**, which are designed to contain all essential components to enable heart contraction and blood flow. After maturation in the laboratory, these could be used as a drug testing platform and for transplantation into patients with cardiac diseases in the future.
- [VOLUME-BIO](#) and the PoC project [HYBRIGEL](#) built an innovative **volumetric bio-printing system for complex 3D tissues and organoids**. It combines a versatile hydrogel with embedded cells and guiding biomolecules to direct cellular maturation and spatially coordinated light signals for rapid, high-resolution curing of a bio-resin. The project also worked on a functional multi-cell-type **bone marrow organoid** to be potentially used for haematopoietic stem cell therapy and resulted in three patents.

More projects on biomaterials for medical uses can be found in the [ERC Advanced Materials report](#).

5.6. Smart prosthetics

At the limit between medical technology and biotechnology, body-machine interfaces are systems that connect the human body to external devices, enabling information exchange, interaction, and control. Unlike traditional ‘passive’ prostheses, which only offer basic mechanical functions with limited user control, smart prosthetics integrate specialised sensors, advanced bio-robotics and continuous data processing to dynamically respond to changes in bodily and environmental parameters. Through neuro-engineering, smart prosthetics are often directly connected to the human nervous system, establishing a bidirectional interface. These devices provide tactile feedback to the user while allowing real-time control of the prosthesis. This gives its wearer advanced functionalities mimicking natural movements, helps with the embodiment of the prosthesis and drastically improves patients’ mobility, independence, and quality of life.

- In the [DBSModel](#) project, Madeleine Lowery from University College Dublin in Ireland advanced **deep brain stimulation implants for treating neurological diseases**, particularly Parkinson’s disease, using small-scale electrodes to stimulate pathologically-active neurons. The researchers created a closed-loop platform that dynamically calibrates electrical impulses in real time based on the patient’s clinical state. They created a sophisticated *in silico* model of the neuromuscular network and validated it with experimental data from healthy individuals and Parkinson’s patients. Based on this model, they built new **algorithms for adaptive stimulation control**. The PoC project [DBScontrol](#) further developed the algorithm and assessed the closed-loop system in animal models, and the researchers filed two patents ([1](#), [2](#)).
- In the [MYKI](#) project, Christian Cipriani from the Sant’Anna School of Advanced Studies in Italy, developed innovative arm and hand prostheses with a novel technology, using small magnets that are implanted into the muscles of the remaining limb. and magnetic sensors and actuators in the prosthetic socket. Aiming to recreate the natural sensory-motor control loop, the **prosthesis responds to magnet movement generated by muscle contraction** while simultaneously **enabling sensory perception** in the patient’s brain. The project resulted in promising [clinical testing](#) of the [Mia hand prosthesis](#), developed in collaboration with the researcher’s spin-off company [Prensilia](#) and a PoC project ([MYTI](#)) to refine the technology, towards clinical adoption.
- In the [FeelAgain](#) project, Stanisa Raspopovic from ETH Zurich in Switzerland, introduced a novel **neuro-prosthesis** for patients who had undergone a leg amputation. This technology converts signals collected by sensors in the prosthesis’ foot sole into stimulation patterns to the sciatic nerve, which in turn creates a sensation in the brain. A [clinical trial](#) led to promising outcomes. Additionally, the project adapted the approach to diabetes patients experiencing neuropathy (a loss of sensing in the feet) by creating a **sensing and nerve-stimulating wearable sock**. The project was followed by the PoC project [NEURO-SOCK](#) to further advance the sock’s development and an additional ERC grant ([DiabetManager](#)) on designing a neuro-prosthesis for blood sugar control in diabetes patients.
- The [NGBMI](#) project, led by Surjo Soekadar from Charité – University Hospital Berlin in Germany, combined brain-/neural-machine interfaces controlling a hand exoskeleton with transcranial magnetic stimulation and transcranial electric stimulation systems. They developed a mobile system allowing direct brain-machine interaction for assisting patients with neuropsychiatric and neurological disorders, such as depression, dementia and stroke, focused specifically on tackling impaired motor or cognitive function.

6. Industrial biotechnology

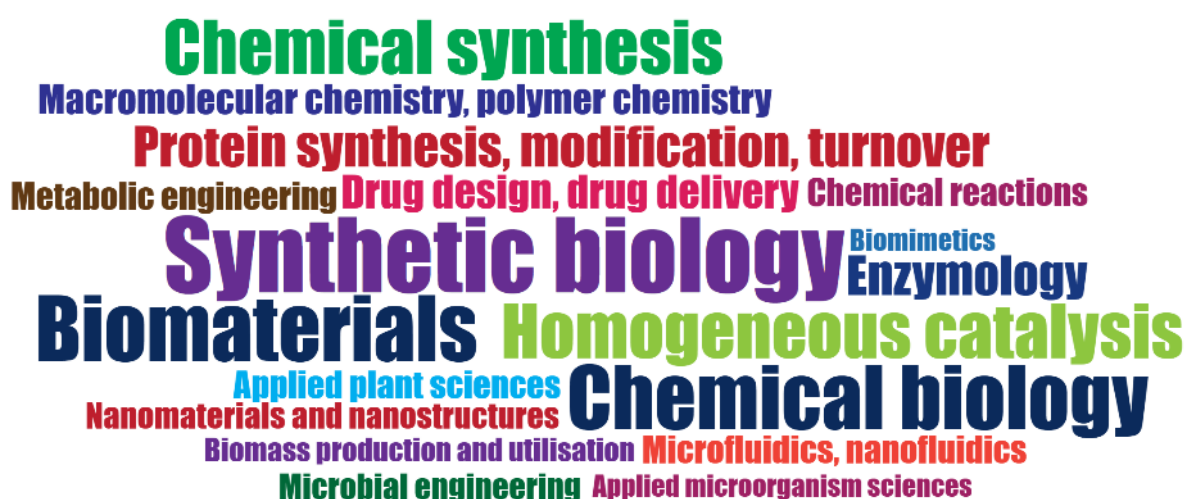
Biotechnology is one of the EU's fastest-growing innovative industries. It promises to transform several industrial sectors by applying biological systems and processes to produce industrial consumer goods, materials and energy in a more sustainable way.

A large share of ERC projects with applications in industrial biotechnology use microorganisms (such as bacteria or yeast), their parts, and the molecules they produce (such as enzymes) to manufacture products at scale.

By using genetic engineering (e.g. [CRISPR](#)), biochemistry and synthetic biology, researchers design or rewire metabolic pathways. This turns microorganisms into 'living factories' optimised to produce high-value compounds, including fuels, chemicals and biomaterials. When projects use renewable resources, waste, or CO₂ under milder conditions, this approach offers a lower-cost, circular alternative to petroleum-based methods while significantly reducing energy use and environmental harm.

This chapter explores four key applications addressed by ERC projects: industrial fermentation and bioprocesses, biocatalysis, biomaterials manufacturing, and bioenergy production.

Figure 25: Main scientific topics in ERC industrial biotechnology projects

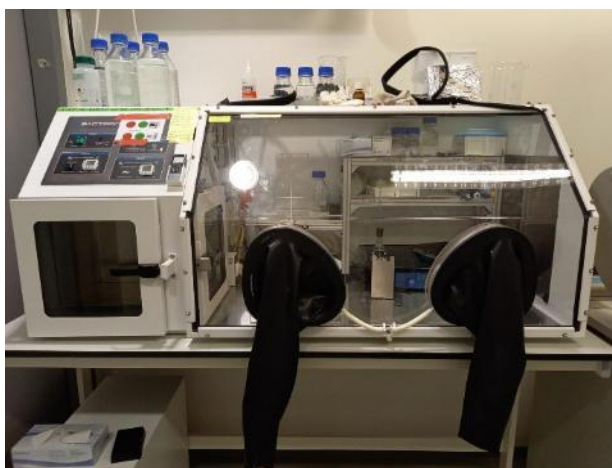
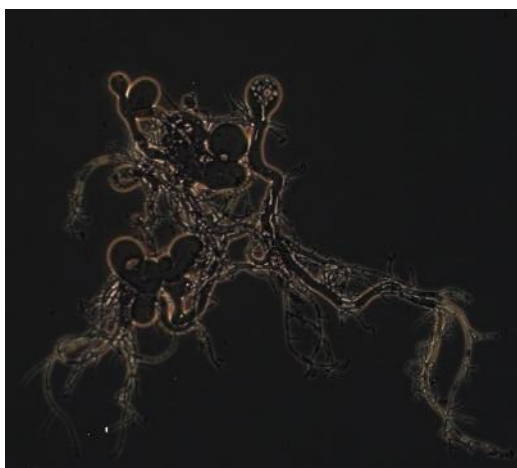


Source: Mapping Frontier Research (MFR)

6.1. Industrial fermentation and bioprocesses

This group of ERC projects mainly aims at designing **cell factories that produce target compounds**, while other research lines focus on the engineering of bioreactors, optimising nutrient inputs and refining downstream processing (e.g. harvesting and purifying products). These initiatives bridge biology with mechanical and chemical engineering to ensure these processes are both commercially viable and reliable at industrial scale.

For example, the [ELOXY](#) project led by Jack Pronk at the Delft University of Technology in the Netherlands addressed a grand challenge in industrial biotechnology – oxygen requirements. While many yeasts ferment sugar into ethanol (a process not requiring oxygen), most cannot synthesise the essential components they need to grow without some oxygen. ELOXY used synthetic biology to reprogramme conventional and non-conventional **yeasts to grow anaerobically (i.e. without oxygen)**. The researchers took inspiration from organisms that naturally grow anaerobically and introduced specific fungal and bacterial genes to bypass oxygen-dependent pathways. This unlocks various microbes of industrial interest, for example because of their thermotolerance, to produce **biofuels** at maximum efficiency, reducing industrial costs and carbon footprints. ELOXY led to two patents ([1](#), [2](#)).



1. Microscopic photograph of a *Neocallimastigomycete*, a key model organism in the [ELOXY](#) project; 2. Anaerobic chamber for cultivation of microorganisms in the absence of oxygen. Source: CORDIS.

[YEAST-TRANS](#), led by Irina Borodina at the Technical University of Denmark, addresses the transport bottleneck in industrial biotechnology. When products remain trapped inside cells, they can become toxic and expensive to extract. Borodina's team mapped the protein networks controlling molecule transport and engineered secretion pathways to continuously export products. This foundational work led to a licensed technology for ergothioneine production and to the PoC project [NaturalCOLOURS](#). This project uses the yeast *Yarrowia lipolytica* to produce **sustainable alternatives to synthetic dyes**. Unlike plant extraction, which is often resource-intensive, seasonal, and wasteful, the project combined specific enzymes in an optimised yeast cell factory to produce large quantities of pure, antioxidant betalain-type pigments. These disruptive strategies, protected by a [patent](#), provide alternatives to synthetic **additives for the food and cosmetics industries**, with potential health benefits and at reduced environmental cost. Read more about NaturalCOLOURS in the ERC science story, [The future of food dyes](#).

In the PoC project [OPTIGO](#), Rodrigo Ledesma Amaro at Imperial College London in the UK, produces **indigo dye** via yeast fermentation, **avoiding the toxic chemicals used in traditional textile dyeing**. To achieve high yields, he applies insights from his previous project ([DEUSBIO](#)) on microbial subpopulations with different metabolic phenotypes. In large bioreactors, even genetically-identical

cells start acting differently; 'lazy' cells emerge that eat nutrients without producing the desired chemicals or display limited growth. DEUSBIO uses single-cell analysis and synthetic biology to eliminate these underperformers. The project focuses on creating homogeneous cell populations for single cultures and members of microbial consortia where every single microbe works at peak efficiency. These advances can be applied to **improve yeast-based production across industries**.

[BioMet](#), led by Ilan Marek at the Technion University in Israel, developed a **hybrid chemo-bioprocess to convert cheap, oily substances (alkanes) into high-value products** such as medicines, plastics and specialised chemicals. It is usually extremely difficult to activate these molecules because they are chemically not very reactive. The project solved that problem in two main steps: (1) a first biological step using a **specialty engineered bacterium** (*Rhodococcus*) instead of high heat and harsh chemicals. This living factory acts as a precise tool that prepares oil molecules by turning them into alkenes. (2) In a second chemical step: a metal catalyst is used to find the perfect spot – usually the very end of the chain – to attach new functional groups to the alkene molecule.

By merging bioprocessing with advanced chemistry, this method allows transforming cheap and abundant alkanes into useful products more sustainably and with much higher precision than traditional processes.

6.2. Biocatalysis

Biocatalysis uses enzymes, nature's catalysts, to speed up chemical reactions under mild conditions (e.g. low heat or aqueous environments). Unlike traditional methods using harsh chemicals and high pressure, biocatalysis enables selective, eco-friendly production of compounds such as pharmaceuticals and bulk chemicals.

The [BIOSUSAMIN](#) project, led by Francesco Mutti at the University of Amsterdam in the Netherlands, made a breakthrough in industrial biocatalysis by engineering a comprehensive toolbox of **amine dehydrogenases** (AmDHs). AmDHs essentially do not exist in nature, so the team used protein engineering to create them from existing scaffolds. AmDHs are **versatile catalysts**; these enzymes enable hydrogen-borrowing cascades that can directly transform a wide range of substrates including alcohols and ketones with **high selectivity** and **water as the only by-product**. This atom-efficient approach (published in [Science](#)) is protected by several patents, including for [alcohol amination](#) and [nitrile synthesis](#), as well as for the creation of specialised AmDH variants for industrially-relevant, bulky substrates. These breakthroughs provide a **sustainable platform** for producing chiral amines, the core building blocks for pharmaceuticals and fine chemicals.

In the [enzC-Hem](#) project, Anthony Green from the University of Manchester in the UK, pioneered a revolution in industrial biotechnology by expanding the 'amino acid alphabet' beyond nature's standard 20, creating **enzymes with chemical functionalities not found in nature**. He integrated the genetic code expansion with computational design and directed evolution, to produce biocatalysts, including metalloenzymes, enantioselective photoenzymes and organocatalytic proteins, that act as biocatalysts and can perform **challenging chemical transformations, such as the breakdown of cellulose, with high efficiency and selectivity**. The team's research strategies provide a platform for building fully programmable biocatalysts for highly valuable industrial reactions. Their development led to numerous collaborations with industrial partners and Anthony Green was awarded the prestigious 2024 Blavatnik Award.

Through his [METACELL](#) project, Fernando López Gallego at CIC biomaGUNE in Spain has developed artificial metabolic cells that fix complex enzymatic networks on hierarchical porous materials. This approach addresses the suboptimal efficiency, instability and poor reusability of soluble enzymes, which often hinders large-scale bio-manufacturing. By precisely controlling the spatial organisation and

orientation of up to five enzymes and their co-factors, the researcher and his team created cell-free, self-sufficient heterogeneous biocatalysts that function without additional expensive supplementation of co-factors such as NADH. The platform was successfully demonstrated in flow reactors for the continuous production of enantiopure hydroxy acids. It offers a sustainable **green alternative for drug discovery and fine chemical synthesis**. The project resulted in the PoC project [NIBIOX](#) addressing **oxygen diffusion** and solubility limitations that hamper efficient oxidative reactions in industrial biocatalysis. Instead of relying on molecular oxygen, the project uses innovative **anaerobic biocatalysts** and **inorganic salts** (nitrates). This allows for high-yield oxidation independent of oxygen availability, eliminating **oxidative damage** and reducing energy costs. This disruptive technology, successfully demonstrated in **continuous-flow systems**, is protected by a [patent](#).

The PoC project [FuelVesicles](#), led by Bert Poolman from the University of Groningen in the Netherlands, solved a core synthetic biology problem, namely energy depletion. In a living cell, metabolic networks continuously recycle energy. In man-made cell-like systems, such as synthetic vesicles, reactions typically stop once the initial fuel (ATP) is spent and waste (ADP) builds up. FuelVesicles has developed a way to **mimic life's constant energy flow**, creating a long-lasting engine for biotechnology.

6.3. Biomaterial manufacturing

Biomaterial manufacturing develops **materials from biological sources** such as plastics, lab-grown leather, spider silk, or medical scaffolds. Often inspired by nature (i.e. biomimetics), these materials can be used in industrial products and often outperform synthetic counterparts while reducing waste and environmental impact. Biomaterials also include promising engineered living materials (ELMs): materials that can react to changes in their surroundings. Engineered living materials are a hot topic in material science owing to their potential to, for example, autonomously regenerate or show adaptive properties.

The [PRISM](#) and [PROTECT](#) projects, led by Ilja Voets at Eindhoven University of Technology in the Netherlands, translated nature's survival strategies into industrial biotechnology by engineering [synthetic 'antifreeze' polymers inspired by polar fish](#). These proteins function by blocking nascent ice crystal growth within a specific temperature range, preventing the crystallisation that typically destroys soft materials and is lethal for most living cells. Through world-first single-molecule experiments on these proteins, Voets' research group decoded the molecular mechanisms of ice-binding, allowing them to design macromolecular agents with superior functionality for **cryopreservation** (of, for example, cells and tissues for regenerative medicine), crop hardiness, and materials and coatings resistant to freezing that can be used in extreme environments.

The project demonstrated practical applications by significantly enhancing the freeze-thaw resistance of concrete. Moreover, in the associated PoC project [PPricelessCOAT](#), the researchers developed novel **car windshield fluids** to prevent and remove ice. In a second PoC project, [PEPTOX](#), the researchers build on the **similarities between anti-freeze proteins and cholera-related adhesion proteins** to develop strategies to detach the pathogen from intestines for disease treatment.

Another project pioneering engineered living materials is [AM-IMATE](#), led by Kunal Masania at the Delft University of Technology in the Netherlands, which integrates fungal mycelium into high-performance structures. It enables **harnessing the intrinsic electrical signalling of fungi** to create responsive, self-sensing composites. By functionalising mycelium with biochar-laden hydrogels and conductive nanoparticles, Masania and his team have enhanced biological data transmission without compromising growth. These 'living circuits' are embedded within 3D-printed, friction-welded wood architectures. Supported by cellular automata modelling to predict fungal behaviour, the project transforms biology into a functional engineering component capable of environmental adaptation, self-repair and real-time structural health monitoring.

Led by Anna Rising at the Swedish University of Agricultural Sciences and the Karolinska Institute in Sweden, [ARTSILK](#) and its associated PoC project [ArtSilkTex](#) achieved a breakthrough in sustainable materials by engineering recombinant **spider silk**. By refining an **all-aqueous spinning process**, the team reached protein yields 10 times higher than previous standards, spinning [125 km of fibre](#) from a 1.6-litre culture. This could enable artificial silk to compete with petroleum-based fibres such as Nylon and Kevlar: the produced artificial silk fibres are reported to be tougher than those. This research led to a [patent](#) and collaborations with SLU Holding and the fashion industry.

Focus on functional 'super-materials'

- The PoC project [SILKENE](#) uses silkworm ingestion of graphene to create bionic, reinforced fibres.
- [NeuroMeta](#) leverages the inherent piezoelectric and hygromorphic properties of plant fibres and spider silk to create neuroactive metamaterials.
- [STEADY](#) uses synthetic biology to build a sensor-controller-actuator module (i.e. 'living control circuits') that maintains homeostasis in engineered living materials so that they retain their beneficial functional properties over time.
- [MycoSub](#) developed bio-based fungal materials (i.e. mycelium) to print flexible circuit boards for electronics in a sustainable way. The project produced demonstrators for Near Field Communication (NFC) tags and sensors.

More information on ARTSILK and ArtSilkTex, as well as further examples of ERC-funded research in novel biomaterials, can be found in the [ERC Advanced Materials report](#).



1: Collection of multifilament artificial spider silk fibres ([ArtSilkTex](#)); 2: Biomimetic artificial spider silk fibres spun within the [ARTSILK](#) project. Source: CORDIS.

6.4. Biofuels and bioenergy

These biotechnological processes traditionally aim to convert biomass such as lignocellulose or algae into renewable energy – e.g. ethanol or biodiesel. At the same time, pioneering projects are now engineering synthetic organisms to bypass traditional feedstocks altogether and allow direct harvesting of carbon and ambient energy from the environment.

[SYBORG](#), led by [Tobias Erb](#) at the Max Planck Institute for Terrestrial Microbiology in Germany, aims to surpass natural photosynthesis by engineering synthetic CO₂-fixation pathways *de novo*. The [CETCH cycle](#) is central to this process. It is a highly efficient enzymatic mechanism, combining seventeen optimised enzymes from nine organisms. The research team managed to house a CETCH cycle in synthetic organelles and implement it in different host organisms, such as model bacteria. They created a new class of **biological systems optimised for transforming CO₂ into valuable products**, such as polyketides and terpenes. Building on this synthetic foundation, the [pro2neo-RUBISCO](#) project seeks to re-invent the world's most abundant enzyme by resurrecting ancient 'proto-Rubiscos' and re-engineering their core structure into novel, high-efficiency architectures that can be integrated directly into living chloroplasts. Findings from this project could help further boost photosynthesis and open the way for new bioenergy production pathways.

While the SYBORG project focuses on the *internal* chemistry of carbon fixation, the [EpiC project](#), led by Fabian Meder at the Sant'Anna School of Advanced Studies in Italy, focuses on the *external* physics of the leaf to harvest electricity. By exploring **contact electrification on plant surfaces** – the spontaneous generation of electric charge from raindrops or solid contact – this research intends to develop **artificial leaves** that can be sprayed or installed on plants. As such, this research bridges the gap between plant biology and sustainable manufacturing. These engineered material systems could harvest ambient energy to drive integrated synthetic reactors and electrocatalytic reactions. By transforming the leaf-air interface into a functional bio-electrochemical platform, EpiC intends to enable energy-autonomous sensing and the production of biomaterials. Ultimately, it leverages natural surface phenomena to create **self-powering, eco-friendly technologies** for smarter agriculture and bio-based energy systems.

The [PhotoRedesign](#) project reaches deeper into the light harvesting machinery of plants and photosynthetically-active bacteria to optimise the very foundation of bioenergy: light absorption. This Synergy Grant, led by Dario Leister (Ludwig Maximilian University Munich, Germany), Neil Hunter (University of Sheffield, UK) and Josef Komenda (Institute of Microbiology, Czech Academy of Sciences), aims to **boost photosynthetic performance to produce biomass and biofuels**. Their approach is based on expanding the range of wavelengths that can be used for photosynthesis, with the final goal of creating '**black cyanobacteria**' that can use the entire light spectrum. Using genetic engineering, synthetic biology and adaptive evolution, PhotoRedesign integrates various parts of different photosynthetic organisms (cyanobacteria, plants and purple bacteria) that each naturally use different spectra of light. The project also covers the development of *de novo*-designed antennas and evolving the host to tolerate high photosynthetic activity. In the future, any advancements could be transferred to plant biotechnology as well. Read more in the ERC science story, [Harnessing plant power](#).

Acetogens are bacteria that can use C1 compounds e.g. CO₂, as feedstock in gas fermentation and can do so without oxygen or light. In the [ACETOGENS](#) project, Volker Müller, based at the Goethe University Frankfurt in Germany, used acetogenic bacteria for the **production of bulk chemicals and biofuel precursor** molecules such as acetate, lactate, formate or butyrate. Additionally, he used the microbes' ability to reverse the formation of formic acid by H₂ and CO₂ for **hydrogen storage, creating a safe biobattery**, an eco-friendly alternative to conventional transport fuels.

7. Agrifood biotechnology

New biotechnologies are transforming agriculture and food production and processing by helping crops and farming practices adapt to global challenges. They provide solutions for pest resistance and plant climate-related stresses (such as heat, drought, and salinity), and to meet the need for higher yields, better food quality and safety, and more sustainable food systems.

To support these innovations, in 2023, the EU initiated to [update](#) its rules on genetically modified organisms (GMOs) by proposing a legal framework for plants obtained by targeted mutagenesis and cisgenesis through the use of new genomic techniques (NGTs). The amended rules for the use of NGTs in plants were adopted by the European Parliament on 17 June 2026.

By using plant and microbial biotechnologies – and, to a lesser extent, livestock breeding – researchers funded by the ERC are developing disease-resistant crops, nutrient-rich foods, and scalable production methods. These innovations aim to improve global food security while reducing environmental harm.

Around half the ERC-funded research in this chapter covers novel plant breeding techniques and crop enhancement for resistance and resilience (73 projects). These projects leverage advances in genomics, synthetic biology, and bioengineering to push beyond traditional agriculture. For example, scientists are using multi-gene editing, grafting-assisted genome transfer, and AI-driven synthetic cells designs to improve crop resilience and photosynthesis.

A smaller group of projects, mainly PoC grants, focuses on food production, food safety and smart farming, including on precision fermentation (see also Section 6.1) or cultured cells (27 projects). Other projects cover a wide range of topics including livestock sciences and microbial biotechnology.

This chapter presents a selection of these projects. More ERC-funded research contributing to sustainable food systems is highlighted in ERC report on [Sustainable Food production and consumption](#).

Figure 26: Main technologies in ERC projects with applications in the agrifood sector



Source: ERC biotechnology projects classified according to EIC deep-tech taxonomy.

7.1. New crop breeding technologies

Conventional crop breeding is time-consuming, labour-intensive and often limited by genetic redundancy and dragging of non-targeted traits. In this analysis, around 20 ERC-funded projects are developing new genomic techniques based on the engineering of plant or plastid genomes, chromosomes or cell division and improved grafting-based techniques to overcome these barriers. This is opening the field for a wider range of crop breeding biotechnologies.

In plants, many important agricultural traits are linked to large duplicated gene families, which makes single-gene editing ineffective. Editing several genes, called multiplex editing, is needed to produce relevant phenotypic changes, but requires the manual selection of gene candidates. The PoC project [Multi-crop](#), led by Elon Shani, at Tel Aviv University in Israel, addressed this issue by developing a genome-scale, multi-target CRISPR platform compiling thousands of designed single guide RNAs sorted by gene function. It enables editing of several members of the same gene family at once and successfully enabled a higher hit rate in phenotyping screening for **enhanced agronomic traits** such as in tomato. This technology is now being commercialised through the spin-off company [NetaGenomiX](#).

In the [GENEVOSYN](#) project, Ralph Bock and his team at the Max Planck Institute of Molecular Plant Physiology in Germany, used the potential of the chloroplast genome to introduce new pathways and traits into plants. They modified tobacco chloroplasts to produce **artemisinin, an anti-malarial drug**, by inserting core pathway genes in a first generation of plants and then adding extra enzyme genes. They also developed a technique of [horizontal gene transfer](#) between plant species, combining different chloroplast and cells genomes using grafting, paving the way for **new crops with original traits**.

Another approach, explored in the [BUNGEE](#) project, led by Etienne Bucher at Agroscope in France, uses transposable elements (TEs) to create new crop varieties. In the model plant *Arabidopsis thaliana*, heat stress-induced TE bursts can create insertions that generate new genetic diversity, with enhanced heat tolerance. The team enhanced this natural ability through controlled TE mobilisation in order to create **new wheat and rice crop lines with increased heat and drought resistance**.

In [Bi-BLOCK](#), Rita Helene Groß-Hardt from the University of Bremen in Germany, investigated the mechanisms of polyspermy control in plants and discovered that plant egg cells can fuse with two sperms, producing offspring with three parents instead of two. This technique enables breeders to **combine beneficial genes from currently incompatible species** and speeds up the breeding process. The findings led to a [patent](#) and a follow-up PoC project [TriVolve](#), which is adapting the method from *Arabidopsis* to the sugar beet crop. The technology is now being developed with industrial partners through an EIC Transition grant ([3P-Tec](#)).

7.2. Crop resistance and resilience

Over the last few years, tremendous progress has been made, including by more than 50 ERC projects, in the identification of mechanisms, genes and pathways underlying crop traits of interest for sustainable farming in a changing world. These projects study and have discovered effective targets for new or enhanced traits through genetic engineering.

Engineering plant immunity for pest resistance

Crops bred for resistance to specific pathogens often have reduced yield, so new strategies are increasingly needed to enhance plant immunity, while preserving yield. Close to 30 projects address this challenge, for example, by addressing the immune receptor complex or signalling pathways that could enhance general plant immunity to a wider spectrum of attacks.

- The [BLASTOFF](#) project, led by Sophien Kamoun at the Sainsbury Laboratory in the UK) engineered the rice immune receptors that target ***Magnaporthe oryzae*, a fungus that infects rice crops**. Through structure-guided mutagenesis and protein engineering, they modified the Pikp immune receptor to recognise and respond to previously elusive variants of the pathogen effectors. In the project [ImmunityByPairDesign](#), their colleague Jonathan Jones investigated the *Arabidopsis* immune complex RPS4/RRS1, which activates defences when it detects pathogens. By redesigning this receptor pair, the team created **plants resistant to multiple threats**, including ***Xanthomonas* bacteria**, **Potato virus Y** and **phytoplasmas** (bacterial parasites). Both projects demonstrate that targeted genetic changes can broaden disease resistance to different pathogen lines or even species, reducing the need for chemical treatments.
- The [UbRegulate](#) project focuses on broad spectrum immunity by targeting ubiquitin, which regulates the salicylic acid immune hormone receptors within plant cells and thus the expression of resistance genes. They revealed that ubiquitin has several forms and has the ability to fine-tune the level of cellular response to prevent genomic instability. These findings can be exploited to generate novel **crop resistance engineering strategies that avoid undesirable side-effects**.
- Some projects target pests directly to understand their pathogenicity and identify targets for their resistance and control. The [POLYADAPT](#) project led by Thomas Van Leeuwen at Gent University in Belgium, studied the **spider mite *Tetranychus urticae***, a major crop pest that has developed resistance to many pesticides. Using experimental evolution and gene editing, the team identified the genetic basis of the mite's resistance and adaptation. They also developed **new CRISPR tools for arthropods**, which are now being refined in the PoC project [CRISPART](#).



Source: CORDIS, [BLASTOFF](#) project.

Building resilience to abiotic stresses

Climate change is increasing the frequency of extreme weather events, such as heatwaves, droughts and floods, which threaten crop productivity. ERC-funded research is uncovering how plants adapt to these stresses and developing ways to enhance their resilience.

In [CHROMADAPT](#), Isabel Bäurle at the University of Potsdam in Germany discovered that plants can ‘remember’ heat stress. After exposure to high temperatures, certain genes involved in protein repair undergo chromatin modifications, allowing them to respond more quickly to future heatwaves. The team identified several heat memory genes in *Arabidopsis* and barley and used CRISPR editing to analyse their function. This mechanism will help breed **heat-tolerant crops**.

Drought is another major challenge. The [iDRICA](#) project led by Ana Caño-Delgado at CSIC in Spain, investigated how **brassinosteroids plant hormones regulate drought responses** in *Arabidopsis*. Normally, these hormones slow growth under stress, but the team engineered the signalling pathway to maintain growth even in dry conditions. The technology is now applied to sorghum, with potential application to other cereals and other stress types. This discovery led to a [patent](#) and a high-throughput screening platform, [EARTH@](#), developed in the PoC project [PLANeT](#), which tests thousands of compounds to identify those that improve drought and heat tolerance.

The [MECHSYS](#) project develops a computational framework that builds on biochemical and physical principles and omics data validation to reconstruct how environmental factors interact with plant anatomy, water transport, photosynthesis and metabolism, and shape plant physiology and fitness. Through computer simulations of plant evolution, the team demonstrated that both thin-leaved C3 plants (such as cereals) and succulent CAM plants (such as cacti) represent optimal solutions under specific conditions. They are now using **AI to predict which traits could make crops more drought-resistant** and identify targets to genetically engineer them.

Flooding is equally destructive, as low oxygen levels (hypoxia) can kill plant tissues. The [LOKI](#) project, led by Daan Weits at Utrecht University in the Netherlands, is studying how plant meristems develop under hypoxia, as they are naturally nested in low-oxygen zones of the plant tissues. By developing genetically-encoded oxygen biosensors and manipulating the oxygen sensing machinery, the project will uncover how oxygen levels regulate development and create tools to **improve growth and resilience under flooding stress**.

New pathways for photosynthesis enhancement and synthetic biology

Understanding and redesigning crop metabolic pathways, such as photosynthesis could significantly increase crop yields and the production of products of interest. Several projects are exploring ways to make this process more efficient.

- In [AgriRedox](#), Shilo Rossenwasser, from Hebrew University of Jerusalem in Israel, is investigating the inhibitive effects of oxidative signals on carbon absorption during photosynthesis, using advanced redox biology methods to elucidate the regulatory elements and oxidation-sensitive proteome. They aim to **increase the photosynthesis yield of potatoes** by engineering redox modifications counter-acting the oxidative signals.
- The [FARED WELL](#) project, led by Roberta Croce at the Vrije Universiteit Amsterdam in the Netherlands, focuses on far-red light (wavelengths beyond 700 nm), which land plants cannot use efficiently, investigating the mechanisms underlying far-red light acclimation in aquatic cyanobacteria. The project addresses how novel pigments can be synthesised and introduced into photosynthetic proteins, with the ultimate goal of engineering **more efficient crops which use a wider light spectrum** for photosynthesis.

- Plants also produce many medically valuable compounds. The project [MedPlant](#) harnessed the chemical diversity of plant metabolites, in particular the monoterpene indole alkaloids, that include many molecules of interest in medicine, from chemotherapy to anti-malaria or anti-pain medication. They identified the genes involved in the main alkaloid biosynthesis pathways and successfully modified the chemical activity of some associated enzymes to create new types of alkaloids. By genetic engineering, they also demonstrated how to use plants as heterologous hosts for the **production of medically important natural products**.

Focus on smart farming: Technologies for process optimisation and sustainable farming

- The [AGRISCENTS](#) project created sensors that detect volatile compounds released by crops under pest attack. These sensors could be integrated into agricultural robots for targeted real-time treatments, reducing pesticide use.
- [LEAPHY](#) is designing nano-inorganic fertilisers and pesticides with optimised morphologies for better absorption by plants, improving efficiency and reducing waste.
- [NanoCropProtective](#) combines molecules from beneficial soil bacteria and nanoparticles to stimulate seed germination and plantlet resistance to pathogens.
- Building on DNA from grape seeds dating back to the Byzantine era, the [Negev Wine Revival](#) project proposed a multidisciplinary approach to restore ancient grapevine varieties that are more resilient to climate change and high temperatures.



A Spodoptera littoralis caterpillar on a maize seedling and structures of plant volatiles released. Source: CORDIS, [AGRISCENTS](#) project.

7.3. Food production, properties and safety

Biotechnology is also improving food production, processing, nutritional quality, and safety. Close to 20 ERC projects address these issues and many in this domain are **PoC grants**, which help bring innovations to market. These technologies encompass the improvement of productions and processes, such as the development of strains for the dairy industry (e.g., [BLUE](#) project), or the protection of foods against pathogens using enhanced antibacterial or anti-biofilm properties (e.g., [Antiseptic-Wax](#), [AntiCamp](#)).

Other projects develop radically new paradigms in food production by synthesising new cells, tissues or organoleptic properties.

- Building on the ERC project [MYOCLEM](#), in which cascade signalling components in muscle development were identified, Ori Avinoam and his team at the Weizmann Institute of Science in Israel developed a method for faster *in vitro* muscle tissue growth (PoC project [SuperFusion](#)). They tested a new signalling molecule for enhancing cell-to-cell fusion of muscle progenitor cells in animal-free medium, a critical step in the **production of cultured meat**, and set up yield quantification methods for future industry scale-up.
- The PoC project [Nutricells](#), led by Avi Schroeder at the Technion- Israel Institute of Technology, developed lipid-based vesicles loaded with controlled nutrients, vitamins and fatty acids specifically designed to meet the needs of persons with immune or neurological deficiencies. Using AI and liquid-handling robotics, they scaled-up production for incorporation into food matrices as **smart nutritional supplements**.
- Biotechnologies can also improve food qualities, in terms of nutrients content and palatability. This is the focus of the [BeTASTy](#) project, led by Susana Soares at the University of Portoin Portugal, which dives into the perception of astringency and bitterness by testing how compounds interact with the tongue's perception cells. Using a combination of human organoids and electroencephalography, this project explores the physico-chemical mechanisms of gustative perception at the cellular membrane level and will shed light on the pathways involved in astringency perception. This will, in turn, inform the future treatment of **perception deficiencies**, but also the design of **food compounds to optimise their gustative properties**.

Focus on food processing techniques

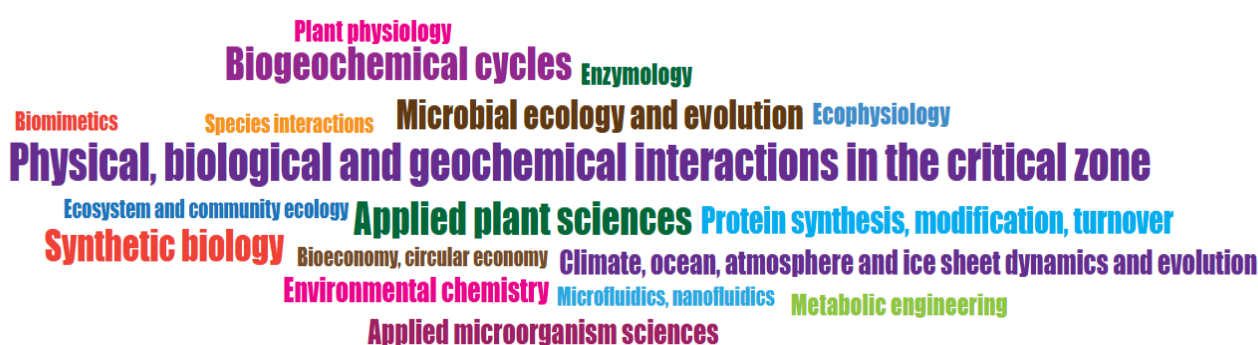
- [ELFO](#) aims to design a new enabling technology for disruptive edible electronic systems, introducing imperceptible intelligence in any edible item with the goal of gaining more information about what we eat and how it is assimilated.
- [NaturalCOLOURS](#) (already mentioned in the industrial biotechnology chapter) aims to develop a novel technology for producing natural food colours through yeast fermentation. They could become alternatives to synthetic additives for the food industry, with health benefits at lower cost, and with less environmental footprint.
- The [ImproVITA](#) project aims to technically and commercially validate a technology that significantly extends the antioxidant activity and freshness of fruit products, representing a substantial improvement over conventional methods, which typically slow oxidation for only a few hours.

8. Environmental biotechnology

Biotechnology is inherently multidisciplinary, spanning applications across multiple scientific and technological domains. Within this landscape, environmental biotechnology occupies a critical interface with environmental and climate sciences, addressing challenges linked to ecosystem degradation, resource management, and climate change mitigation. Anthropogenic climate change and the progressive deterioration of environmental conditions due to human activities and cascading effects are the biggest challenge of our time. Addressing this requires coordinated solutions across disciplines, sectors, and scales.

Within the ERC biotechnology portfolio, environmental biotechnology projects reflect this diversity of approaches. They cover a broad range of applications, including sustainable biomimetic and biomass-based technologies, environmental monitoring and resilience, as well as waste management and bioremediation. The following sections present representative examples of ERC-funded projects in these areas.

Figure 27: Main scientific topics in ERC projects with applications for environmental biotechnology



Source: Mapping Frontier Research (MFR)

8.1. Sustainable biomimetic and biomass technologies

Reducing greenhouse gas emissions and enabling carbon circularity are central to climate mitigation strategies. The [CO2LIFE](#) project, led by Patricia Luis at UC Louvain in Belgium, developed an original solution on this front: a biomimetic process that converts CO₂ into valuable products, such as glucose, using enzyme-supported membranes. The team combined amino acid salts to absorb CO₂ and enzymatic reactions to transform it, creating high-value compounds with strong industrial demand. This [approach](#) partially closes the carbon cycle, preventing new emissions while reusing captured CO₂. By optimising the conversion and recovery stages, the project proposed these new greenhouse gas capture methods, reaching technology readiness level 4 and demonstrating technical feasibility. Its scalable, cost-effective design has sparked industrial interest, leading to a spin-off company (CO2MTECH) to explore scaling-up efforts. Findings on enzyme immobilisation and economic viability were published in peer-reviewed publications, proving both scientific and commercial potential.

Changes in the environment can also affect human infrastructures. One innovative approach for the protection of materials from environmental degradation is developed by the [ARCHI-SKIN](#) project, led by Anna Sandak at the University of Primorska in Slovenia. This project develops **fungal biofilms to create eco-friendly self-healing coatings** that shield engineered surfaces from degradation. Unlike traditional coatings, these biofilms reduce environmental impact, repair themselves and, in the future, could even break down pollutants through bioremediation. The team is studying how fungal biofilms form and function to replicate these properties in protective materials. By combining time-lapse microscopy, mathematical models and computational tools, they have built a high-throughput screening system to identify the best fungal candidates for different surfaces. A key [focus](#) is the building sector, where these coatings could extend material lifespans while offering protection and pollution-cleaning.



© European Union, 2026, Science4EU, [ARCHI-SKIN](#) project.

In a related field, the [BIOGEOS](#) project, led by Lyesse Laloui at EPFL, Switzerland, tackles two major environmental challenges linked to cement production, namely high carbon emissions and the need for climate-resilient infrastructure. The project [explores bio-mediated soil improvement](#), using native soil bacteria to engineer natural materials through controlled bio-mineralisation. This process creates calcite bonds that act as a natural cement, strengthening weak foundations, protecting against erosion and enhancing soil cohesion. The resulting **bio-cemented material** offers solutions for different applications, including seismic retrofitting, foundation repair, and improved heat transfer in thermo-active structures. Its success led to a PoC project ([CEBREWA](#)) and a [patent](#), highlighting its real-world application potential. The approach was further developed in an EIC Transition grant ([BIGALPS](#)).

To accelerate the shift towards bio-based materials in architecture, the [ECO-METABOLISTIC-ARC](#) project, led by Mette Ramsgaard Thomsen at the Royal Danish Academy, explores innovative ways to integrate renewable and carbon-neutral materials in architecture. They developed a framework that provides design solutions for timber, bio-polymer composites and bioluminescent bacteria.

8.2. Environmental modelling and resilience

Climate change interacts with the biosphere in complex ways. Understanding these interactions requires advanced modelling and observational approaches for two key purposes: studying these effects and designing measures to mitigate them and build resilience.

One of the most complex interactions involves rising CO₂ levels, the resulting heat, and the rate of photosynthesis in the biosphere. The terrestrial nitrogen and phosphorus cycles play a critical role in how ecosystems store carbon and manage water. However, their interactions remain poorly understood. The [QUINCY](#) project, led by Sönke Zaehle at the Max Planck Institute for Biogeochemistry in Germany, aimed to clarify these dynamics by focusing on two key uncertainties in global biosphere models, namely how nutrient availability affects plant photosynthesis and respiration, and how vegetation-soil interactions influence plant nutrient uptake and soil carbon turnover. Using stable-isotope labelling, the project uncovered **new insights into future terrestrial carbon uptake**. These findings contribute to refining [global carbon budget assessments](#), supporting global efforts to limit climate change.



[QUINCY](#) mesocosm experiment with 16 tree chambers (back) and 4 soil control chambers (front). Source: CORDIS.

As habitats shift due to warming temperatures and changing environmental conditions, disease transmission patterns also evolve. Vector-borne diseases –such as malaria, dengue, Zika and yellow fever – are now spreading to new regions, including to Europe, posing a significant global public health threat. To combat this, scientists are exploring novel strategies, including **targeting the natural microbiota of mosquitoes** (such as *Wolbachia* bacteria) to control their population. Led by Julie Reveillaud at INRAE in France, the [RosaLind](#) project takes a biotechnological approach to study *Wolbachia*'s interactions with other microbes and pathogens. Using advanced omics and molecular biology techniques, the team is conducting comprehensive research, including studying a newly discovered *Wolbachia* plasmid and testing its potential for genetic transformation. If successful, her [research](#) could enable **scalable, non-chemical strategies for vector control**, offering a new pathway to reduce disease transmission.

Complementing the above biological approach, the PoC project [MOSQUAREL](#), led by Jérémy Bouyer at the CNRS in France, focuses on **reducing mosquito populations through sterile male release**. By deploying sterilised males via drone-based systems, the project aims to suppress wild mosquito populations without using insecticides. This [strategy](#) could be particularly effective in hard-to-reach areas, where conventional spraying is impractical. This project is translating into intellectual property and applied efforts towards commercialisation.

Beyond terrestrial ecosystems, marine habitats are also under threat. As oceans warm and acidify, coral bleaching is destroying reefs, vital ecosystems that support 25% of all marine life. The [CoralStem](#) project, led by Benyamin Rosental at the Ben-Gurion University in Israel, proposes a groundbreaking solution, **stem cell therapy for corals**. While stem cells are typically associated with human health and biomedicine, this original approach adapts the technology to repair damaged coral tissues and enhance reef resilience and regeneration in response to climate-induced stress. In these ongoing efforts, the team successfully demonstrated candidate stem cell transplantation in the sea anemone, *Nematostella vectensis*. They proved the existence of candidate stem cell populations that can be transplanted in corals and that successfully persist, supporting coral functional recovery. The team also isolated an enriched population of candidate stem cells and showed that they possess differentiation capabilities. By pioneering cellular-level restoration, CoralStem opens new avenues for reef restoration, which, in turn, can contribute to mitigating the impact of ocean warming and acidification on marine ecosystems.

8.3. Waste management and remediation

Plastic pollution, especially with micro- and nanoplastics, is a growing environmental crisis. The [VORTEX](#) project, led by Helge Niemann at the Netherlands Organisation for Scientific Research, identified ocean microbes that break down plastics. Using ¹³C-labelled polymers, the team discovered that the marine fungus *Rhodotorula mucilaginosa* effectively degrades polyethylene, a common plastic. The findings also reveal that different plastics attract distinct microbial communities, suggesting that microbes colonise and degrade materials selectively. However, plastic waste accumulates faster than microbes can break it down, dangerously worsening pollution. The project's findings highlight the need for targeted interventions and the pressing need to reduce plastic use to protect ocean ecosystems. These [insights](#) are critical for shaping policies that address plastic contamination.

Plastic pollution is not just an ocean problem, it also threatens terrestrial ecosystems, with 60% of European soils already contaminated with microplastics according to a 2024 [report](#) of the European Commission's Joint Research Centre. The [MiCoS](#) project, led by Caroline De Tender at Ghent University in Belgium, investigates how microplastics harm soil health, focusing on agricultural soils in the Benelux region. The team combines large-scale soil sampling with biological and chemical analyses to assess contamination levels and their effects on plant and soil health, and to identify degradation mechanisms. Initial findings, based on an analysis of 240 soil samples, highlight significant risks to plant health, soil microbiomes, and food safety.

Beyond plastic degradation, ERC biotechnology projects also study **solar reforming (using sunlight to upcycle waste)**. Harsh pretreatment conditions have typically limited these approaches. Erwin Reisner at Cambridge University in the UK, addressed this challenge through the PoC projects [MatEnSAP](#) and [SolReGen](#). In these projects, his team studied and developed enzymatic pretreatments that led to new methods and a [patent](#). These innovations demonstrate how biotechnology could transform waste into valuable resources while reducing environmental impact.

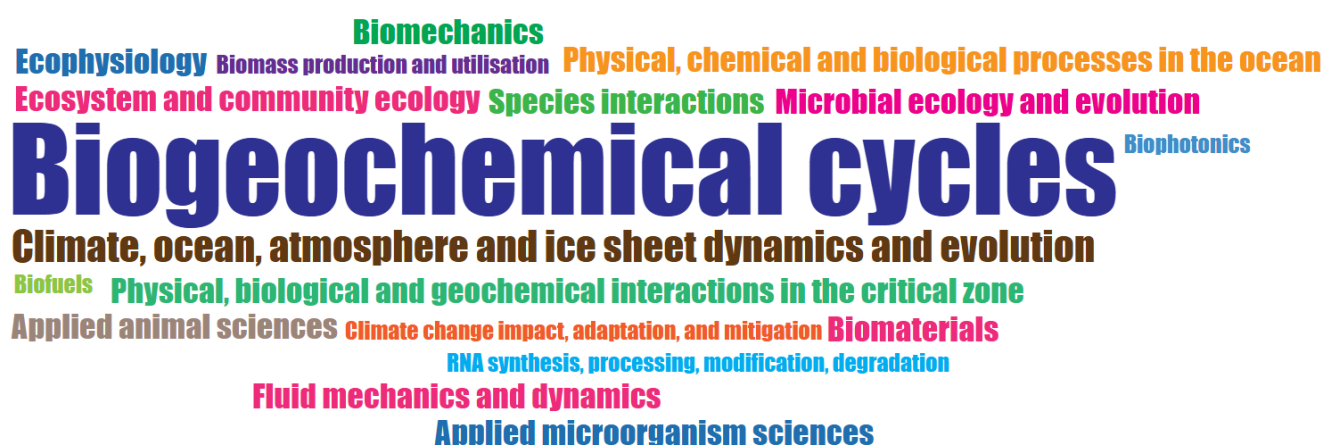
9. Blue biotechnology

Blue biotechnology is the application of science and technology to living aquatic organisms for the production of knowledge, goods and services (OECD, 2016). Many model organisms used in fundamental research or in health, industrial, food or environmental applications are aquatic species, which can be grown in high volumes (e.g. micro-algae such as diatoms) or easily adapted (e.g. invertebrates such corals).

The ERC funds a diverse portfolio of blue biotechnology projects, leveraging marine and freshwater organisms to address challenges in medicine, pharmaceuticals development, food, materials, and energy. Projects highlighted in previous chapters of this report include [VORTEX](#), which explores the potential a marine fungus and microbial communities to degrade plastics polluting oceans, and [Coralstem](#) that proposes a stem cell therapy for corals to restore reef ecosystems (see Section 8.3).

This chapter highlights further research with a focus on algae biotechnology, projects for aquaculture and the study of marine ecosystems.

Figure 28: Main scientific topics in ERC projects with applications in blue biotechnology



Source: Mapping Frontier Research (MFR)

Algae and microalgae research

Several ERC projects work on algae as model organisms or harness their potential for applications in various areas from pharmaceuticals and nutrition to biomaterials and biofuels.

- [TREATCilia](#) focused on dynein-related ciliopathies, a group of rare genetic disorders linked to defective cilia, hair-like structures critical for cellular function. The project explored innovative therapeutic approaches including high-throughput drug screening in model organisms such as the green algae *Chlamydomonas*.
- In the food sector, [ASTAOMEGA](#) used a marine algal species (*Nannochloropsis gaditana*), to produce high levels of the omega-3 fatty acid and a high-value antioxidant astaxanthin, overcoming issues that current, isolated production methods have been facing for years, while [ASTEASY](#) employed metabolic engineering to enhance astaxanthin industrial production in *Chlamydomonas reinhardtii*, making it more cost-effective for nutraceuticals and aquaculture applications.

- [BioSilica](#) harnessed microalgae to synthesise nanostructured silica intracellularly, paving the way for sustainable **biomaterials** in industries such as electronics and construction.
- Finally, [SOLENALGAE](#) enhanced the productivity of engineered algae biomass for versatile applications ranging from food and feed to **biofuels**, achieving up to an 80% increase in lipid content, a critical macromolecule for biofuel production.

Aquaculture

Blue biotechnology plays a key role in supporting aquaculture, which today provides around half of the fish consumed globally. ERC-funded projects in this area contribute to improving fish health and enhancing breeding strategies.

- In the [EPIFISH](#) project, Jorge Manuel De Oliveira Fernandes at NORD University in Norway investigated epigenetic modifications occurring during domestication of the commercial fish Nile tilapia *Oreochromis niloticus*. They identified large DNA methylation events and several non-coding RNAs targeting genes involved in metabolic pathways and muscle development at the onset of domestication. These results provide a basis for the implementation of epigenomic selection as a new feature in future selective breeding programmes. The research has been further developed through the two PoC projects [EPIMARK](#) and [EPISELECT](#), which focus on applying epigenetic markers for fish growth optimisation, including through patented technologies.
- Fish health is also of primary concern as crowded farming conditions are hotspots for disease outbreaks. The project [TEMUBLYM](#), led by Carolina Tafalla at CSIC in Spain) aimed to understand the role of B lymphocytes and antibodies in fish long-term immune memory. Using plasmablast cell models, transcriptomics analyses and gene editing in trout, they demonstrated how immune responses are established in mucosal tissues, such as the intestine and gills, offering new venues for mucosal vaccination strategies. In the follow-up PoC project [PKDControl](#), they tested a new approach for a treatment against proliferative kidney disease, a major disease affecting salmonids. Based on interactions with a B cell activating factor, the patented methodology has been licensed to a vaccine company, demonstrating strong translational potential.

Focus on biotechnology to study marine ecosystems and their response to global change

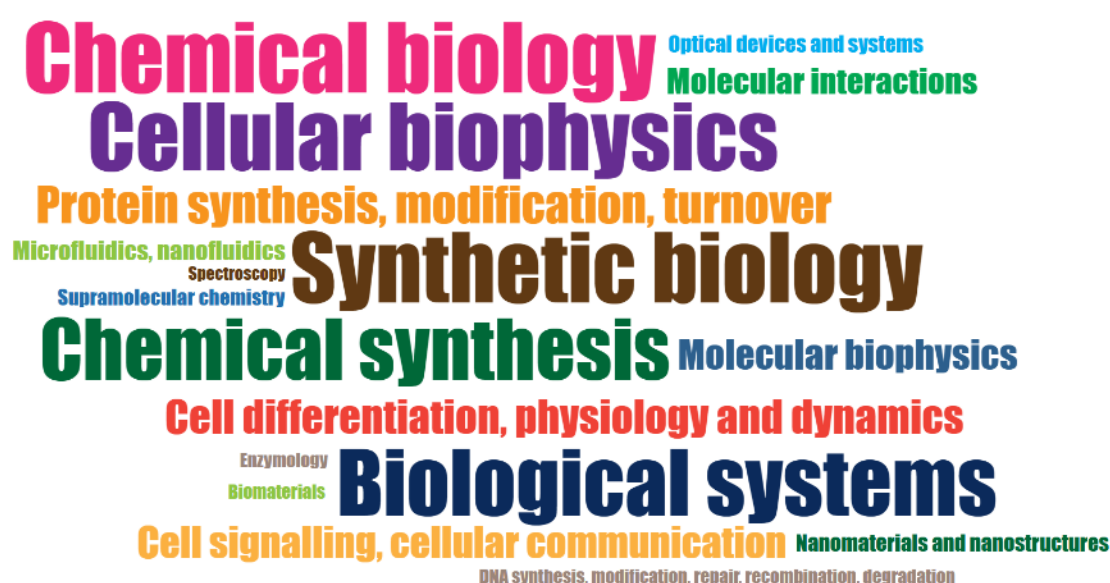
- [ALKENoNE](#) aims to manipulate alkenone production in haptophyte algae to improve their use as biomarkers for reconstructing past ocean temperature changes.
- [ICY-LAB](#) develops high-precision silicon isotope measurements in diatoms to study marine ecosystem responses to environmental change.
- [MYCO-CARB](#) uses omics approaches to investigate the role of marine fungi in carbon cycling and ecosystem functioning.
- [VirFix](#) studies how viruses affect carbon fixation in cyanobacteria, providing insights into oceanic CO₂ regulation mechanisms.
- [APPELS](#) investigates biochemical pathways involved in metalloprotein production in phytoplankton.
- [MARIX](#) unravels microbial pathways driving methane and ammonium oxidation in marine environments.
- [EnLightEN](#) investigates the metabolic processes of acetate-degrading methanogens, key contributors to global methane production.

10. Cross-sector and non-specific biotechnology applications

Many ERC-funded biotechnology projects bridge multiple scientific fields and offer applications that could benefit research and applications across diverse sectors. This cross-cutting research includes advances in synthetic biology, enabling platform technologies and biotechnology methods and tools supporting research more broadly.

Together, these projects contribute to expanding fundamental knowledge while also developing technologies with potential applications in areas such as healthcare, agrifood, industry and environmental monitoring.

Figure 29: Main scientific topics in projects with non-specific biotechnology applications

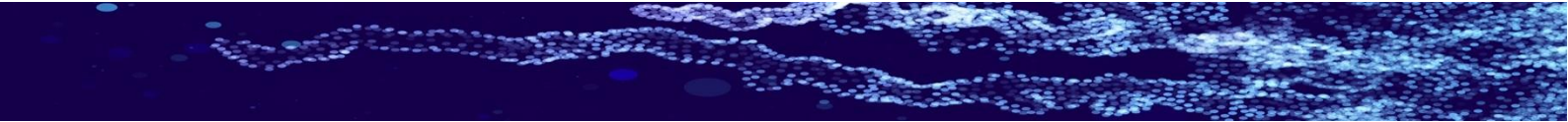


Source: Mapping Frontier Research (MFR)

10.1. Synthetic biology

Scientists have long dreamed of creating living systems *de novo* or from scratch. However, the sheer volume of data, expertise and research required to achieve this goal made it seem impossible until recently. Recent advancements in biotechnology and research have changed this.

The [MiniLife](#) project, a Synergy project bringing together Eörs Szathmáry (Parmenides Foundation, Germany), Andrew Griffiths (ESPCI Paris, France), Sijbren Otto (University of Groningen, Netherlands), and Gonen Ashkenasy (Ben-Gurion University, Israel), aims to develop the first synthetic chemical systems that encompass all core features expected of **synthetic living systems, that are self-sustained and can evolve**. This project leverages expertise in chemistry and biology, along with the strengths of a robust consortium of collaborations with access to essential technologies, research and experts. The team has already coupled replication with metabolism in self-replicating molecules and developed responsive systems that can signal, replicate and catalyse reactions. Key [results](#) include the development of compartmentalised autocatalytic systems displaying heritable variation. By advancing the understanding of complex chemical networks, the project contributes to progress towards the development of future synthetic biological systems, technologies that could lead to a wide range of applications, together with deep philosophical implications.



An important focus in synthetic biology closely relates to the field of DNA and RNA nanotechnology. Advances in **DNA origami technologies** (DNA sequences that self-assemble into nanostructures) have allowed an unprecedented control of the spatial organisation of these biomolecules at the nanoscale. The [DNA ORIGAMI MOTORS](#) project, led by Hendrik Dietz at the Technical University of Munich in Germany, takes this approach to construct **functioning synthetic motor units**. The [idea](#) is to develop repeating, diffusive systems that lack inversion symmetry and operate under non-equilibrium conditions. These mechanisms are evaluated and iteratively refined using cryo-electron microscopy. Additionally, conventional and super-resolution microscopy are used to study the real-time diffusive motion of these systems. The aim is to create robust load-bearing nanoscale motor units comparable to natural macromolecular motor proteins, enabling innovative applications such as chemical synthesis, targeted drug delivery, and molecular separation and packaging.

In a related project called [ENSYNC](#), Kerstin Göpfrich at Heidelberg University in Germany goes a step further and uses RNA origami structures in the quest to **achieve self-replicating and evolving synthetic cells**. The researchers develop RNA-based cytoskeleton mimics that self-assemble within lipid vesicles, enabling the study of structural organisation and dynamic behaviour in synthetic cells. These findings provide new [insights](#) into the design of self-replicating systems and contribute to advancing the field of synthetic cell engineering.

A big question in biology relates to how biological processes are compartmentalised inside cells. Recent research shows that further compartmentalisation of biological processes is achieved by the intrinsic capacity of many biomolecules to cluster in dense assemblies known as biomolecular condensates. These condensates enhance molecular interactions, allowing for the formation of highly specific and efficient biochemical reactions.

[BlobMech](#), led by Andrew J. Baldwin at the University of Oxford in the UK, tests whether intermolecular interactions drive liquid droplet formation, creating regions of solvent tailored to promote specific chemical functions. By studying a diverse range of biological liquid droplets, the project aims to reveal **under which conditions liquid droplets mix and which molecules are absorbed**. Fundamental results on this front should help clarify why cells naturally create these regions during their life cycle, how this relates to human diseases and aid in the design of functional sequences for synthetic biology.

10.2. Platform technologies

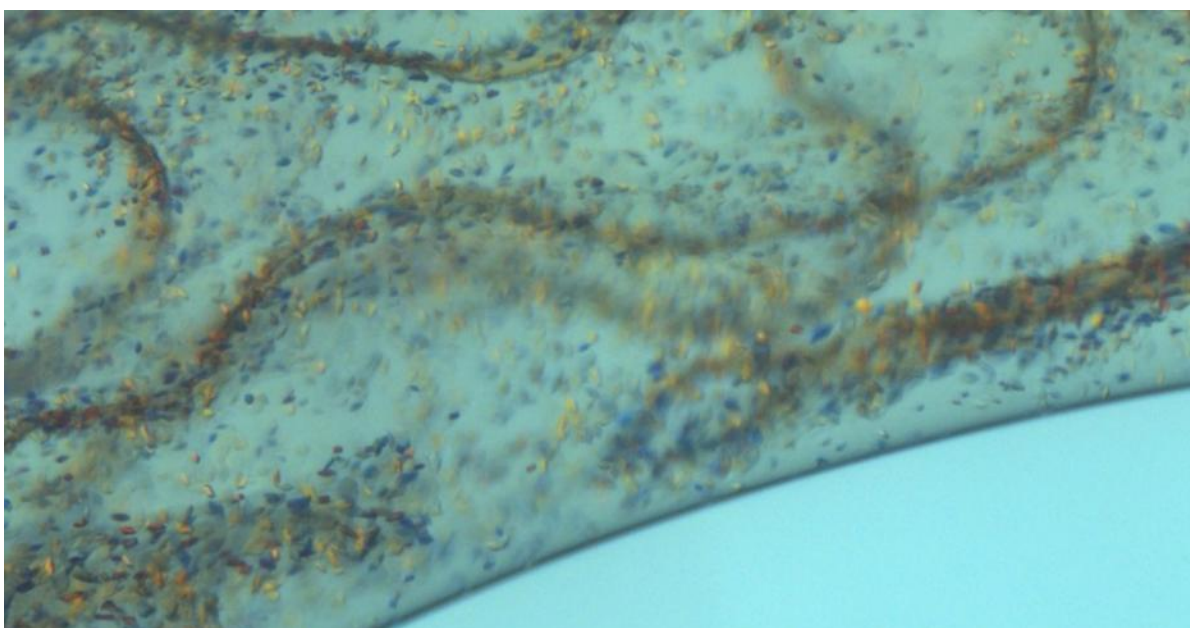
Platform technologies are key in biotechnology as they provide methods and tools that can be applied across multiple applications, diseases or therapeutic areas without needing to be redesigned from scratch for each new use case. As such, they have the potential to enable and accelerate the development of a wide range of biotechnology products and solutions.

- Scientists now use light to control biological systems with extreme precision. However, current methods have major limitations. Andrea Di Falco at the University of St Andrews in the UK compares these restrictions to how a nurse's hands are restricted by the fixed openings and the geometry of an infant incubator. Through his ERC project [AMPHIBIANS](#), Di Falco has developed a new **biophotonics platform** that uses innovative meta-surfaces to overcome these challenges. His team has proven that this technology can: (1) trap biological samples on a microchip as effectively as high-end microscopes, but at a far lower cost, and (2) detect and image biological substances in small affordable devices. These breakthroughs were published in Nature Photonics and led to two follow-up PoC projects: [HAZGUARD](#) that develops augmented reality displays that could replace glasses for people with sensory impairments and [APOLLON](#) that explores the feasibility of self-powered optics for smarter environmental monitoring.
- The [ROBOCHIP](#) project aimed to develop advanced robotic systems that can precisely manipulate 3D biological samples -automatically and with high accuracy in both space and time. Led by Mahmut Selman Sakar at EPFL in Switzerland, the team designed new **microrobotic tools**. These can integrate smoothly with high-speed bioengineering systems and generate signals that mimic natural biological processes, helping guide cell and tissue development. Using microfabrication, computer modelling and robotic control, the researchers demonstrated that collagen gels, a key material in tissue engineering, can be reshaped mechanically. This breakthrough could pave the way for **lab-grown tissues that closely match natural human tissue**, making them suitable for transplants or drug testing. The follow up PoC project, [MagFlow](#) produced **tiny flexible catheters that can be steered magnetically** to reach even the smallest blood vessels (0.2 mm in diameter).
- In the [REM](#) project, Selim Hany from Bilkent University in Türkiye developed electronic sensors that measure the internal properties of microparticles and cells. His system combines microwave technology with optical microscopy to verify results independently. Hany and his team designed several types of highly sensitive microwave resonator, integrated with microfluidic channels, to measure the size and electrical properties of individual cells and microparticles. These **high-resolution sensors** can now distinguish between different materials, e.g. polystyrene (a common microplastic) and soda-lime glass (a standard glass material). A key achievement was the creation of **3D sensing electrodes, which simplify data analysis for microparticles and cells**. This work led to the PoC project [RAMP-UP](#), which focuses on **detecting microplastics in drinking water**.

10.3. Biotechnology tools for research and discovery

ERC projects develop biotechnology tools and methods that enable scientific discovery and open new avenues for research. These advances can deepen fundamental understanding of biological systems, disease pathways and cellular functions, while also providing new approaches for the discovery, development and optimisation of technologies and therapies.

- Life's complexity cannot be explained by DNA alone. Scientists now know that a second layer of chemical information plays a crucial role. The [EPIR](#) project provided strong evidence for this idea. Its findings suggest that modified RNA bases – chemical building blocks found in human RNA – are remnants of early Earth's chemistry. These molecules likely existed alongside the standard genetic bases, acting as both competitors and partners in life's origins. A key breakthrough was the team's success in inserting highly modified nucleosides into polymers. This allowed them to propose a plausible scenario for how an RNA-peptide world emerged and how chirality (molecular handedness) was passed on. The project's high-impact research was featured in a television documentary (*Life from Outer Space*, ARTE). Thomas Carell, at the Ludwig Maximilian University Munich in Germany, took these findings even further in the follow-up project [leuCAB](#). He used them to develop a new nucleoside-based drug for leukaemia, supported by a PoC grant.
- The [ProtonPump](#) project used time-resolved X-ray crystallography to study how cytochrome c oxidase, a key enzyme in cells, changes its structure over time. The goal was to understand how electron movements within the enzyme control proton exchange between amino acids. The team made major advances in analysing data from (1) time-resolved serial crystallography, and (2) time-resolved X-ray solution scattering. Richard Neutze, at the University of Gothenburg in Sweden, led the project. His team also used photocaged oxygen to trigger and study structural changes in the enzyme. This approach expanded the scope of time-resolved X-ray crystallography, moving beyond systems that rely on natural light-driven reactions. The findings led to the follow-up project [SERIAL-X](#), which developed affordable, flexible, and user-friendly technologies to improve sample delivery in serial crystallography experiments. These innovations helped launch a new company, [SerialX](#).



Microcrystals of cytochrome c oxidase used in the [ProtonPump](#) project. Source: CORDIS.

10.4. Projects with multiple applications

Many biotechnology projects funded by the ERC have applications that span multiple fields. During the standard 5-year duration of an ERC grant, many projects advance knowledge in their fields while developing or using biotechnology for more immediate applications.

- One example is the [ABLASE](#) project, led by Malte Gather at the University of St. Andrews in the UK. ABLASE addresses current limitations in our understanding of the forces that cells exert in their environment; existing approaches only allow researchers to monitor a small number of cells and often risk killing them in the process. This area of knowledge is essential to answer biomedical questions related to cell growth, tissue formation, wound healing and cancer cell invasion of healthy tissue. The research team developed **biocompatible micro-lasers** that can be inserted into cells without affecting their behaviour or properties. These tiny lasers possess a green fluorescent dye, which can be distinguished when scientists generate distinct emission patterns. This method has allowed the research team to introduce lasers into tens of thousands of cells simultaneously and test them in cells involved in immune responses. The project is highly interdisciplinary, spanning the fields of photonics, genetic engineering and material science. Beyond its scientific contributions, it has the potential for medical and industrial applications: as a **new microscopic tool for medical and biological research**; for the development of **flexible electronic applications** in material sciences; and as a **barcode-like security tool** to identify counterfeit banknotes or authenticate identification documents. Gather also leads the PoC project [CELL-FORCE](#), which aims to validate the commercial feasibility of their elastic resonator interference stress microscopy (ERISM) and explore its potential use in **fundamental research, drug development and diagnostics**.
- The [EVOMICROCOMM](#) project, led by Sara Safwat Mitri Labib in the University of Lausanne, in Switzerland, aimed to develop theoretical and experimental tools to study and control **how microbial species interact**. Microbes play a key role in many aspects of our lives, from environmental health to our own well-being. Better understanding them could help reduce infectious and other microbe-dependent diseases. The [research team](#) studied four bacterial species in a controlled environment, analysing how different toxicity levels shaped microbial ecology and how to design and breed microbial communities, using computational models to predict community growth rates in toxic conditions. The study shed light on community co-evolution and environmental dependencies; a key finding was that microbial interactions are context-dependent, with toxic environments sometimes leading to positive interactions. The project results could potentially be used in the medical, environmental and industrial fields, ranging from designing **custom treatments for intestinal diseases and antibiotic therapies** to **degrading pollution and plastics** and **producing efficient biofuels**.



Colonies of bacterial species used in the community breeding experiments of the [ECOMICROCOMM](#) project. Source: CORDIS.

- The [CaLA](#) project, led by Bastian Rapp at the University of Freiburg in Germany, addresses the limited progress made in recent decades in the development of tactile displays that convert text and graphics into touchable pixels – called taxels – that can be primarily used by people unable to perceive information visually. With this objective in mind, the research team developed the capillary lock actuator (CaLA) and used CaLA actuator arrays to set up the very first portable tactile graphic display with 30 000 individually addressable taxels, using glass manufacturing techniques developed by the research team. The result outperforms current technologies and provides the first robust cost-effective solution for large-scale **tactile displays for visually impaired people**. The project has potential **applications in both industrial and medical fields**. Progress in actuator technologies can drive multiple microsystem applications, such as large-scale tactile displays, while expanding access to digital information and communication technologies to visually impaired individuals addresses a global health issue affecting around 285 million people and contributes to greater social inclusion.

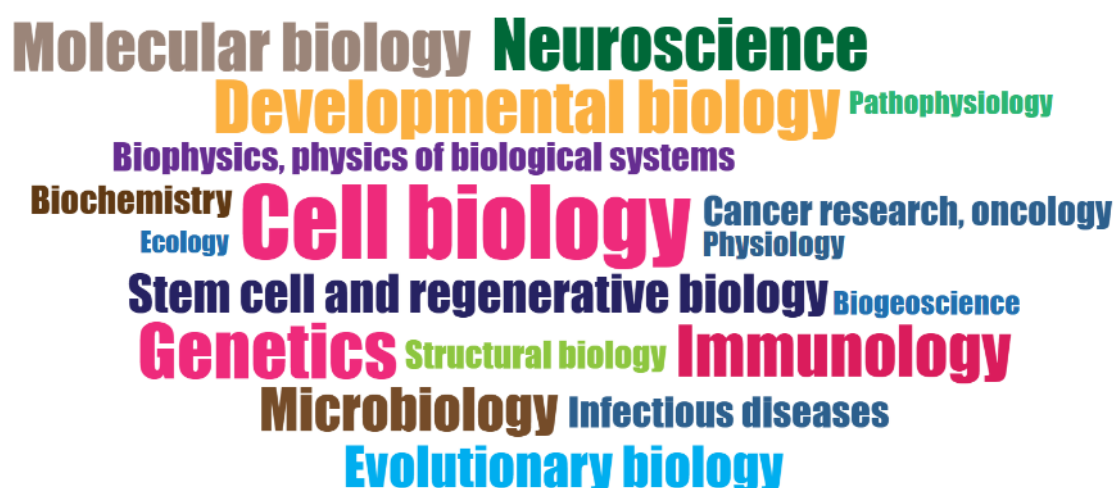
11. Advancing knowledge for biotechnology

Frontier research is the pioneer of innovation. It may be funded with no immediate applications in sight. Yet, time and again, it results in findings that revolutionise medicine, agrifood and industry. In this chapter, a broad group of curiosity-driven projects not aiming at an application in the medium term, but which might lead to future breakthroughs in different fields of biotechnology, are outlined.

One such example is in the field of genetics. The CRISPR/Cas technology that began as a study of bacterial immune systems is now the backbone of gene editing, enabling everything from curing genetic diseases to engineering drought-tolerant crops (see [ERC report](#)). mRNA research is another example; once niche academic research, receiving funding including from the ERC, it became the cornerstone of COVID-19 vaccines in record time. These are just two recent examples of results stemming from curiosity-driven research that led to societal applications.

Frontier research thrives on risk-taking, asking bold questions and putting forth what was previously thought impossible or unbelievable. The projects presented below are examples of research across fields as diverse as cell biology, health, microbiology and the development of novel enabling technologies, which could be conducive to future biotechnology innovation and have sometimes already led to concrete solutions.

Figure 30: Main scientific disciplines in projects advancing knowledge for biotechnology



Source: Mapping Frontier Research

11.1. Cell biology

Cell biology research investigates various cellular functions. Such knowledge can lead to breakthroughs in engineering of cells and tissues for regenerative medicine or tailored microbial factories for sustainable bio-production. By deciphering complex cellular mechanisms, such as signalling pathways or organelle dynamics, biotechnology innovations can emerge, from next-generation therapeutics to lab-grown meat and high-value industrial products. Here some examples:

The [BARCODED-CELLTRACING](#) project aimed to better understand how blood and immune cells develop naturally. Hans-Reimer Rodewald from the German Cancer Research Center (DKFZ) used a novel animal model with a fluorescent marker that allows to observe haematopoietic stem cells in their original native environment. Additionally, a sophisticated DNA tagging system (Polylox) was developed to track exactly **how haematopoietic stem cells evolve into various cell types**, which uncovers the complex pathways and connections within the immune system. Research outcomes may become relevant to regenerative medicine and the development of personalised therapies for genetic and other diseases.

Myelin is the protective coating around nerve fibres crucial for fast and efficient brain signalling. The [MyelinPlasticity](#) project aimed to uncover how myelin can change and adapt due to neuronal activity, similar to how connections between neurons can become stronger with use. Using advanced techniques and models, Ragnhildur Káradóttir at the University of Cambridge in the UK) sought to understand **how myelin is affected by learning and activity**, which could lead to **new treatments for conditions such as multiple sclerosis** and other neurological disorders where myelin is damaged.

Other examples of ERC projects

- The [BRIDGING](#) project investigated how plant cells communicate via plasmodesmata, enabling direct exchange of materials and signals for growth and defence, potentially revolutionising our grasp of plant physiology.
- The [EVOCLOCK](#) project explored the genetic and cellular mechanisms of circalunar clocks to reveal how marine organisms adapt to lunar cycles, with potential implications for ecology and aquaculture through genome editing and neural mapping.
- The [SYMBIOSES](#) project aimed to experimentally engineer endosymbiosis to introduce complex traits, such as nitrogen and carbon fixation, combining synthetic biology, modelling, and nanotechnology to drive controlled organelle-like evolution.



Bacteria are injected into a fungus with a fine tip. Image by Sean Kilian. Source: CORDIS, [SYMBIOSIS](#) project.

11.2. Health research

Research in the area of health uncovers physiological mechanisms or disease pathways, providing the basic knowledge for the development of biotechnological applications such as gene therapies or precision and personalised medicine. The insights gained through fundamental research can thus be rapidly translated into innovative diagnostics, treatments or bioengineered therapies that can revolutionise patient care.

The [ASTHMACRYSTALCLEAR](#) project led by Bart Lambrecht at the VIB in Belgium, has made significant strides in understanding the role of protein crystallisation in type 2 immunity and asthma. The research explored the concept that protein crystals, particularly Charcot-Leyden crystals (CLC) in humans, play a crucial role in asthma. These crystals, produced by immune cells, such as dendritic cells and eosinophils, contribute to chronic inflammation by promoting type 2 immunity. Importantly, the team developed humanised monoclonal **antibodies capable of dissolving CLC crystals**, offering a potential innovative treatment for asthma symptoms. This groundbreaking work is paving the way for **clinical trials and new therapies for asthma** sufferers.

The [SENSIT](#) project aimed to unravel how human tumours respond to the body's T-cell-based immune defence. By studying which factors affect the sensitivity of tumours to immune attacks, the team led by Antonius (Ton) Schumacher from the Netherlands Cancer Institute, discovered that many T-cells present in certain tumours are bystanders rather than actively fighting the cancer. This finding helps explain why some tumours have low response rates to certain immunotherapies. Their research has not only paved the way for **new therapeutic approaches, such as vaccination and adoptive T-cell transfer**, but also potential strategies to ensure the immune system targets the cancer cells more effectively. Besides showcasing the interplay between activated T-cells and tumour cells, they have identified **a promising target within the tumour environment** that could be harnessed to improve treatments. The project's achievements are important for advancing novel cancer immunotherapy.

Other examples of ERC projects

- The [PlasmoSilencing](#) project uncovered how RNA modifications regulate virulence of the malaria-causing parasite *Plasmodium falciparum*, leading to the discovery of novel antimalarial drug candidates targeting epigenetic pathways, offering fresh avenues for malaria treatment.
- The [CHUbVi](#) project focused on RNA viruses and the role of ubiquitin in viral infections. The project has made significant progress in understanding these molecular processes, resulting in numerous publications. The project's results have real-world implications, potentially influencing new treatments for viral infections.

11.3. Genetics

Frontier research in genetics, such as CRISPR-based gene editing or single-cell genomics, reveals deeper insights into genetic variation and disease mechanisms, enabling the development of highly targeted approaches. These advances drive biotechnology innovation by facilitating breakthroughs such as personalised gene therapies, engineered cell treatments, or other synthetic biology applications.

Many projects using CRISPR/Cas technologies for basic and applied research are described in ERC 2024 report [Frontier research in CRISPR/Cas technology](#). The report analyses how ERC-funded curiosity-driven research supported the development and application of CRISPR/Cas. A few examples in other areas of genetic research are highlighted below:

- The [DDREAMM](#) project explored cells' DNA damage response, mapping repair mechanisms through mutant cell lines and new software, with findings that could advance cancer treatments and drug development.
- The [TRANS-3](#) project investigates how mRNA actively influences genome structure and nuclear organisation, challenging the idea that inter-chromosomal interactions are random, and revealing dynamic mRNA factories with potential impacts on disease research and therapy development.
- The [RNArepair](#) project advanced precision RNA editing by optimising tools, such as SNAP-ADAR enzymes, enabling targeted correction of single-point mutations in cells, primary tissues, and even *in vivo* in worms, paving the way for future medical breakthroughs.

ERC-funded research using CRISPR/Cas techniques

- The ERC funded 1297 projects using the CRISPR/Cas technology in its calls from 2014 to 2022.
- In the Life Sciences domain, the adoption of CRISPR/Cas grew from 25% of ERC projects in 2014 to over half by 2022.
- Most projects (86%) focus on basic research and understanding biological mechanisms and human diseases.
- 14% target practical applications in agriculture, biotechnology and medicine.

ERC report [Frontier research in CRISPR/Cas technology](#) (2024)

11.4. Microbiology

Fundamental research in microbiology, such as exploring extremophiles, microbiome dynamics or synthetic microbial systems, can unlock new biological pathways and enzymes that can be harnessed for industrial and medical applications. These discoveries fuel biotechnology innovation by enabling the development of next-generation antibiotics, sustainable biofuels or engineered probiotics that transform healthcare, agriculture and environmental sustainability.

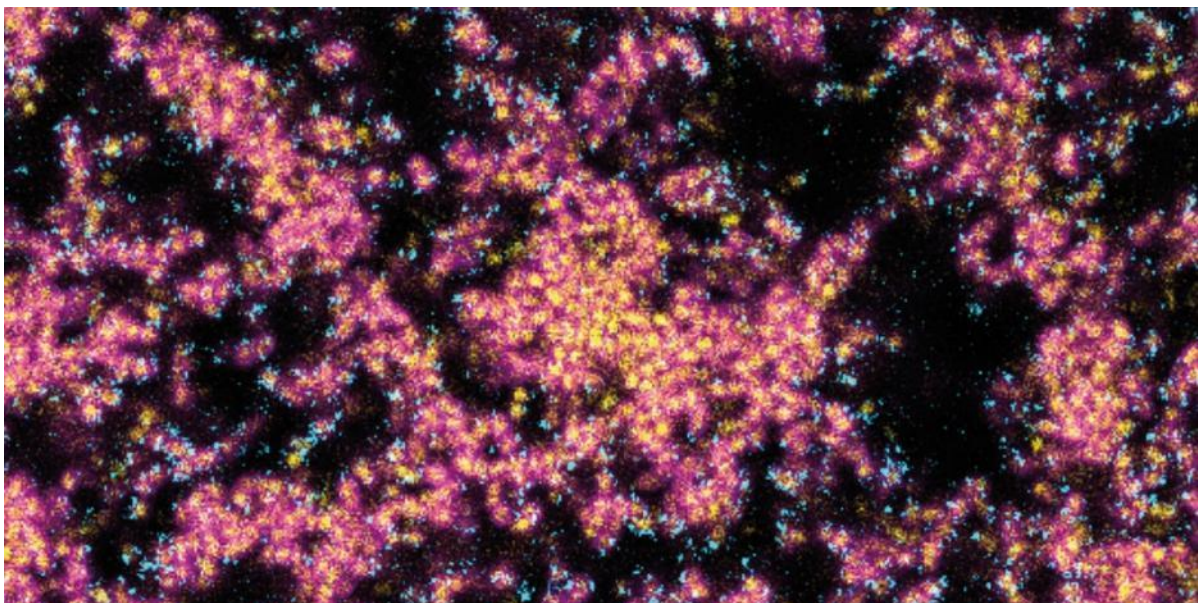
The [BacCellEpi](#) project, led by Pascale Cossart at the Pasteur Institute in France, explored the intricate dynamics of bacterial infections in the gut. Researchers investigated **how bacteria interact with host cells** and how they influence the host's genetic expression. This groundbreaking research has uncovered new insights into how bacterial infections establish and persist, revealing key factors at the bacterial, cellular and epigenetic levels. With significant discoveries published in high-impact journals, the project has not only advanced scientific understanding but also **set the stage for future**

exploration in gut microbiota, underscoring the vital role these microorganisms play in health and disease.

The [microTOUCH](#) project, led by Nicola Segata at the University of Trento in Italy, is pioneering in the field of microbiome research. It seeks to uncover how the human microbiome is acquired and transmitted between individuals and explore the possibility of microbiome-linked non-communicable diseases being partially communicable. The team has developed novel **methods and bioinformatic tools to model and track microbiome transmission**, generating key insights into microbial species' transmission patterns across various ages and body sites. Their findings underline the impact of microbiome transmission on health, suggesting links to conditions such as autism and obesity. The project's outcomes are already being applied in practical settings, including cancer research and nutrition. This work is not only at the cutting edge of microbiome science but also promises transformative advancements across medicine, nutrition and environmental health.

More examples of ERC projects in microbiology

- The [BIOFAGE](#) project has advanced understanding of bacterial biofilm-phage interactions through innovative experimental systems, including cutting-edge imaging and analysis. Findings revealed **how biofilm matrices influence infection and protection**, alongside methods to modulate phage resistance. This pioneering research could enhance phage therapy and combat bacterial infections.
- The [whyBOther](#) project sought to uncover the mechanisms governing **botulinum neurotoxin** (BOT) production by *Clostridium botulinum*. By examining how individual bacterial cells regulate botulinum neurotoxin synthesis, mapping the cellular networks involved, and identifying DNA-related factors influencing toxin production, the project has deepened our understanding of bacterial pathogenesis. The findings could enhance safety measures and treatments related to bacterial toxins.



E. coli bacteria (yellow), surrounded by an extracellular biofilm matrix (pink) and phages (cyan). Source: CORDIS, [BIOFAGE](#) project.

11.5. Enabling technologies

Frontier research in enabling technologies, such as nanotechnology, lab-on-a-chip systems or advanced bioinformatics, provides powerful tools to adapt, analyse and visualise biological processes with unprecedented precision. While sometimes still far from implementable biotechnology applications, this type of research can lead to innovations in a broad range of supporting areas that accelerate biotechnology breakthroughs. They can enable, for example, faster drug development, real-time diagnostics and scalable biomanufacturing.

- [DeE-Nano](#) revolutionises **protein analysis** by designing synthetic protein nanopores paired with molecular machines that unfold proteins, controlling their transit and identifying individual amino acids via ionic current, enabling real-time low-cost single-protein sequencing with potential for disease biomarker discovery.
- [HOLOVIS](#) advances **neuroscience with holographic technology**, enabling all-optical neuronal manipulation in freely moving mice and improving live brain circuit studies via multi-photon microscopy and wavefront shaping.
- [RNAActivate](#) pioneers the **control of cell fate using light** (optochemical control) with light-activated FlashCaps to regulate mRNA translation, enabling precise manipulation of processes such as cell death and migration in models such as zebrafish embryos.
- [CADABRE](#) aims to design **AI-optimised synthetic antibody libraries** with superior stability and low polyreactivity, combining computational modelling and phage display to accelerate therapeutic antibody discovery.

12. Biotechnology in society

Frontier research does not only deliver scientific advances in biotechnology but also plays an essential role in understanding the societal impact and challenges posed by these innovations. 45 ERC projects from the social sciences and humanities address a large array of research topics related to biotechnology in society, and more broadly the role and impact of life sciences and health research.

This chapter highlights a selection of these projects focusing on two main aspects. First, projects that provide insights into innovation dynamics in the life sciences and biotechnology, and which results could inform policy. Secondly, research that examines the societal impacts of biotechnology and biomedical research and which covers governance and ethical issues for research involving patients and other living organisms; aspects related to safety concerns and public trust; and finally, societal and cultural effects of biotechnological advances.

Figure 31: Main scientific topics in the 45 ERC projects in the social sciences and humanities



Source: Mapping Frontier Research (MFR)

12.1. Innovation dynamics in biotechnology

A selection of ERC projects provides insights into the drivers and dynamics underlying innovation in biotechnology, addressing issues from early development to market uptake stages.

The [EHCI](#) project advances understanding of how markets can be structured to drive efficient innovation for novel health treatments, which is made possible by the development of new cell and gene technologies. It identifies optimal combinations of public policies and regulatory interventions, not only considering intellectual property incentives, but also pricing regulations and innovation and competition policies in drug R&D more broadly. Concretely, EHCI compares the efficacy of different pricing mechanisms, highlighting that current incentive structures may be less effective for biologics and high-cost gene therapies (see [working paper](#)).

The [TechEvo](#) project presents a novel perspective on how research and innovation policies can shape technological change, economic growth and prosperity. The project examined the long-term evolution of knowledge creation in European regions from 1981 and how the knowledge produced within specific places shapes their innovative capacity and future technological prospects. Furthermore, it developed an [online evaluation and planning tool](#) – the ‘knowledge space methodology’ – to assess regional knowledge capabilities leading to future growth opportunities, which policymakers can use to elaborate more effective policy instruments for regional development and innovation.

The [RIPPLE](#) project studies positive tipping points in the transition to a green economy, highlighting how innovation in and diffusion of key green technologies can reduce costs and enable a swift transition away from fossil fuels. It also explores material and financial feasibility challenges while elaborating new ways to identify early signals of positive tipping and designing policies that respond to those signals. The project aims to challenge the limitations of current climate mitigation models, which do not properly account for or leverage these shifts.

The [PatentsInHumans](#) project examines the governance and function of patents for technologies related to the human body. The project identifies potential bioethical issues, including those arising [with biobank research](#), [and maps institutional avenues](#) to integrate bioethical considerations into the European patent system and [for health data use in research and innovation within the EU](#).

More projects on innovation dynamics in biotechnology

- [TRANSGENE](#) offers a historical perspective on the practices and modes of organisation of the scientific field of genomics and biotechnological innovation, demonstrating how long-term networking relationships can generate an innovation ecosystem that effectively responds to external challenges and leverages new techno-scientific opportunities.
- [ALTERBIOTIC](#) focuses on antimicrobial resistance and the measures needed to drive innovation to respond to this emerging global health crisis.
- [SIRI](#) investigates, through the concept of serendipity in research and innovation, how important scientific discoveries can result from both targeted funding and unanticipated research outcomes, highlighting the importance of spillovers and coordination in research, medical research and drug development.
- [SYNTHLIVES](#) provides a critical anthropological perspective on technological innovations in the mining sector, including those that seek to replace or complement natural resource mining with synthetically produced substances and biomining.

12.2. Societal, legal and ethical perspectives on biomedical and biotechnological research

Several ERC-funded projects examine the challenges arising in biomedical and biotechnology research, from patient participation in health research to the governance of human and non-human data (collection, access, ownership, infrastructure and benefit-sharing) to the development and use of organoids.

- The [POLICYAID](#) project examined the unprecedented scale of human tissue sample and healthcare data collection to inform ethical and legal oversight in biomedical research. It provided insight into [public attitudes](#) to health data reuse in the EU, patient awareness about [biobanking and secondary use](#) of samples for research, challenges to the sustainability of [university-run biobanks](#), limitations of [opt-out systems for health research](#) participation, [participant trust](#) in international genetic research and [ethical sharing of health data](#) on online platforms. The project's outputs have informed [studies](#) of the European Parliament Research Service and [reports](#) from the European Commission.
- The [DataSpace](#) project further examines health data issues by analysing substantial investments in cross-border health data infrastructure, such as the [European Health Data Space](#). It identifies the types of [data infrastructure](#) being established and explores their [implications](#). Similarly, the [Digital Good](#) project addressed ethical and societal challenges of

data-intensive research, examined research collaborations between technology firms and public institutions and assessed researchers' use of [medical research tools developed by large technology companies](#).

- The [DecoLawBiodiv](#) project examines challenges in biotechnological research related to historical inequalities in the collection and use of plant genetic resources, where existing benefit sharing mechanisms are challenged by the emergence of digital sequence information. Meanwhile, the [MARIPOLDATA](#) project explores the debate and legal uncertainty regarding access and ownership over marine genetic resources.
- Perspectives on organoid research: The [ASENT](#) project contributes to debates on human neural organoids by providing parameters to determine when [ethically relevant traits appear in human brain organoids](#). [ReConAg](#) addresses the issue of [consciousness of human brain organoids](#) and their associated [ethical implications](#).

Another challenge for policymakers is to address safety concerns related to possible unknown impacts of biotechnologies or the commercialisation of new biologic medicines and biotechnology-derived therapeutics. These also affect public trust in science and emerging therapies. At the heart of this issue lie questions about risk assessment and evidence standards, and how to translate these into robust regulatory frameworks and pharmacovigilance processes.

- Precautionary principles have often guided decision-making in contexts of scientific uncertainty, typically due to concerns about potential (unknown) harmful impacts from emerging technologies such as geoengineering, biotechnology or machine intelligence. Building on recent advances in decision theory, computational modelling and domain-specific risk assessment techniques, the [UnPrEDICT](#) project developed an alternative approach that incorporates ethical parameters and information hazards, informing a new theoretical and policy framework [for dual-use biotechnology and biosecurity risks](#). This framework has been widely cited in strategic reports from the [EU](#), [WHO](#), [UNEP](#) and the [US Congress](#).

More projects on risks, regulation, and trust in biotechnology

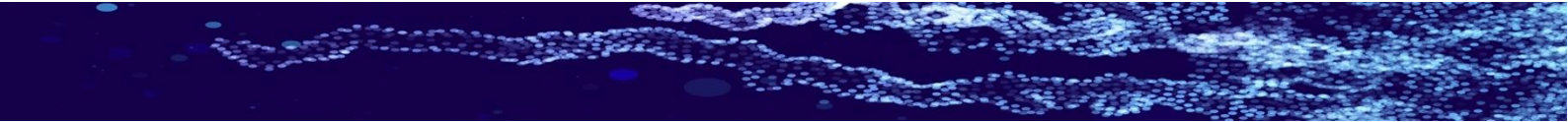
- The [BeyondThalidomide](#) project looks into how societies address risks in medical development and which actors drive change and progress. It offers a historical perspective on the ways in which patients have engaged with, influenced, and reshaped biomedical knowledge, medical practices, global markets and legal frameworks in reproductive health.
- [PhilPharm](#) developed a theoretical framework for novel drug evaluation in close [collaboration with regulatory authorities](#). The framework provides probabilistic measures of causal connections between pharmaceutical treatments and potential side effects.
- [DEBUNKER](#) project looked at misperceptions and fake news regarding immigration, vaccines, and climate change in Europe. The project results have informed the work of numerous national and international institutions, for instance the European Commission's [Joint Research Centre](#).

Finally, several ERC-funded research projects address how biotechnological advances that have life-altering potential can reshape societal values, norms and expectations, with the potential to inform policymaking.

- [Family Justice](#) is one of the projects that examine the impact of advances in human-reproductive technologies. The project studies the normative significance of procreation, biological parenthood and genetic ties, as well as the bioethical and societal implications of advancements in human reproductive technologies. Key topics analysed include [preimplantation genetic testing and selection](#), enhancement, [surrogacy and the right to genetic parenthood](#).
- Biotechnology research and innovation rely on techniques for freezing and storing cells, tissues and other biological materials, and subsequently thawing them at a later date without apparent loss of vitality. The [CRYOSOCIETIES](#) project explores the crucial role of cryopreservation and how it [impacts](#) our understanding of life and death, introducing the concept of ‘suspended life’, where biological substances are neither fully alive nor dead. By examining the social dimensions of collecting, storing and using human and non-human organic material through deep-freezing technologies, this project highlights ethical implications, including concerns about privacy, data protection, potential misuse and prospects of patenting and commercialisation. Additionally, it addresses the [cultural, social, and political dimensions](#) of cryopreservation practices, particularly in [assisted reproduction and social egg freezing](#).

More projects on biotechnology impacts on societal values

- The [BIOUNCERTAINTY](#) project explores the challenges of moral reasoning in the context of rapid scientific developments and moral uncertainty. It investigates how such uncertainties trigger emotional and cognitive responses that shape normative judgements and decisions and examines whether these influences affect bioethical reasoning and rules in genetic research, preventive medicine and reproductive choices.
- [IDEM](#) provides novel insights into how biological identity – what defines an individual organism – is continuously shaped through time and interactions with its biotic environment. The project introduces novel philosophical perspectives on biomedical sciences, challenging scientific and societal assumptions about biological individuality and the immune system.
- [The BoS](#) explores the role of values in cattle selection and reproduction related to health, environmental sustainability, or biodiversity, as well as the methods and techniques through which these values transform animal bodies, highlighting the divide between human and non-human genomics in terms of institutional and ethical constraints.



Conclusion

This report maps the breadth of ERC-funded frontier research in biotechnology, spanning fundamental biological mechanisms, synthetic biology and enabling platform technologies, as well as research with applications ranging from gene and RNA therapies to biomanufacturing, agriculture, food production and environmental monitoring. Across these areas, ERC-funded research generates new knowledge, methods and technologies that expand the scientific and technological foundations on which future advances in biotechnology can be built.

Beyond these scientific contributions, the analysis shows that ERC grantees are actively taking steps to translate their research towards innovation, including through patents, spin-off companies and follow-on funding. Their responses to the survey, carried out for the purpose of this report, provide further insights into the factors that enable this transition, as well as the barriers that can hinder the journey from scientific discovery to wider application.

Looking towards 2030, ERC grantees identify a diverse set of emerging technologies – from AI-driven biology and RNA therapeutics to engineered living materials – with the potential to reshape biotechnology, increasingly through the convergence of different scientific disciplines and technological approaches.

Taken together, the findings highlight the importance of frontier research as a foundation for Europe's scientific leadership, innovation capacity and long-term competitiveness in biotechnology. They also illustrate the value of sustaining the full pathway from fundamental discovery to technological development and innovation.

In a field evolving as rapidly as biotechnology, the curiosity-driven research of today provides the knowledge, capabilities and breakthroughs from which tomorrow's transformative technologies can emerge.

Methodology

- The portfolio analysed in this report consists of 2 416 ERC projects funded in ERC calls from 2014 to 2023.
- A first set of projects was identified through the in-house classification of projects of the ERC, [Mapping Frontier Research](#) (MFR), and using the panel descriptors and keywords proposed by researchers to describe their proposed research. The search was expanded by extracting additional projects from the European Commission's internal database, using a keyword search for biotechnology-related terms in project proposals.
- All projects were reviewed manually and linked to their **biotechnology application areas** according to the [OECD biotechnology statistical definition](#) and, as described in Section 2.3, based on the information available in the project abstracts and keywords. A single project may relate to multiple application areas.
- The analysis of the **scientific publications** resulting from this portfolio of projects was conducted through [SciVal](#), which provides analytics to help evaluate research performance and understand broader research impact. It was based on a dataset that includes both publications reported by researchers and those identified through [OpenAIRE](#). The dataset includes 28 438 project-related publications up to February 2026. 3 946 publications cited in patents and 1 257 publications cited in policy documents were identified in SciVal. Data extracted from SciVal is as of April 2026. The analysis focused on the publications impact in terms of citations, in scientific publications, patents, and policy documents (see Section 2.4. and 4.1).
- To provide a more detailed view of the sectors and subsectors addressed by ERC projects, including the technologies they address, projects were classified using a deep-tech taxonomy developed by the **European Innovation Council** (EIC). This taxonomy is a technology-oriented classification system that includes 11 primary categories, 64 secondary categories and 161 tertiary categories, all corresponding to underlying technologies, applications and sectors, and has been used to report on the impact of EIC with coverage at technology readiness levels (TRLs) from 1 to 9. Every project was classified using a European Commission large language model (LLM) tool, which was validated through LLM prompts and manual spot checks.
- A **survey** was sent to all ERC grantees leading projects selected for this analysis and yielded a response rate of 19.6% (1 979 researchers were contacted using [EUSurvey](#); 388 responses were received). The survey questions covered: (1) key results and outputs of ERC-funded projects; (2) pathways towards commercialisation and exploitation, as well as challenges and enabling factors (where applicable); and (3) perspectives on emerging technologies and future developments in biotechnology. The results are reported in Chapters 3 and 4.
- The descriptions of projects and their results are based on self-reported data from principal investigators in their reports submitted to the ERCEA and on summaries available in public sources such as the [CORDIS](#) database, project websites, scientific publications and news articles.
- Information provided about patents and companies resulting from ERC projects is provided, when available, in grantees' reports, survey results and online pages but may not be exhaustive.
- A complementary list of 45 projects from the SH domain was identified. These projects study a wide range of topics related to biotechnology (and more broadly life sciences, health, medical and pharmaceutical research) and their potential impact on society in terms of innovation and markets; risks and public trust; ethical issues; and cultural impacts. These projects are not included in the statistics presented in Chapter 2 but are described in Chapter 12.

Survey questionnaire

The ERC Feedback to Policy Biotechnology survey was sent to ERC grantees leading projects in the biotechnology portfolio in May 2026, using [EUSurvey](#).

Your ERC-funded research and outputs

What is your latest ERC grant? Please indicate your project number and acronym.

Please briefly describe the main achievement of your ERC-funded research related to biotechnology.

Which types of output have resulted from your ERC project so far?

- Advancement of knowledge as the main output.
- New or improved experimental or analytical methods.
- Technological innovations: e.g. platforms, tools or enabling technologies. (Please specify technological innovations: technology, potential users, whether the technology used or exploited etc.)
- Contributions to clinical, industrial, agricultural practice. (Please specify)
- Contributions to policy guidelines or policy recommendations. (Please specify)
- Other. (Please specify)

Do you plan to have your research innovation/results exploited or commercialised in the coming five years? (e.g. via technology transfer, patenting, creating a spinoff company, input to guidelines or policy) If you have done so already, please answer 'Yes'.

- Yes, I have plans to exploit an ERC-funded result or innovation or have started to do so.
- No

Challenges and opportunities from frontier research to innovation

(only if 'Yes' to previous question)

What outcomes have your ERC project(s) achieved?

- Novel data, method, process that was picked up by other researchers. (Please specify)
- Proof of concept or demonstrators. (Please specify)
- Patents or other IP protection. (Please indicate for which technology/innovation the patent is filed. Has the patent been exploited and if so, how?)
- Spin-off or start-up company. (Please provide some information on the company (name, website, your role in the company))
- Other. (Please specify)

Which factors have been most important in enabling your frontier research to progress towards innovation? (Maximum 3 selections)

- Unique result or novelty.
- Flexibility of ERC funding and project design.
- Complementary funding (EU including ERC and European Innovation Council grants, national, regional or private funding). (If you received complementary funding from the EU (ERC Proof of Concept grant, EIC Transition or Accelerator grant, others such as Horizon Europe collaborative grant), Please specify)
- Interdisciplinary collaboration or strategic partnership (industrial, clinical or other stakeholders). (Please specify)
- Institutional support structures (TTOs, incubators, legal/IP training or support) (Please specify)
- Access to investors' networks.
- Enabling regulatory or policy environment.
- Other (e.g. market demand, customer engagement, award, mentoring, etc.) (Please specify)

Which challenges have you encountered when moving from frontier research towards innovation? (Maximum 3 selections)

- Scientific, technological challenges or unclear market demand.
- Lack of follow-up funding.
- Difficulty identifying and managing intellectual assets.
- Regulatory or legal complexity.
- 'Cultural' barriers between academia and industry.
- Access to pilot, scale-up or manufacturing facilities.
- Skills gaps (IP, business, regulatory, manufacturing, etc.).
- Time horizons of research incompatible with innovation cycles.
- Ethical or societal concerns.
- Other. (Please specify any other challenges)
- None so far.

European biotechnology at the horizon of 2030

Looking ahead to 2030, which emerging technologies do you believe are most likely to significantly transform biotechnology and its applications?

The technologies listed below were extracted from recent reports such as, for example, the OECD's [Synthetic biology in focus: Policy issues and opportunities in engineering life](#), the European Commission's [Weak signals in Science and Technologies](#) and [Healing the Future — Horizon scanning for emerging technologies and breakthrough innovations in the field of cell and gene therapies](#). Please add any missing promising technology under 'Other'.

(five-point scale: Highly unlikely, Unlikely, Likely, Very likely, Too uncertain to assess)

Genetic and molecular engineering

- Omics technologies, including fragmentomics, spatial omics
- Metagenome-assembled genome
- CRISPR-Cas12, CRISPR-Cas13
- Engineered viral and non-viral vectors (including Sleeping beauty transposon system)
- Life Science data mining by artificial intelligence

Cellular and tissue engineering

- Pluripotent stem cells
- Mitochondrial transplantation
- Xenotransplantation
- Conversion of tumour cells
- Tissue engineering (including 3D bioprinting and printed scaffolds)

Synthetic and living biological systems

- Engineered living material, synthetic cells
- Living computer platforms

Immuno- and targeted biological therapies

- CAR-based therapies (CAR-T, CAR-macrophage, CAR NK)
- Proteolysis-targeting chimeras (PROTACs)
- Immunotherapy cold tumour
- mRNA vaccines
- Exosomes and extra cellular vehicles (EVs)

Microbiome and environmental biotechnology

- Microbiome and postbiotic therapies
- eDNA metabarcoding
- Bioremediation and biocontainment
- Microplastic biodegradation

Sustainable and efficient agriculture

- Non-model organisms
- Genotype-independent plant transformation
- Biofertilisers, biopesticides, bioherbicides
- New crop breeding technologies
- Engineered, resistant and resilient crops

Industrial and sustainable biotechnology

- Precision fermentation
- Enzymes, biocatalysis development
- Cultivated meat and scaffold for cultivated meat
- Biofoundries

Other: please add any other promising emerging technologies that could benefit the biotechnology sector.

Looking ahead to 2030, which of the following drivers and enablers are most likely to strengthen biotechnology in Europe?

(five-point scale: Highly unlikely, Unlikely, Likely, Very likely, Too uncertain to assess)

- Breakthroughs in quantum computing will support complex biological modelling.
- Advances in synthetic biology will lead to applications across health, industry and environmental domains.
- AI-driven methods will reduce the time from discovery to proof-of-concept and support precision medicine and agriculture.
- Access and integrations of large biological datasets will become a competitive advantage for research.
- Access to pilot and scale-up infrastructure will speed up the translation of research into market-ready solutions.
- A coordinated, coherent regulatory framework across EU Member State could accelerate innovation deployment.
- Stronger regional and cross-border collaboration on innovation could support Europe' competitiveness.
- Fast access to investments in biotechnology innovation and ventures would strengthen the biotechnology sector across EU Member States.
- Increased mobility between academic, industrial and clinical environments can accelerate knowledge circulation and innovation.
- Public engagement and trust-building could shape the uptake of emerging biotechnologies.

Other: please add any other enabler or driver.

Could you recommend any policy initiative - existing or missing - the EU could prioritise to boost the European biotechnology sector by 2030? (e.g. the EU Biotechnology Act, EU Life Sciences strategy, the EU Bioeconomy Strategy)

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- Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing [a framework of measures for strengthening Union's biotechnology and biomanufacturing sectors particularly in the area of health](#) and amending Regulations (EC) No 178/2002, (EC) No 1394/2007, (EU) No 536/2014, (EU) 2019/6, (EU) 2024/795 and (EU) 2024/1938 (European Biotech Act), COM(2025) 1022 final (2025).
- European Commission Communication, [Choose Europe for life sciences — A strategy to position the EU as the world's most attractive place for life sciences by 2030](#), COM(2025) 525 final (2025).
- European Commission Communication, [A Strategic Framework for a Competitive and Sustainable EU Bioeconomy](#), COM(2025) 960 final (2025).
- European Commission Communication, [Boosting Biotechnology and Biomanufacturing in the EU](#), COM(2024) 137 final (2024).
- Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on [plants obtained by certain new genomic techniques and their food and feed](#), and amending Regulation (EU) 2017/625, COM(2023) 411 final (2023).

The ERC has published feedback to policy reports derived from thematic portfolio analyses outlining how ERC-funded projects contribute to major EU policy priorities. Some of these address key sectors described in the present report as well:

- European Commission: European Research Council Executive Agency, [Advanced materials: ERC frontier research for a competitive, sustainable Europe](#), Publications Office of the European Union, Luxembourg (2026).
- European Commission: European Research Council Executive Agency, [Mapping ERC Frontier Research – ERC proof of concept grants: Exploring the innovation potential of ERC-funded research](#), Publications Office of the European Union, Luxembourg (2025).
- European Commission: European Research Council Executive Agency, [Mapping ERC Frontier Research – CRISPR/CAS technology: a revolution in gene editing](#), Publications Office of the European Union, Luxembourg (2024).
- [CORDIS results pack on biotechnology research and innovation](#), Publications Office of the European Union, 2026

In addition, the ERC, EIC and the JRC have published studies on innovation and emerging technologies:

- European Research Council, [Use of patents: empirical evidence from a survey of grantees of the European Research Council \(ERC\)](#) (2024).
- European Research Council, [Assessing the Influence of ERC-funded Research on Patented Inventions](#) (2022).
- European Innovation Council, [Scaling Deep Tech in Europe — EIC Impact Report 2025](#), Publications Office of the European Union, Luxembourg (2025).
- European Innovation Council, [Created and Scaled in Europe — EIC Impact Report 2026](#), Publications Office of the European Union, Luxembourg (2026).
- European Innovation Council, [EIC Tech Report 2024](#), Publications Office of the European Union, Luxembourg (2024).
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