catalysts

MDPI

Conference Report

The 11th International Congress on Biocatalysis (biocat2024), Hamburg, Germany, 25–29 August 2024

Victoria Bueschler [1,2,†], Paul Bubenheim [1,2,†], Barbara Klippel [2,3,†], Ana Malvis Romero [1,2,†], Daniel Ohde [1,2,†], Anna-Lena Heins [2,3], Johannes Gescher [2,4], Franziska Rohweder [1,2,†] and Andreas Liese [1,2,*,†]

[1] Institute of Technical Biocatalysis, Hamburg University of Technology (TUHH), 21073 Hamburg, Germany
[2] United Nations University Hub on Engineering to Face Climate Change at the Hamburg University of Technology, United Nations University Institute for Water, Environment and Health (UNU-INWEH), 21073 Hamburg, Germany
[3] Institute of Bioprocess and Biosystems Engineering, Hamburg University of Technology (TUHH), 21073 Hamburg, Germany
[4] Institute of Technical Microbiology, Hamburg University of Technology (TUHH), 21073 Hamburg, Germany
* Correspondence: liese@tuhh.de; Tel.: +49-(0)40-42878-3018; Fax: +49-(0)40-42731-4512
† 8th International Congress on Biocatalysis (biocat2024)—Member of the local organizing committee.

Abstract: The "11th International Congress on Biocatalysis (biocat2024)" was part of a biennial series that unites the fields of biology and chemistry, attracting researchers from the life sciences, engineering, and computer science. This international forum provides an opportunity for scientists worldwide to connect, seek collaboration for future projects, and gain insights into contemporary topics and innovative techniques. Biocat covers a range of compelling subjects and recent advancements in biocatalysis, including enzyme discovery, evolution, and applications. This congress focused on six key topics: AI and computational methods, structure–function analysis and enzyme engineering, enzymatic and whole-cell biotransformations, reaction cascades (electro-, chemo-, and photoenzymatic synergies), bioprocess engineering and the design of smart reactors, and facing climate change through sustainability and a circular bioeconomy. In 2024, we welcomed 344 expert delegates alongside 21 internal attendees, including 154 women and 1 non-binary participant, bringing the total number of participants to an impressive 365. Established researchers and emerging scientists from academia and industry delivered a total of 119 presentations, comprising 59 standard lectures, 60 lightning talks, and 195 posters. Six industry exhibitors showcased their latest products and services, providing an excellent opportunity to strengthen the connection between science and industry. Furthermore, the biocat award, recognized as one of the most prestigious honors in biotechnology, was presented for the eleventh time in the categories of "Science in Academia", "Lifetime Achievement," and "Industry".

Keywords: bioprocesses; biotransformation; circular economy; computational methods; enzyme engineering; enzymes; reaction cascades; smart reactors; structure–function analysis; sustainability

Academic Editor: Evangelos Topakas

Received: 14 May 2025
Revised: 5 June 2025
Accepted: 7 June 2025
Published: 10 June 2025

Citation: Bueschler, V.; Bubenheim, P.; Klippel, B.; Malvis Romero, A.; Ohde, D.; Heins, A.-L.; Gescher, J.; Rohweder, F.; Liese, A. The 11th International Congress on Biocatalysis (biocat2024), Hamburg, Germany, 25–29 August 2024. *Catalysts* **2025**, *15*, 574. https://doi.org/10.3390/catal15060574

1. Introduction

The 11th International Biocatalysis Congress (biocat2024) took place from 25 August to 29 August 2024 at the Technical University of Hamburg (TUHH) (https://biocat-congress.de, accessed on 6 June 2025). The event was organized by the Institute of Technical Biocatalysis, the Institute of Bioprocess and Biosystem Engineering, and the Institute of Technical Microbiology, in collaboration with Conventus GmbH and with financial support from the German Research Foundation (DFG) and the Office of Naval Research (ONR). The biocat

congress is part of a biennial congress series established in 2002. It provides an overview of the latest advances in biocatalysis and biotransformations by integrating the know-how of experts and early-career researchers from academia and industry. This was the eleventh time that TUHH hosted this prestigious congress.

With its motto "Engineering for climate change", TUHH is sending a clear signal: the urgent challenges of climate change require innovative and interdisciplinary solutions. Biocatalysis is the central area of research in the knowledge-based bioeconomy and one of the most vital technologies for actively combating climate change. As a recognized United Nations University (UNU) Hub, TUHH's biocat congress made decisive contributions to achieving the sustainable development goals (UN SDGs), particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production). By discussing and initializing interdisciplinary collaboration between academia and industry, the congress facilitated innovations in biocatalysis, a key technology for sustainable chemical production and a circular bioeconomy. The event highlighted advancements in enzyme engineering, AI-driven bioprocess optimization, and sustainable biotransformations, all of which contribute to reducing reliance on fossil resources and enhancing green manufacturing. Furthermore, SDG 13 (Climate Action) was addressed through research on enzyme-based CO_2 capture, bio-based feedstocks, and enzymatic plastic recycling, promoting climate-friendly industrial processes. The congress also emphasized diversity and inclusion in science, indirectly supporting SDG 5 (Gender Equality) by encouraging female participation in STEM fields (science, technology, engineering, and mathematics). Through these efforts, biocat2024 played a pivotal role in driving sustainable industrial innovation while fostering a global network for future breakthroughs. At this international event, scientists and industry experts from over 40 nations met to discuss new findings in biocatalysis—a technology that contributes significantly to building a sustainable future and sustainable industrial production of everyday products.

A total of 365 individuals attended biocat2024, including 42% female and 0.3% non-binary participants (Figure 1). These numbers reflect the commitment to promoting diversity and inclusion within the scientific community. In addition, 40% of the participants were from industry, demonstrating the high relevance of this congress to state-of-the-art research and process development in biocatalysis. Biocat2024 welcomed participants from over 40 countries, including Australia, Brazil, Chile, China, Denmark, Finland, France, Germany, Great Britain, India, Ireland, Italy, Japan, the Republic of Korea, Cuba, Mexico, Norway, Austria, Poland, Romania, Saudi Arabia, Singapore, Spain, Sweden, Switzerland, South Africa, Turkey, the Czech Republic, Hungary, and the USA. This international participation demonstrates the global interest in biocatalysis and fosters the exchange of ideas and best practices. Six exhibitors showcased their latest products and services in the field of biocatalysis. The exhibition area provided an excellent opportunity to strengthen the connection between science and industry.

Biocat2024 featured an extensive and diverse program covering current topics in biocatalysis and related research fields. The congress contributions by oral and poster presentations and invited speakers were divided into six central topics that illuminated both innovative approaches and fundamental research:

- Topic 1: AI and computational methods;
- Topic 2: Structure–function analysis and enzyme engineering;
- Topic 3: Enzymatic and whole-cell biotransformations;
- Topic 4: Reaction cascades: Electro-, chemo-, and photoenzymatic synergies;
- Topic 5: Bioprocess engineering and the design of smart reactors;
- Topic 6: Facing climate change: Sustainability and a circular bioeconomy.

Overall, the diversity of the topics and the high quality of the presented work facilitated stimulating discussions and valuable insights. The combination of lectures, lightning talks, and poster sessions encouraged the exchange of ideas and best practices among the participants, making biocat2024 a significant event in the field of biocatalysis.

Figure 1. Impressions from the biocat2024 congress: a group picture of the participants.

2. Highlights of the Congress

As is traditional for the biocat series, the congress began on Sunday with an opening ceremony accompanied by music. Andreas Liese, congress chair and head of the Institute of Technical Biocatalysis at TUHH, welcomed the participants from all over the world. The phenomenal youth choir Gospel Train (https://www.gospeltrain.hamburg, accessed on 14 May 2025), which originated at the partner high school right next to TUHH, infected the participants with their famed feel-good energy and high spirits. This set the mood for the exciting talks given by invited speakers Carlos Martínez, Roland Wohlgemuth, and Seven Hansen. Carlos Martínez from Pfizer Pharmaceuticals, Waterfors, US, gave the participants a great insight into how biocatalysis enables sustainable active pharmaceutical ingredient (API) process applications. This was followed by an exceptional lecture from Roland Wohlgemuth from Lodz University of Technology, Poland. He illustrated how biocatalytic systems are the key enabling tool in sustainable chemistry and biomanufacturing metabolites and metabolite-like compounds. He stressed the necessity for rapid prototyping and bottleneck identification to be at the frontier of biomanufacturing low-molecular-weight components from bio-based resources. The opening ceremony was closed by an inspiring lecture from Sven Hansen from Evonik, Halle (Westfalen), Germany. He showed the process of developing a completely new approach to small-scale shaken bioreactors that closely mimic the characteristics of a large-scale bioprocess. This interdisciplinary approach featuring hydrodynamic models can overcome relevant problems like the oxygen supply when scaling down industrial bioprocesses. The evening continued with a buffet-style dinner, allowing for enriching discussions about the opening lectures, reconnecting with colleagues, and making new connections on a sunny summer afternoon.

Each congress day began with a plenary session featuring invited speakers, each an expert in one of the topics. They led the way into the following sessions dedicated to contributions on the same topic. The congress program included one poster session each day, starting with a lightning talk session that gave the audience a great overview of the research presented on that day. The exhibiting companies also presented their research and informed the participants about their products during short hands-on sessions after lunch. There are very few parallel sessions at the biocat congresses, so each participant

can listen to all the high-level contributions they are interested in. The following chapters briefly summarize the highlights presented for each congress topic.

2.1. Topic 1: AI and Computational Methods

This topic focused on applying artificial intelligence and computational techniques to optimize biocatalytic processes. Presentations and posters showcased new algorithms and modeling approaches that allow for the prediction of enzyme activities and the identification of targeted mutations for enzyme optimization. This emerging field was recently brought from the scientific community to the center of the public eye by awarding the Nobel Prize in Chemistry to David Baker, Demis Hassabis, and John Jumper. With invited speakers showing progress from in silico screening during protein design to biocatalytic process development, biocat2024 had 13 contributions on this topic. Martin Schürmann from the company InnoSyn, in the Netherlands, expertly provided the participants insight into developing and implementing AI tools for accelerated in silico screening and biocatalytic process development. Birte Höcker, head of the protein design lab and a professor at the University of Bayreuth, Germany, gave a detailed glimpse into advances in protein design using computational methods and the potential they hold for the field of biocatalysis. Sílvia Osuna, a research professor at the University of Gerona, Spain, followed up on this during her lecture. She showed her achievements in enabling fast yet accurate computational enzyme design using molecular dynamics and enhanced sampling techniques and incorporating AlphaFold2 predictions. They are leading experts in the field to address the challenge of predicting distal active sites to improve functionality.

2.2. Topic 2: Structure–Function Analysis and Enzyme Engineering

This area examined the connection between enzymes' molecular structures and functions. The participants discussed innovative methods in enzyme engineering aimed at improving the catalytic properties of enzymes, including targeted mutagenesis and high-throughput screening techniques. A staggering 83 contributions to this topic showed the high relevance of advances in this field. Stephan Lutz (Codexis, Redwood City, CA, USA) presented impressive advancements in siRNA manufacturing using the company's proprietary enzyme-catalyzed oligonucleotide (ECO) Synthesis™ platform. This approach offers high catalytic efficiency, even at elevated substrate concentrations, and demonstrates enhanced performance with challenging sequences and modifications near ligation junctions. Miguel Alcalde from the Institute of Catalysis, Madrid, Spain, gave a fascinating talk about recent advances in engineering fungal peroxygenases for specific and more efficient oxyfunctionalization reactions. He also discussed the prospects in this fast-moving field of research. Although their limited availability and development have hindered their incorporation in the industry, the conjunction of directed evolution and computational design allows unspecific peroxygenases (UPOs) to be used in practical applications. Their importance and potential were also reflected by the many poster contributions on different UPOs presented at biocat2024. Industrial insight on the implementation of the CodeEvolver technology from Codexis (Redwood City, US) for designer enzymes for the synthesis of complex pharmaceutical molecules was provided by Frederic Stanger of the company Novartis Pharma, Basel, Switzerland. He emphasized that a culture change in favor of early implementation of biocatalysis, facilitated by enzyme engineering, is the key factor on the road to sustainable catalysis in the pharmaceutical industry. Christian Gruber of Innophore, Graz, Austria, presented the fruitful cooperation of several pharmaceutical companies and academia to tackle asymmetric reductive amination to yield chiral amines, a crucial class of compounds in the pharmaceutical industry. Their cooperation enabled fast and in-depth identification and characterization of novel highly selective NADH-dependent imine

reductases (IREDs), ultimately leading to a comprehensive understanding of the IRED enzyme family. Another highly relevant enzyme class for the pharmaceutical industry is the family of amide bond synthetases (ABSs), which couple an amine and a carboxylic acid, on which Gideon Grogan from the University of York, UK, presented an encompassing study. Presenting an approach mixing organic synthesis, molecular biology, structural biology, and enzyme engineering, he showed that he could broaden the substrate spectrum and improve the selectivity of chiral amides.

2.3. Topic 3: Enzymatic and Whole-Cell Biotransformations

This topic highlighted advances in applying enzymes and whole cells to conduct complex biotransformation reactions. The presented work ranged from developing new biocatalytic pathways to practical applications in the pharmaceutical and chemical industries. Given the broad spectrum of this topic, a great variety of research was presented in the 90 contributions. A view on this topic from an industrial perspective was presented by Laura Grabowski from the company BASF, Ludwigshafen am Rhein, Germany, in her lecture "Biocatalysis @ scale". She demonstrated how, especially in white biotech, multistep chemoenzymatic routs lead to highly enantioselective production of fine chemicals but require combinatory process development and initial cost estimations in the early project phases. Joyce Breger presented an interesting interdisciplinary approach to enzymatic cascade reactions from the US Naval Research Laboratory in Washington, DC, US. Co-immobilization of enzymes by metal-affinity coordination is possible using semiconductor quantum dot nanoparticles, which form highly active nanoparticle–enzyme clusters. She demonstrated that the proximity and optimized ratio of consecutive enzymes in a seven-enzyme cascade yielded an immense productivity increase in comparison to free enzymes in solution. Advancements in the engineering of aliphatic halogenases were presented by Rebecca Buller-Blomberg, a professor of biocatalysis at Zurich University of Applied Sciences, Switzerland. The enzyme family of Fe(II)/α-ketoglutarate dioxygenases can halogenate or hydroxylate inactive C-H bonds, an essential catalytic step in the route to biologically active molecules. She provided insight into the machine learning-assisted direct evolution approach. This led to the identification of enzyme variants showing high stereo- and regiocontrol and extension of the substrate spectrum to typical late-stage functionalization molecules of pharmaceutical and agrochemical interest like non-natural amino acids, terpenes, and bulky macrolides. Christoph Winkler from the University of Graz, Austria, reported on engineering the fatty acid photodecarboxylase from *Chlorella variabilis* to catalyze C-C bond formations utilizing a range of structurally distinct substrate probes.

2.4. Topic 4: Reaction Cascades: Electro-, Chemo-, and Photoenzymatic Synergies

The exploration of reaction cascades, where various enzymatic and nonenzymatic steps are combined, was another focal point of the biocat2024 congress. Presentations highlighted synergies between electro-, chemo-, and photoenzymatic processes, opening new perspectives for sustainable production of chemicals and energy. Invited speaker Melanie Hall from the University of Graz, Austria, presented advances in identifying and engineering enzymes able to catalyze typical reactions in organic synthesis, like the asymmetric hybrid-free isomerization of non-activated C=C bonds by flavin-dependent old yellow enzymes and the production of nitro compounds by a lyase. This underlines the potential and contribution of enzymes in the sustainable performance of non-natural reactions. Shelley Minteer from the University of Utah, Salt Lake City, US, gave a broad overview of recent advances in bioelectrocatalysis, focusing on the electrosynthesis of commodity and fine chemicals. Especially for the electrocatalytic reduction of nitrogen to ammonia, direct or mediated enzymatic catalysis by nitrogenases can overcome the

challenges of the electrochemical process. She highlighted how developing novel electrode materials is a key factor in the breakthrough of bioelectrosynthesis in industry.

2.5. Topic 5: Bioprocess Engineering and Design of Smart Reactors

This topic addressed innovative approaches to optimizing bioprocesses, including the design of smart reactors. Presentations discussed automating and monitoring biotechnological processes to increase efficiency and sustainability. Most biocatalytic processes operate within a narrowly defined operating window, as John Woodley from the Technical University of Denmark, Kongens Lyngby, Denmark, pointed out in his lecture. Smart bioreactors yield detailed information about the characteristics of processes, and consecutive modeling of said processes is essential for subsequent optimization. He presented advances in the development and application of scaled-down reactors for studying biocatalytic reactions under industrial conditions, allowing for faster and cheaper optimization of production processes.

2.6. Topic 6: Facing Climate Change: Sustainability and Circular Bioeconomy

This critical area discussed the role of biocatalysis in addressing climate change and the shift from fossil fuels to biomass feedstocks. Discussions focused on sustainable production methods and concepts of a circular bioeconomy aimed at utilizing resources more efficiently and minimizing waste. Alessandro Pellis from the University of Genoa, Genova, Italy, highlighted several key platform molecules in his lecture: levoglucosenone synthesized from waste cellulose; itaconic acid produced via fermentation of lignocellulosic feedstock; and glycerol obtained from biodiesel production. He showed a broad range of potential applications, ranging from solvents and specialty drugs to polymers and additives, motivating the participants to engage in this field of research. Invited speaker Yong Hwan Kim from the Ulsan National Institute of Science and Technology, Republic of Korea, focused on a different area where enzymes contribute to sustainability: decarbonizing the steel industry, one of the primary contributors to greenhouse gas emissions. He presented a pilot-scale reactor featuring immobilized enzymes binding CO from steel mill off-gas into formate via hydration under mild conditions, eliminating the necessity for conventional CO combustion, which leads to high CO_2 emissions. Another highly relevant area under this topic is the contributions of enzymatic catalysis to plastic recycling, more precisely polyethylenterephthalate (PET), as presented by Alain Marty from Carbios, Toulouse, France. He discussed the ongoing process of establishing the first industrial-scale enzymatic PET recycling process, an extraordinary achievement since PETases have been optimized to allow complete recycling of PET to its monomers. All 22 contributions under this topic and many others presented under the different topics of biocat2024 expressed and underlined the stunning potential of biocatalysis to face the challenges of climate change and develop a sustainable future for the producing industry.

During the congress dinner, held on a river cruise ship on the Elbe River, outstanding individuals were given the prestigious biocat awards in the categories "Academic Research", "Industrial Research", and "Lifetime Achievement" to acknowledge their accomplishments in the field of biocatalysis (Figure 2a).

The awards given out at this year's 11th International Congress on Biocatalysis were as follows:

- Prof. Dr. Rebecca Buller-Blomberg (Zurich University of Applied Sciences, Zurich, Switzerland) for Academic Research;
- Prof. Dr. Carlos Martínez (Pfizer Pharmaceuticals, NYC, USA) for Industrial Research;
- Prof. Dr. Roland Wohlgemuth (Lodz University of Technology, Lodz, Poland) for Lifetime Achievement.

(**a**) (**b**)

Figure 2. The awards of Biocat2024. (**a**) The award ceremony during the congress dinner. From left to right: congress chair Andreas Liese; co-chair Anna-Lena Heins; Carlos Martínez, awardee for "Industrial Research"; Roland Wohlgemuth, awardee for "Lifetime Achievement"; Rebecca Buller-Blomberg, awardee for "Academic Research"; honorary chair Garabed Antranikian; and co-chair Johannes Gescher. (**b**) The awardees of the oral presentation and poster awards of biocat2024, presented by Selin Kara (left), chair of the poster award committee of biocat2024. The awardees were (in alphabetical order) David Harding-Larsen, Linda Anna Michelle Kulka, Lars Longwitz, Josemarco Mendoza-Avila, Rahel Mühlhofer, Lara Scharbert, Sonja Vaupel, Astrid Winterhalter, Sasipa Wongwattanarat, and Jasmin Zuson.

Rebecca Buller-Blomberg received the biocat award for "Academic Research" for her pioneering contributions to enzyme engineering, particularly in developing highly selective ene-reductases that enable enantioselective synthesis of pharmaceuticals and fine chemicals, significantly improving process efficiency and sustainability.

The biocat award in the category "Industrial Research" was awarded to Carlos Martínez for his successful industrial implementation of enzymatic routes, which replaced hazardous chemical processes in API production, leading to more cost-effective and environmentally friendly pharmaceutical manufacturing.

The prestigious biocat award for "Lifetime Achievement" went to Roland Wohlgemuth in recognition of his decades-long commitment to advancing biocatalysis and enzyme technology. Throughout his career, he has been instrumental in shaping the field through his research, mentorship, and contributions linking industrial and academic research in the field of biotechnology.

3. Conclusions

At biocat2024, the participants experienced groundbreaking research and innovative discussions and established new cooperations that contribute to the scientific discussion and exchange in the field of biocatalysis. The high number of participants and the variety of the presented works reflected the growing interest and advancements in this dynamic research area. The organizers thank all participants, exhibitors, and supporters who contributed to this successful event. Together, we are addressing sustainable development goals for which the Hamburg University of Technology, the host of biocat2024, stands as a United Nations University Hub. We look forward to the next biocat congress and the continuation of this significant scientific tradition. We are looking forward to welcoming you to biocat2026, which will take place in Hamburg August 23–27 in 2026.

Author Contributions: All authors were members of the local organizing committee and directly participated in organizing the congress. A.L. is the congress chair of the biocat congress series, with A.-L.H. and J.G. as co-chairs. V.B. drafted the manuscript with the help of A.L., P.B., B.K., A.M.R., D.O., and F.R. All authors have read and agreed to the published version of the manuscript.

Funding: The 11th International Congress on Biocatalysis (biocat2024) received funding from the German Research Foundation (Deutsche Forschungsgesellschaft (DFG), grant number: 545134274) and the Office of Naval Research (ONR, grant number N62909-24-1-2092). The ONR provided travel grants for 10 PhD students and 5 postdoctoral researchers, facilitating international participation at biocat2024.

Data Availability Statement: Data sharing is not applicable.

Acknowledgments: All members of the Institutes of Technical Biocatalysis, Technical Microbiology, and Bioprocess and Biosystems Engineering and the members of the scientific advisory board are thanked for their valuable contributions.

Conflicts of Interest: We declare potential conflicts of interest because the authors were organizers and participants of the congress "biocat2024".