2023

Projects at the Department of Biological and Chemical Engineering

MSc and BSc in Biotechnology and Chemical Engineering

AARHUS UNIVERSITET

Preface:
This booklet contains information and guidance about project work including bachelor project, master thesis and R&D-projects. In addition, this booklet contains a brief introduction to the different research groups at Biological and Chemical Engineering (BCE) together with pro- posed projects. Additional information about the research groups can be found here: https://eng.au.dk/en/

Bachelor projects, Master Thesis and R&D projects
The project is your independent research work to develop entirely new knowledge. All projects can be performed in a research group at the university, or they can be performed in a company supported by a university supervisor with scientific insights. If you wish to perform your project in a company, you must first make an agreement with a relevant university supervisor. Together with the supervisor you can identify relevant companies.

As inspiration for your projects, you can have a look in our booklet about projects at BCE or you can talk with the research groups at the biannual project days. When you find a relevant supervisor, just send the researcher an email or go visit them in their offices and laboratories to have an informal talk on ideas and expectations.

A project work can be completed in many ways; here is just one example of how this can be done in practice.

A purely experimental project in which the student, on the basis of a prior literature study, elucidates a problem with experimental work. "Experimental work" must be understood in a broad sense, i.e., both as wet-biological/chemical work (in the laboratory) and dry-work (experiments solved by the use of a computer, e.g., by simulation, modeling etc.).

Regarding the format and size of the report, you decide this together with your supervisor. The final report should be less than 40 pages.

Bachelor (BSc) projects at Biotechnology (Bioteknologi) and Chemical Engineering (Kemiteknologi) are 15 ECTS. The project has a scope equivalent to 450 working hours.

Research and Development Projects of 5, 10 or 15 ECTS only have a final report to deliver, while the 20 ECTS R&D both have a report and an oral exam. For 5 ECTS projects, evaluation is only passed/non-passed by your supervisor, while remaining types are graded on 7-scale by your supervisor and an internal censor. For further details, please look at the course catalogue. The project could (but is not required to) be closely related to your master project, however, it cannot overlap with it (including copied text; plagiarism regulations, etc.).

A **Master (MSc) thesis** at Biological and Chemical Engineering can be 30 or 45 ECTS. A 45 ECTS MSc thesis requires higher workload and, typically, a larger project report compared to a 30 ECTS MSc thesis. In total, Master thesis plus R&D project cannot exceed 60 ECTS in your MSc program.

Enrollment

You can register for BSc projects and R&D projects through Student-Self-Service (STADS) based on your approved projects contracts with the Head of Degree Pro- gram. Registration for the projects in the Spring semester is November 1-5, and registration for R&D projects in the Autumn semester is May 1-5.

However, you are automatically registered for your MSc thesis after approval of your MSc Contract (see below with link) on the contract generator. Once registered for your thesis, there is no option of withdrawal. Deadlines for submission of the MSc Thesis Contract, MSc thesis etc. appear on the study portal, which is regularly updated (see below with link).

BSc projects, R&D projects and MSc Thesis Contracts

Before starting a project, a contract is required, which is made by using the contract generator. For BSc and R&D projects, please use the project generator and for MSc Thesis the MSc Thesis generator. The contract generator contains instructions on how to fill in the contracts.

Deadlines for submission of the contracts appear on the study portal. After contract submission, your internal supervisor and your UA will receive your contract for approval; if it is rejected due to some details, you shall just change according to the comment made by one of us and re-submit it.

Contents of BSc projects, R&D projects and MSc Thesis Contracts must contain:

- Project title
- A project plan: A project plan of ¼ to ¾ page including background on the problem that must be solved, the potential solution, and details on how you will investigate the potential solution
- A supervision-meeting plan: 2-4 sentences on who, where, when and topics for supervisor meetings and feedback
- Deadlines: Date for start-up (= semester start) and report deadline (count 1,5 week per ECTS if at full-time, if followed by the MSc thesis in the same semester, you must submit project after 7-8 weeks, and you should not initiate the MSc work before the submission)
- Non-Disclosure agreement (NDA): If it is required by the company or as a part of a research project that you work under an NDA, see further here: https://studerende.au.dk/en/studies/subject-portals/bce/bachelors-project-masters-thesis-and-rd-projects/projects-at-bce. Remember to note the NDA in the contract, which will ensure the necessary confidentiality. Further, note that typically an NDA is not there to protect you, thus there is no reason for you to encourage it, but not discourage it either.

Useful websites:

- **Course registration** https://studerende.au.dk/en/studies/subject-portals/bce/teaching/course-registration
- **Study portal:** Information and guidance about your thesis writing process including deadlines for submission of MSc Thesis Contracts, beginning of the thesis, submission of the thesis, and last examination date https://studerende.au.dk/en/studies/subject-portals/bce/
- **Contract generator:** Study contracts, project contracts and master thesis contracts https://kontrakt.nattech.au.dk/login

Environmental Technology

The environmental technology research area deals with waste streams and pollution of air and water. It includes the study of physical, chemical, and biological processes for treating emissions and waste streams, and- in many cases- recovery of energy or plant nutrients.

Understanding sources of pollution, especially processes and rates, is also an important component. Applications include agriculture, industry and household/municipal emissions. Researchers employ concepts and methods from several disciplines (analytical and physical chemistry, microbiology, mathematical modeling, and mass transfer) to develop new knowledge, technology, and management tools that help reduce negative impacts of humans on the environment while optimizing productivity and efficiency.

Microbial Technologies for Clean Water

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At the group for **Microbial Technologies for Clean Water**, we are working on the transformation of wastewater treatment plants into resource recovery facilities. We exploit the variety of bio- chemical processes that are catalyzed by micro-organisms and investigate how microbes can be optimally managed in biotechnologies to pro- duce clean water and recover valuable products from wastewater. We work with innovative lab- scale bioreactors such as biofilm reactors for removal of micropollutants (pharmaceuticals, biocides, hormones), high-rate activated sludge for energy recovery and biofilm reactors for biological phosphorus recovery. We conduct also several projects that are in close collaboration with industrial partners such as Krüger, Danish Technological Institute and several wastewater treatment plants. Currently, we are involved in a unique project that will accomplish the first full- scale integration of hydrothermal liquefaction in wastewater treatment to produce biofuel from sewage sludge.

We use advanced equipment and methods such as liquid chromatography coupled to mass spectrometry for chemometric analysis of micropollutants in water and DNA sequencing
combined with bioinformatics to characterize the microbial communities in bioreactors.

List of BSc/MSc thesis project topics:

- The first full-scale integration of hydrothermal liquefaction in wastewater treatment to produce biofuel from sewage sludge
- High-rate activated sludge to recovery energy from wastewater
- Biofilm-based enhance phosphorus recovery from wastewater
- Biofilm reactors of removal of micropollutants from wastewater
- In vitro bioassays for measuring (eco)toxicity cause by micropollutants
- Hydrothermal liquefaction for the degradation of PFAS in sewage sludge

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The research at '**Air Quality Engineering**' within the area of **Chemical and Biological Air Cleaning** focuses on the development and characterization of advanced technologies for protection of environment and human health. The activities include development of new highly reactive chemical processes for air scrubbers, application of advanced oxidation processes and optimization of biological air filtration. Mass transfer is often a key parameter to be optimized. Our research group offers challenging and novel projects for students aiming for a career in **Environmental Engineering**, exploring the increasing demand for cost-effective technologies in many areas.

List of project topics:

- Kinetics of metal-ion-catalyzed degradation of volatile sulfur compounds (P. Kasper)
- Mass transfer optimization in air scrubbers for removal of poorly soluble contaminants (P. Kasper)
- Minimization of formation of adverse byproducts from photocatalytic air cleaning for indoor air quality (A. Feil- berg)
- Optimizing removal of volatile sulfur compounds in biological filters for mitigation of biogas emissions (M. Kofoed)

The research at '**Air Quality Engineering**' within the area of **Process Analytical Chemistry** focuses on the development and characterization of online technologies for monitoring chemical processes in real time. The methods include new applications of online mass spectrometry for measuring volatile organic com- pounds, cavity-ringdown spectroscopy for isotope ratio measurements and development of low-cost microscrubbers. The methods can be used for optimization of e.g., environmental technologies, emission processes and for indoor air quality research. Our research group offers challenging and novel projects for M.Sc. students aiming for a career in **Chemical and Environmental Engineering**, exploring the increasing demand for time-resolved data in many areas.

List of project topics:

- Optimization of a microscrubber-fluorescence method for measuring ammonia (J. Kamp)
- Application of PTR-TOF-MS for eddy-co- variance flux measurements (J. Kamp, A. Feilberg)
- Characterization of indoor air pollution and source contributions (K. Kristensen)
- Combining PTR-MS and cavity ring- down spectroscopy for characterizing methane formation and mitigation (A. Fuchs, F. Dalby)

Air Quality Engineering

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The research at 'Environmental Engineering' within the area of Low-Emission Livestock Facilities focuses on mechanical and chemical technologies that can prevent the emission of greenhouse gases, ammonia, hydrogen sulfide and volatile organic compounds from animal houses and storage facilities for manure. The activities include development of mechanical liquid manure systems with low- emission footprint and chemical additives for inhibition of emission driving microbial processes in liquid manure. Projects within this area are for students aiming for a career in Environmental Engineering, working with some of the most important environmental challenges in our society. List of project topics (MSc, BSc, R&D)

List of project topics:

- Development and design of mechanical liquid manure systems with small surface area and residence time for emission reduction
- Chemical additives for inhibition of methane producing bacteria in liquid manure
- Biogas methane potential of manure from different types of manure systems and manure treated with additives
- Feed enzyme for reduction of methane emission from manure systems
- Modelling of greenhouse gas emissions from production systems based on chemical and biological parameters

Air Quality Engineering

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The research at 'Air Quality Engineering' within the area of Indoor Air Quality focuses on development and implementation of technologies for monitoring and improving air quality. The activities include fundamental research on the sources, fate, and impact of air pollution, development of analytical methods and sensors, material selection and ventilation/air purification strategies. The research is highly interdisciplinary including atmospheric, analytical and environmental chemistry, public health, civil, architectural, electrical, and chemical engineering.
Projects within this area are for students aiming for a career in Environmental Engineering striving to ensure clean and healthy air for all.

List of project topics (MSc, BSs, R&D):

- Characterization of air pollution and source contributions using state-of-the-art analytical techniques, e.g., PTR-TOF-MS
- New sensors for monitoring outdoor and indoor air pollution
- Development of techniques for time-resolved collection and analysis of airborne chemicals
- Current and future strategies to reduce hazardous chemicals in our build environments, including low-emission building materials, chemical scrubbers and sealants

Microbial Biointerfaces in Water Engineering

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In the Microbial Biointerfaces group, we aim to develop innovative solutions to environmental challenges through an understanding of biofilm composition and formation. We are particularly interested in the extracellular polymeric substances (EPS) that bind the biofilms. One major focus area is developing technologies that enable the recovery and valorization of EPS from microbial biomasses derived from waste treatments, which are one of society's largest biosolid waste streams. We thus hope to help build a new circular economy in water management. We also aim to elucidate new strategies to control biofilm growth, specifically those targeting EPS production, composition and structure. Both focus areas require innovative approaches for downstream processing, and chemical and biophysical analyses. We are always looking for motivated students at both Bachelor and Master level. Please contact us if your interest and/or expertise aligns with the activities of the group.

List of BSc/MSc thesis project topics:

- Producing Bioplastics from EPS hydrogels isolated from activated sludge
- EPS hydrogels for removing persistent chemicals by sorption
- Optimization of EPS hydrogel recovery from activated sludges
- Comparison of aerobic granular sludge EPS from continuous and sequencing batch re- actors
- Method development for partial hydrolysis of activated sludge exopolysaccharides to oligosaccharides for structural elucidation by NMR
- EPS recovery and analysis from activated sludge microbial isolates

Water Engineering Innovation Lab

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The **Water Engineering Innovation (WEI) Lab**, led by Dr. Zongsu Wei, has focused on developing advanced treatment processes to purify water and promote water safety. The ubiquitous presence of emerging contaminants (ECs) such as micropollutants and pathogens in water sources (e.g., subsurface water and groundwater) poses serious health threats to both humans and the environment. Yet, conventional treatment technologies have failed to remove those ECs in wastewater treatment plants, necessitating innovation and upgrade in current technologies. Our research interests are motivated by the need to address these problems and are focused on a fundamental understanding of the nexus of contaminant-water- environment.

List of project topics (MSc, BSc, R&D):

- Radical-based advanced oxidation processes
- Photocatalytic defluorination of PFAS
- Advanced reduction of PFAS
- Sonochemical degradation of PFAS
- Engineering carbon based photoregenerable composite materials for efficient removal of emerging micropollutants
- Power-to-X, e.g., electrodialysis-based acid/base production for CO_2 capture

Media coverage for our research:

2023

Teknisk Nyt: Ét-trins løsning til at fjerne og nedbryde PFAS

Plast Panorama: Danske forskere udvikler ét-trinsløsning til at fjerne og nedbryde PFAS"

ING/WATERTECH: Ny metode både renser vand for PFAS og destruerer det med biokulfilter og UV-lys

AVISENDANMARK: Århusiansk forskerteam med megagod nyhed: Mener at kunne smadre evighedskemikalierne PFAS med ét smæk

AU Engineering News: Danish research team aims to develop a single-step solution to remove and break-down PFAS

2022

DFF Case: Kan PFAS indsamles og nedbrydes enkelt og billigt?

AU Engineering News: New research project aims to make it easier to remove PFAS from nature

Interview on TV2 ØSTJYLLAND: FUND AF OMDISKUTEREDE FLUORSTOFFER PÅ ØSTJYSK FABRIK (PFAS Found at Fire Scene)

2021

Avisen Danmark: Forskere får millioner til at eliminere skadeligt PFOS

TV2 ØSTJYLLAND News: Forskere får millioner: Skal eliminere giftigt stof i jorden

AU Engineering News & EurekAlert! News: AU researchers develop solar-powered tech to make “forever chemicals” harmless

DFF Case: Solar-driven process must convert environmental toxins into harmless substances

Faculty of Technical Sciences News: Nine researchers from Tech receive share in green IRFD funding

Baltic Sea PFAS Network News: A project at Aarhus University to develop greener methods to break the PFAS bond

2020

AU Engineering News & EurekAlert! News: Research project to eliminate ‘forever chemicals’

Anaerobic digestion technologies

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The research within the Anaerobic digestion (AD) group is focused on improving biogas production and covers technologies that can increase gas pro- duction, improve impact on greenhousegas emissions, optimal use of digestate and biogas. The research covers pre-treatment, new innovative digester design, improved process understanding, up-stream and downstream processes as well as process kinetics, greenhouse gases, value of the digestate as fertilizer by separation. Furthermore, the integration of the AD technology in organic farming has increasing interest. The research covers both basic research and final application with a strong collabo- ration with industry.

List of projects:

- Chemical pre-treatment of biomass with (ammonia, KOH, acids etc.)
- Improved biogas from manure by up- stream reduction of losses
- New improved reactor designs like re-di- gestion of fibers, UASB, filter reactors etc.
- Biological and physical pre-treatment of bio- mass
- Improving the value of nutrients by digestate processing.
- Additives for improved biogas
- Integration of biological gascleaning and fertilizer production
- Micro-aeration of the biological process

Industrial Biotechnology

The industrial biotechnology research area focuses on design, engineering and application of enzymes and microorganisms for the synthesis or modification of chemicals of our daily use including active pharma intermediates (APIs), food, agrochemicals, personal care products and commodities. A special interest is devoted to the conversion of renewable raw materials into products in a sustainable way. The industrial biotechnology research area covers protein design, bioinformatics (omics) and cell system engineering on one side; and chemical production and reaction engineering on the other side, and it lies next to the research field of process engineering in our section.

Agro-Biotechnology Science Group

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The research interest at the **Agro-Biotechnology Science Group** is to seek for innovative methods, new chemistry and greener solutions for effective and efficient utilization and valorization of natural and agricultural resources. Green chemistry and enzyme catalysis are the cores of biotechnological science to be advanced and developed. In our laboratory we develop green technology and enzyme catalysis to transform lipids, biomass and industrial crops into new value-added products. These products include food ingredients, agro-chemicals, biofuels, biomaterials and cosmetic/pharmaceutical excipients for oriented applications.'

List of project topics:

- Programmable Synthesis of Designer Lipids for Continuous Liquid Interface (3D) Printing;
- Engineering of extra dioxygenase for enzymatic production of lignin-based biochemicals;
- Enzyme Engineering of P450 for New-to-Nature chemistry;
- Facile synthesis of hierarchical-structured layered double hydroxides as catalysts for oxidation of alcohols
- Synthesis and characterization of solvent- free liquid cellulases

Biocatalysis and Bioprocessing

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The research at '**Biocatalysis and Bioprocessing**' focuses on the development of environmentally benign and highly productive biotransformations by combining (i) biotechnology, (ii) chemistry and (iii) re- action engineering in a multi-disciplinary platform. Our research group offers challenging and novel pro-jects for B.Sc. and M.Sc. students aiming for a career in **Industrial Biotechnology**, exploring the great potential of enzymes for the synthesis of chemicals *e.g.* fine-, speciality- or bulk chemicals.

List of project topics:

- Light-driven hydroxylations in non-conventional media
- Reaction engineering of light-driven decarboxylations
- Design and development of artificial (redox-neutral) enzymatic reaction cascades
- Evaluation of the effect of organic solvents on redox enzymes
- Immobilization of (redox) enzymes for their use in non-conventional media and in continuous processes
- Kinetics modelling of multi-enzymatic re- action cascades

Enzyme Engineering

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The research in our group focuses on improvement of biocatalytic capacity of enzymes through biocatalyst engineering. We aim to explore natural and non-natural enzymatic reactions for the synthesis of industrially and medically useful compounds. Our research also includes discovery of novel enzymes as well as mechanistic and kinetic studies of enzymatic reactions. Through our projects, students can develop skills in molecular biology, protein expression & purification, enzyme kinetics and enzyme assay design.

List of project topics:

- Engineering Fatty Acid Utilizing Enzymes for the Production of Biofuels and Value-added
- Chemicals (multiple projects)
- Exploring Decarboxylase Enzymes for Their Potential in CO2 Fixing Synthetic Reactions
- **Industrial Master Thesis Opportunity at Novo Nordisk & Helix Lab – Kalundborg:** "Investigation of the Enzymatic Reaction Kinetics in Insulin Purrification"

Functional Microbe Technology

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The **Functional Microbe Technology Group** investigates activities of food and gut microbes which might have beneficial or adverse impact. We want to manipulate these activities and are interested in the role these functions play in their ecosystem. Our research program employs a combination of advanced molecular tools, enzymatic assays, aerobic and anaerobic cultivation, biotechnological processes such as food, batch and continuous fermentation systems and downstream processing, and various analytical chromatography techniques.

List of project topics:

- **More than slick seaweed (FERMOSE).** Identify the potential of seaweed polysaccharides to act as next-generation prebiotics.
- **Develop novel bioprotective consortia (BIOFUNC).** Predict strains that form interactive networks to produce propionate based on genome data. Combine and test candidate strains in co-culture studies with different substrates. Optimize production to employ consortia as bioprotectants in food fermentations.
- **Make them glow!** Develop a biosensor hosting the redox sensitive expression system roGFP that can be used in model systems *in vitro* and *in vivo*.
- **How do gut microbes and diet components interact? (BiODairy and InfantAD)** Combine in vitro models with nutrient/microbial modulations to determine the causal effects of food-gut microbiome interactions.

Microbial Biosynthesis

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The research at '**Microbial Biosynthesis**' focuses bacteria producing complex natural products. We aim to isolate new microorganisms and identify natural products with antibiotic or anticancer activity. We work on understanding how enzymes construct complex natural products and exploit these enzymes for new purposes and we work on optimizing the production in both shaker flasks and bioreactors. We are a dynamic research group and have several projects for creative students within **Industrial Biotechnology**.

List of project topics:

- Using CRISPR-Cas9 genome editing tools to investigate the enzymes involved in natural product biosynthesis
- Expression and characterizing enzymes involved in RiPP (RIbosomally synthesized and Post-translationally modified Peptides) biosynthesis
- Isolating and characterizing antibiotic-producing microorganisms
- Optimizing production and isolation of complex natural products from microorganisms
- Screening novel antibiotics against human pathogens
- Using bioinformatics to identify new natural products for heterologous expression

Microbial Conversion Technologies

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The research at '**Microbial Conversion Technologies**' focus on the use of microorganisms for solving some of the great societal, environmental and technical challenges that we as a society has to deal with.
Although our primary focus is the biological conversion of electricity to methane (CH4) through the process of biomethation - we work with a range **environ- mental technologies** where microorganisms are in- volved including, anaerobic digestion and air treatment.

List of projects with biomethanation:

- Operation of pilot-scale CSTR bioreactor for biogas upgrading using new injector technology
- Conversion of syngas to methane using lab- scale reactors
- Ex situ biomethanation of CO2 from industrial sources
- Microbial CO2 conversion using redox-mediators as electron donor

Microbial Electrosynthesis

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Our group studies microorganisms, which have the intriguing capacity to convert CO2 with H2 into valuable products, including acetate and methane. These anaerobic microbes are thus of high interest to develop biological CO2 utilization technologies. The required H2 can be added by an electrode placed in the bioreactor, in this case the process is called **Microbial Electrosynthesis**, which is also the name of our research group. Microbial electrosynthesis also offers opportunities to store excess renewable electricity.

Our research mainly focusses on understanding these acetogenic and methanogenic microbes better, by studying their H2 consumption characteristics, and other properties. Our research aims to deliver new insights that contribute to the optimization of microbial electrosynthesis applications.
We offer BSc/MSc thesis topics for students eager to learn how to work with anaerobic microbes or mathematic modelling and are interested in microbial biotechnologies for CO2 utilization.

List of BSc/MSc thesis project topics:

- Competition experiments to investigate which strains are best for microbial electrosynthesis
- Exploring the H2 consumption characteristics of methanogens
- Mathematic modelling to investigate the effect of intermittent current input on microbial electrosynthesis
- Exploration of N2 fixation by acetogenic bacteria

Microbial synthetic biology

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In the group of **Microbial Synthetic Biology** we **harness microbial C1 metabolism** to establish methanol-based bioprocesses for production of industrially relevant **value-added compounds**. Our research is centered around thermophilic *Bacillus methanolicus* which has potential to become an industrial work- horse for biotechnological production. We aim at development of a technology where **C1 compounds are converted into higher carbon molecules** using native and synthetic metabolic pathways in methylotrophic microorganisms. Such approach has twofold impact on current challenges of (bio)chemical industry (i) in-troduction of sustainable feedstock for biotechnology which we do not compete with food and feed industries for resources, (ii) establishment of biocatalysts for activation of stable C1 molecules and their selective transformations, particularly formation of C-C bonds.

List of project topics:

- Development of a novel system for cloning of toxic genes in *Escherichia coli* and their expression in *Bacillus methanolicus*
- Development of gene tic tools for genome reduction (i.e. deletions of at least 10,000 bp genome fragments), using CRIPSR/Cas9 system
- Investigation of catalytic properties of methanol dehydrogenase of *B. methanolicus* with regards to butanediol

Multiscale Microbial Engineering

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In our research group we aim at reprogramming microbial cells to improve their robustness for biomanufacturing. We combine genome edition, metabolic engineering, and synthetic biology strategies to developed streamlined and smart cells with superior performance to produce recombinant proteins and DNA vaccines. The engineered microbial factories display advantages for small scale cultures and potentially for industrial bioprocesses.

List of project topics:

- Dynamic control of the metabolic fluxes to improve biomass formation under oxygen limitation.
- Streamlined *Escherichia coli*: Less is more?
- Production of a novel DNA vaccine vector in proteome-reduced E. coli
- Production of an auto inducible DNA vaccine vector
- Microaerobic production of the *Clostridium difficile* toxin A subunit in proteome reduced *E. coli*

Medical Biotechnology

The medical biotechnology research area focuses on designing, engineering and applying macromolecules and cells used in health-related biotechnological applications. The research spans from fundamental insights into physiological processes and their function to engineering of biological molecules and their interaction with tissues and biomaterials for precision medical applications. Cellular systems for production and application in health technologies are studied and de- signed using experimental and computational methods. The research area includes and lies next to research areas of protein design, cell engineering, sensors and diagnostics, and protein and industrial biotechnology.

Immunological Biotechnology

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The research of the '**Immunological Biotechnology**' group focuses on the development of **diagnostic and therapeutic concepts** within biomedical applications.
We apply a broad spectrum of **protein technologies**, e.g. production in higher expression hosts, combinatorial approaches, *in vitro* and cellular assay systems, functional and structural characterisation, etc.

Our research group offers challenging and interdisciplinary projects for B.Sc and M.Sc. students within the research of **Medical Biotechnology**, designing and exploring the potential of highly evolved proteins and other biomolecules for a future patient-tailored **precision medical treatment**

List of BSc and MSc thesis project topics:

- Identification, characterisation, production and application of proteins such as biomarkers and antigens involved in disease
- Establishment of novel binding molecules against clinically important molecular and cellular structures
- Functional and structural analyses of antibodies
- Targeting immunologically important key molecules and biomarkers for disease

Infections, carcinogenesis and regeneration

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The **Infections, Carcinogenesis, and Regeneration** (**ICR**) research group focuses on uncovering cellular and molecular factors critical for antimicrobial and early cancer intervention strategies. We investigate the dynamics of tissue regeneration, particularly how infections, inflammation, and dietary factors disrupt tissue balance and exploit conditions like metaplasia contributing to cancers.

Our approach centers on advanced techniques, including 3D-organoids, co-culture systems, *in vivo* models, CRISPR/Cas9 genome editing, high-resolution microscopy, and single-cell and spatial omics analysis.

We offer wet lab and bioinformatics research opportunities. Choose your focus, and let's advance our understanding of these critical areas together.

List of project topics:

- Developing novel complex preclinical patient-derived organoid systems
    - Establishing Epithelial-stromal-immune co-cultures.
    - Analyzing organoids from healthy, infection, and pathological states.
    - Generation of mutant organoid lines applying e.g. CRISPR/cas9.
    - Biomarkers screening and validations
- Modeling infections and carcinogenesis in vivo
    - Establishing and optimizing infection and precancer mouse models
    - Characterizing tissue alterations in mouse models
- Integrated bioinformatics
    - Single-cell sequencing and spatial-transcriptomics and mutational analysis
    - Data mining and integration with public datasets

Organoid and imaging biotechnology

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The research in the OIB group focuses on developing organoid and imaging technologies to improve dis- ease modelling and drug testing.

Organoids are mini-organs – tiny, self-organised three-dimensional tissue cultures derived from stem cells or tumours. Their size, advanced differentiation, and potential human origin provide a convincing alternative to "classic" cell culture and animal models for preclinical drug testing and disease modelling. We primarily use imaging and biochemical analysis to compare development and responses of healthy and disease organoids.

List of BSc and MSc thesis project topics:

- Development and functional characterization of epithelial and endothelial model systems.
- Automation of organoid screening technology – how to streamline the process for drug screening
- Assay development for intestinal or- ganoids – how to monitor uptake of food and drugs
- Cerebral organoid imaging – what can we learn about neurodegenerative diseases
- Imagining technology and processing - development of analysis and segmentation tools
- Microscopy and labelling development – identifying cell types and morphologies
- Electron- and X-ray tomographic imaging of organoids

Nanofiber Technology and Cellular Engineering

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The research at '**Nanofiber Technology and Cellular Engineering'** focuses on developing novel and func- tional nanofibers for biomedical applications. Working at the interface between nanomaterials and medical biotechnology, we engineer biocompatible, nanofibric, artificial extracellular matrix to synergize the nano-structural induction and the bioactive signaling to affect cellular behaviors, such as gene de- livery, cell adhesion and migration, stem cell differentiation. The three-dimensional (3D) nanostructured fibers are also investigated to present functional molecules, enzymes or antibodies for biosensing, catalysis, neural, muscle and connective tissue engineering, circulating cancer cell capture and cancer therapy.

List of project topics:

- Nanofibers/nanoparticles-based drug release system
- Coaxial hydrogel nanofibers for 3D cell culture
- Stimuli-responsive nanofibers based 4D printing for on demand stimulation

Biomechanics and Mechanobiology

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The research at '**Biomechanics and Mechanobiology'** is closely linked to Medical Biotechnology. We focus on understanding and using molecular mechanisms related to how mechanical forces alter biological and chemical functions. The aim is to develop new bio- technologies that quantify mechanobiological mechanisms or take advantage of them in new ways to de- liver drugs or to understand diseases initiation and progression. You can join the group by focusing on an experimental or computational topic selected from be- low. Most projects are in collaboration with scientific or industrial partners.

<u>The open projects are:</u>

- Theoretical Bioinformatics and Systems Bio-chemistry:
  - Mechanobiology of gastrointestinal in-flammation and regeneration.
  - Mechanobiology of structural guided or-ganoidal self-assembly.
  - Blood Brain Barrier mechanobiology.
  - Mitral Heart Valve mechanobiology.
- Experimental Medical Device Development:
  - Microfluidic device for Blood Brain Barrier replication – mechanosensitive drug screening.
  - Mechano activated mitral valve devel-opment.
  - Nanostructured SiN membranes and foams for screening of mechano sensitivity.
- Nanostructured foams for gastrointestinal organogenesis.

Process Engineering

The process engineering research area focuses on understanding biological and chemical processes and developing, optimizing and upscaling the technologies based on these processes via open and closed bio- and chemical reactor systems. Biochemical profiling and microbial physiology are applied to design bioprocess technologies for production of feed and food, pollutant degradation, resource recovery of nutrients and carbon sequestration in the form of energy carriers and plat- form chemicals. This research area lies next to industrial biotechnology and environmental technology.

Sustainable Process Systems Engineering (SuPSE)

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Research in the Sustainable Process Systems Engineering (SuPSE) group focuses on the development of highly efficient processes for the successful transition into a sustainable future. The group uses a combination of computational and experimental methods to advance the development of emerging sustainable technologies. Computational methods include the use of Process Systems Engineering (PSE) tools to synthesize, integrate and analyze processes by taking into account the needs of people (social), planet (environment) and profits (economy), the tri-fold metrics of sustainability. These tools include process synthesis/modeling and integration, techno-economic (TEA) and Life Cycle Assessments (LCA). Particular interest is given in integration of chemical and renewable energy tech-nologies for exploiting synergies leading to optimization of processes in a circular economy concept. Of particular interest are renewable fuels and chemicals based on biomass & waste (with special focus on hydrothermal liquefaction-HTL), chemical energy storage (Power-to-X), circular economy and waste (water) treatment.

Examples of available projects:

- Modeling of sustainable aviation fuel (SAF) production from CO2 and H2 via reverse water gash shift and fischer-tropsch.
- Modeling hydrotreatment of bio-crude oils.
- Modeling and Techno-economic analysis (TEA) of the integration of hydrothermal liquefaction (HTL) in wastewater treatment plants.
- General projects on modeling, Technoeconomic evaluation and Life Cycle Assessment (LCA) of advanced biofuels, synthetic fuels and sustainable bio-refineries.

Green Biorefining Technologies

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The research at the **Green Biorefining Technologies** group focuses on development of sustainable proteins, biochemicals, bio-based materials and bioenergy made from green biomasses (e.g. grasses and legumes). We´re studying biomass conversion processes in the lab and apply process- and chemical engineering to optimize demonstration scale production at the Centre for Biorefining Technologies in Foulum. We aim to integrate and scale up several biorefining technologies to get the maximum value out of our biomass resources and utilize this in a circular bio-economy concept. These technologies include plant protein extraction and separation, membrane filtration, pretreatment of lignocellulosic biomass, enzymatic hydrolysis of biomass, fermentation technology for high value products, pyrolysis of biomass, and cellulose utilization for biotextiles, bioplastic and packaging-biomaterials.

List of general project topics:

- Production of chemicals and high value products from grass fibre (after protein ex- traction) - incl. Pretreatment, enzymatic hydrolysis
- Textile from grass: Biopolymer (cellulose) refining and characterisation, and biotextile manufacture, by dissolution in “green” ionic liquid solvents, and regeneration into textile fiber shape. (Size exclusion chromatography, viscosity, fiber-spinning, composi-tional analysis)
- Recycling of biotextiles - characterization and biochemical regeneration of biopolymers; cellulose from cotton/hemp/linen/viskose, and protein from wool and silk.
- Membrane separation of amino acids and sugars from the residual process liquid (after taking out precipitated protein)
- Fermentation of up-concentrated residual process liquid to produce valuable bio- chemicals
- Optimizing protein separation process in lab and in demonstration scale to increase yields
- Optimization of lab-scale Protein analysis (sds-page) of protein for food, feed or bio- materials/biotextiles
- Green proteins for food applications
- Pyrolysis of woody and herbaceous biomass in relation to biochar production and carbon capture technology
- Modelling and Technoeconomic analysis of green biorefineries

Hydrothermal Processing

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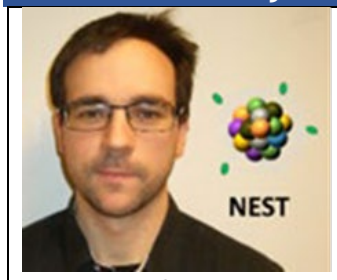
The **Biorefining** group focuses on the development of sustainable chemicals, fuels and nutrients made from biomass and wastes. We apply process and chemical engineering to optimise pilot scale pro- duction technologies at the Centre for Biorefining Technologies in Hangøvej and Foulum. We aim to integrate and scale up different biorefining technologies to get the maximum value out of biological resources in the circular bio-economy concept. The main technologies we work with employ high temperature and pressure, termed hydrothermal liquefaction and carbonization which can replace petroleum based fuels and chemicals.

List of project topics:

- Phosphorous recovery as fertilizer from wet wastes/sludges
- Recycling of textile wastes via HTL
- Integration of HTL at wastewater treatment plants
- Recycling of plastic waste via HTL
- Development of hydrothermally stable catalysts.
- Hydrotreatment in a fixed catalytic reactor for jet and marine fuel production

Nanomaterials engineering for sustainable technologies – NEST



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At **NEST** we focus on developing new approaches to design and prepare outperforming **nanomaterials** and in particular **nanocatalysts**. We (i) develop new synthetic approaches. We (ii) understand the strong relationships between *synthesis-structure-properties* at the nanoscale (*i.e.* how nanomaterials form and how does that influence the resulting properties, *e.g.* collaboration with iNano). We (iii) investigate their applications in energy conversion (*e.g.* a range of small molecules electro-oxidation for fuel cells or electrolyzers, possibly CO2 electro-reduction). To date we focus on precious metals such as gold, silver, platinum, iridium, ruthenium, but we are open to new opportunities and horizons. To date we focus on electrocatalytic applications but we are also open to new horizons and collaborations since the nanomaterials are relevant for energy conversion, catalysis, medicine, water/air treatment, sensing, imaging and many more.

Examples of project topics (MSc, BSc):
Following up on two recent patent applications:

- Development of *green* scalable surfactant- free colloidal syntheses of nanomaterials at low (room) temperature – towards high throughput and/or automation for machine learning
- Development towards bi/multi metallic nano-particles (*e.g.* high entropy alloys)
- Electrocatalysis (*e.g.* alcohols oxidation – possibly CO2 reduction)

See also: http://nestresearchlab.com/

Carbon Engineering

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The carbon engineering group predominantly investi- gates the production of engineered carbons from bio- mass. The group used hydrothermal carbonisation (HTC), a process which uses hot compressed water to simulate a natural coal forming process to produce a biocoal and pyrolysis which uses heat to thermo- chemically reform a carbon-based feedstock to a charcoal. The group works at a range of scale from small lab scale for fundamental research to larger scale pilot reactors at Foulum. Applications of the carbon materials include fuels for combustion and metal making, biochar for carbon sequestration, growth substrates, pretreated carbon for liquid fuel and chemical production, carbons for water treatment and carbon electrodes.

Current projects include:

- Effect of surface coating on carbon deposition/ fouling in hydrothermal reactors (can be tailored to BSc or MSc students).
- High temperature settlement behaviour of solid carbon in subcritical water conditions and the influence high temperature char ex- traction will have on char carbon structures, yield and toxicity (can be tailored to BSc or MSc students).
- Influence of metals and heteroatoms on hydrothermal carbon polymerisation chemistry (can be tailored to BSc or MSc students).
- Synthesis of metals and heteroatoms on hydrothermal carbon polymerisation chemistry (can be tailored to BSc or MSc students).
- Influence of pyrolysis processing conditions on biochar pH, structural integrity and energy yield, with the intention to use the resulting char as growth media in commercial green- houses (MSc).
- Carbon recalcitrance of anaerobic digestates and the influence of recalcitrance following hydrothermal and/ or thermal treatment (MSc
- students).
- The use of biochar augmented sand filters in cleaning water for drinking and groundwater recharge (can be tailored to BSc or MSc students or R&D project).
- Review of standards in the production of com- posted material for the use in commercial greenhouses (R&D project).

Power-to-X research group for technology development

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The PtX research group is working on the development of novel technologies at a high Technology Readiness Level, known as TRL. The test facility is located at the PtX process hall in the biogas plant at the AU Viborg campus, and the core of the research is converting electrical energy to chemical energy with different PtX technologies. As part of technology development, a new product or process should be tested on a pilot scale at an industrially relevant environment (TRL 5-6) and operational environment (TRL-7) for a sufficient time (typically 1000 to 4000 hours). The PtX process hall is a unique environment where academia meets the industry and works closely to demonstrate and test new technologies. You will experience research projects that target real industrial problems and investigate the feasibility of novel solutions. We offer a wide range of projects, including both experimental and simulation works. Currently, we are testing two technologies, namely Solid Oxide Electrolyser cells (SOEC) for hydrogen production and Electrified Steam Methane Reforming (eSMR) for syngas production, using renewable feeds and (renewable) electricity. At the same time, we are developing two new pilot plants, one for methanol and one for the Jet Fuel production from CO_2-rich mixtures.

Currently, we have 6 master projects in line with the mentioned projects. You can write to me or come and visit us at Foulum to discuss a master project.

Note: Due to the confidentiality agreement of projects, all projects need to be approved by our industrial partners, and your thesis will be confidential.

Carbon dioxide capture research

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While different technologies exist for carbon capture as the first link in CCS, to achieve the ambitious path for decarbonization, novel, less energy-demand technologies must be developed, especially when small to medium size emission sources are taken into account. Based on energy statistics reported by the Danish Energy Agency, in 2020, approximately 14.8% of heat and power (40% of heat), equivalent to 15.3 TJ, was produced from smaller-scale plants. To produce such energy, 0.66 MT of CO_2 were emitted in 2020 by smaller-scale plants in Denmark. Approximately 900 small and medium-sized local heat plants exist in Denmark, in which both CAPEX and OPEX of capturing CO_2 are too high for a broad implementation to be feasible. Developing cheaper and more efficient CO_2 capture technologies targeting these smaller-scale industries could be key to achieving the 2030 goal. A novel technology aims to explore the potential of gas hydrate-based carbon capture (GHBCC) as one of the most promising low-energy demand CO_2 capture alternatives and clarify the potential bottlenecks in further technology development. A GHBCC technology could be used for all scales of CCS; however, it will open up an opportunity for smaller emitters to engage in the global efforts of reducing GHG emissions.

At the first step, I have a project to investigate promoters to change the thermodynamic equilibrium of flue gas mixture (experimental work) and perform a techno-economic assessment of a GHBCC process (theoretical). I can offer two MSc projects for Spring 2024 in line with these topics.
You can write to me or come and have a cup of coffee to discuss a master project.

Electrochemical Engineering

The research area electrochemical engineering focuses on technological applications of electrochemical phenomena including electrochemical reactors, sensor technology, batteries, fuel cells, surface modification by electrodeposition, electrochemical separation and corrosion. This research area lies next to materials and polymer engineering, catalysis, reactor and separation technology and it includes development of both novel processes and materials alike.

Power to Chemicals

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Power to Chemicals group researches in electro- chemical conversion technologies for producing value-added chemicals in situ (e.g. ammonia and its salts from N2 and water). Ammonia and its salts find their main use as fertilizer which is essential for modern agriculture. However, ammonia production is highly centralized and emits 1-2% of total CO2 on a global level. Our quest is to find a combination of an electrolyte and a catalyst which would enable energy-efficient local production of fertilizers in an electrochemical cell powered by photovoltaics or wind- mills. We also look into how to exploit the rich electrochemistry of organic redox species to create new types of dry-cell and flow batteries.

Examples of project topics:

- Controlling the reaction of lithium nitride with water by utilizing organic solvents as reaction media
- Nitrogen reduction reaction with Runanoparticle electrodes
- Effect of pKa values on the Nitrogen reduction reaction
- Nitrogen reduction reaction with aluminum/gallium electrode
- Aqueous nitrogen reduction reaction at 10 bar (H2O)
- Aqueous nitrogen reduction reaction at 10 bar (H2)
- Electrodeposition method for indium catalyst
- NOx reduction to ammonia under H2

Membrane Engineering

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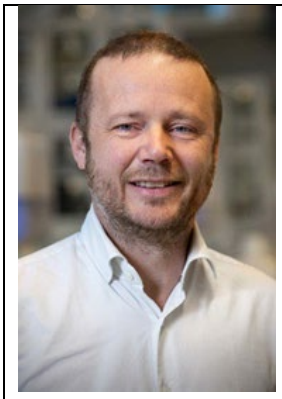
The research group "**Membrane Engineering**" focuses on the synthesis of materials for membrane- based (electrochemical) processes, and on under- standing the theory of transport phenomena of ions in charged thin film and nanopores.
Membranes allow us to selectively separate the com- ponent(s) of interest from a mixture, based on molecular sieving and/or chemical and electrochemical affinity. The research group offers projects in very different fields, such liquid separation and purification, CO2 sequestration and electro-reduction, and membrane reactors.

List of project topics:

- Synthesis of novel catalyst-impregnated membranes and electrodes for CO2 reduction (collaboration with iNano)
- Development of gas flow reactor for electro- chemical CO2 conversion and on-line monitoring (hardware/software).
- Characterization of membranes for (reverse) electrodialysis (possible secondment at Wet- sus, the Netherlands) and water purification

Electrochemical Energy Conversion and Batteries



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Research and projects focus on electrochemical conversion technologies and in particular batteries and alkaline electrolysers. The aim of the research is to develop and up-scale new low-cost battery technologies for storage of renewable electricity from solar cells and wind turbines. Current scope in this area is (i) Flow batteries (vanadium and Zinc/air) (ii) Optimisation of components for alkaline electrolysers (electrodes, membranes, geometry). In general, we focus on known battery chemistries and try to solve challenges related to upscaling with respect to battery design and life-time. Besides battery tests all projects will typically also involve use of more general techniques like cyclic voltammetry, imped- ance spectroscopy and half-cell battery tests.

Examples of project topics

- Optimisation and test (new) of flow battery chemistries.
- Optimisation of components for alkaline electrolysers (electrodes, catalysts, membrane seperators)

Materials and Polymer Engineering

The materials and polymer engineering research area focuses on the synthesis and characterization of novel materials and composites through the incorporation of organic and inorganic materials. The purpose is to tailor material performance towards specific applications and production technologies.
Materials are omnipresent in our society and utilized in textiles, household items, food ingredients, specialized biomedical devices and components for aerospace, boats, wind tur- bines, solar cells, and computer hard drives. The research seeks new approaches improving sustainability in a circular economy perspective.

Plastic and polymer engineering

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The research at **Plastic and polymer engineering (PPE)** focuses on polymerization, formulation and testing for polymeric and plastic systems. This includes e.g. Adhesion of rubbers, Medicinal Gels, 3D printing of food, and novel polymer degradation.
Further PPE is active within open science at AU and developing and making advance glass flow reactors, controllers, etc. Please note: None of the pro- jects below is "ready-made" all projects in the PPE group are made in collaboration between the industrial partner(s), the Student and PPE.

Examples of project topics:

- Synthesis of medicinal gels for prediction of premature birth.
- Inline plastic analysis and sorting of household waste plastic.
- Plastic degradation during recycling
- Development of fire-retardant coating for construction paints

Hybrid materials lab

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The research in '**Hybrid materials lab**' focuses on i) engineering of advanced materials with tailored properties. We use such compounds in ii) heterogeneous photocatalysis i.e. solar-light driven chemical reactions, and iii) electrocatalysis using electricity for chemical conversions. For example, we focus on the reduction of CO2 and on hydrogen production from water splitting. This is achieved through iv) modification of the catalyst light adsorption/conductive properties and v) modifying the materials surface area and gas adsorption (e.g. CO2) capacity. Scaling-up of these processes is envisioned.

Examples of project topics

- Synthesis of novel porous materials for gas ad- sorption (e.g. CO2)
- Modifying light absorption properties of solids
- Screening of novel materials for heterogeneous photo- and electrocatalysis, e.g. CO2 reduction and hydrogen production
- Investigation of catalytic mechanisms to rationally engineer improved catalysts or processes