School of Process and Chemical Engineering

Study packages for exchange incoming students of the School of Process and Chemical Engineering

Updated: 30.01.2019
# Overview of the study packages

<table>
<thead>
<tr>
<th>Study package 1a – Bioprocess Engineering – WiSe</th>
<th>Study package 1b – Bioprocess Engineering – SoSe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Biofuels</td>
<td>Bioprocess and Biosystems Engineering</td>
</tr>
<tr>
<td>Biocatalysis</td>
<td>Technical Microbiology</td>
</tr>
<tr>
<td>Applied Thermodynamics: Thermodynamic Properties for Industrial Applications</td>
<td>Cell and Tissue Engineering</td>
</tr>
<tr>
<td>Industrial Bioprocess Engineering</td>
<td>Molecular Modelling and Computational Fluid Dynamics</td>
</tr>
<tr>
<td>Separation Technologies for Life Sciences</td>
<td>Heterogeneous Catalysis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study package 2a – Chemical Process Engineering – WiSe</th>
<th>Study package 2b – Chemical Process Engineering – SoSe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Systems Engineering and Transport Processes</td>
<td>Heterogeneous Catalysis</td>
</tr>
<tr>
<td>Special Areas of Process Engineering – Interfaces and Colloids, Chemical Kinetics and Environmental Analysis</td>
<td>High Pressure Chemical Engineering</td>
</tr>
<tr>
<td>Applied Thermodynamics: Thermodynamic Properties for Industrial Applications</td>
<td>Waste and Energy</td>
</tr>
<tr>
<td>Separation Technologies for Life Sciences</td>
<td>Molecular Modelling and Computational Fluid Dynamics</td>
</tr>
<tr>
<td>Research Project Process Engineering</td>
<td>Research Project Process Engineering</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study package 3a – Environmental Process Engineering – WiSe</th>
<th>Study package 3b – Environmental Process Engineering – SoSe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioresources and Biorefineries</td>
<td>Waste and Energy</td>
</tr>
<tr>
<td>Rural Development and Resources Oriented Sanitation for different Climate Zones</td>
<td>Geochemical Engineering</td>
</tr>
<tr>
<td>Waste Treatment Technologies</td>
<td>Groundwater Modeling</td>
</tr>
<tr>
<td>Wastewater Treatment and Air Pollution Abatement</td>
<td>Bioprocess and Biosystems Engineering</td>
</tr>
<tr>
<td>Special Areas of Process Engineering – Interfaces and Colloids, Chemical Kinetics and Environmental Analysis</td>
<td>Molecular Modelling and Computational Fluid Dynamics</td>
</tr>
</tbody>
</table>

Alternatively, one module in each study package can be substituted with:

- 2 Non-technical Elective Complementary Courses for Master (each 2 ECTS), or 1 language course of 4 ECTS

and

- 1 course of Business and Management (2 ECTS).
Study package 1a – Bioprocess Engineering – WiSe

Advanced Biofuels | 6 ECTS

Recommended Previous Knowledge:
Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering

Theoretical Knowledge
Within the module, the students learn various process paths for the production of advanced biofuels (for example gas-to-liquid, HEFA and alcohol-to-jet). For this purpose, the procedures are explained and technically designed by the students. This includes the modelling of the overall process for the determination of mass and energy balances. An LCA as well as an economic view of the process are developed.

Capabilities
After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology:

a. Module-spanning solutions for the design and presentation of production processes
b. Comprehensive analysis and processing of a process in technical, ecological and economic terms
c. Systematically document the work results by elaborating a written work and defending the contents.

Biocatalysis | 6 ECTS

Recommended Previous Knowledge:
Knowledge of bioprocess engineering and process engineering at bachelor level

Theoretical Knowledge
After successful completion of this course, students will be able to

a. reflect a broad knowledge about enzymes and their applications in academia and industry
b. have an overview of relevant biotransformations and name the general definitions

Capabilities
After successful completion of this course, students will be able to

a. understand the fundamentals of biocatalysis and enzyme processes and transfer this to new tasks
b. know the several enzyme reactors and the important parameters of enzyme processes
c. use their gained knowledge about the realisation of processes. Transfer this to new tasks
d. analyse and discuss special tasks of processes in plenum and give solutions
e. communicate and discuss in English
Applied Thermodynamics: Thermodynamic Properties for Industrial Applications ‖ 6 ECTS

Recommended Previous Knowledge:
Thermodynamics III

Theoretical Knowledge
The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions.

Capabilities
The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes.

Industrial Bioprocess Engineering ‖ 6 ECTS

Recommended Previous Knowledge:
Knowledge of bioprocess engineering and process engineering at bachelor level

Theoretical Knowledge
After successful completion of the module:

a. the students can outline the current status of research on the specific topics discussed
b. the students can explain the basic underlying principles of the respective biotechnological production processes

Capabilities
After successful completion of the module students are able to:

a. analysing and evaluate current research approaches
b. Lay-out biotechnological production processes basically
Separation Technologies for Life Sciences | 6 ECTS

**Recommended Previous Knowledge:**
Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Chemical Engineering, Bioprocess Engineering
Basic knowledge in thermodynamics and in unit operations related to thermal separation processes

**Theoretical Knowledge**
On completion of the module, students are able to present an overview of the basic thermal process technology operations that are used, in particular, in the separation and purification of biochemically manufactured products. Students can describe chromatographic separation techniques and classic and new basic operations in thermal process technology and their areas of use. In their choice of separation operation students are able to take the specific properties and limitations of biomolecules into consideration. Using different phase diagrams, they can explain the principle behind the basic operation and its suitability for bioseparation problems.

**Capabilities**
On completion of the module, students are able to assess the separation processes for bio- and pharmaceutical products that have been dealt with for their suitability for a specific separation problem. They can use simulation software to establish the productivity and economic efficiency of bioseparation processes. In small groups they are able to jointly design a downstream process and to present their findings in plenary and summarize them in a joint report.
Study package 1b – Bioprocess Engineering – SoSe

Bioprocess and Biosystems Engineering | 6 ECTS

Recommended Previous Knowledge:
Knowledge of bioprocess engineering and process engineering at bachelor level

Theoretical Knowledge
After completion of this module, participants will be able to:

a. differentiate between different kinds of bioreactors and describe their key features
b. identify and characterize the peripheral and control systems of bioreactors
c. depict integrated biosystems (bioprocesses including up- and downstream processing)
d. name different sterilization methods and evaluate those in terms of different applications
e. recall and define the advanced methods of modern systems-biological approaches
f. connect the multiple "omics"-methods and evaluate their application for biological questions
g. recall the fundamentals of modelling and simulation of biological networks and biotechnological processes and to discuss their methods
h. assess and apply methods and theories of genomics, transcriptomics, proteomics and metabolomics in order to quantify and optimize biological processes at molecular and process levels.

Capabilities
After completion of this module, participants will be able to:

a. describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess
b. plan and construct a bioreactor system including peripherals from lab to pilot plant scale
c. adapt a present bioreactor system to a new process and optimize it
d. develop concepts for integration of bioreactors into bioproduction processes
e. combine the different modelling methods into an overall modelling approach, to apply these methods to specific problems and to evaluate the achieved results critically
f. connect all process components of biotechnological processes for a holistic system view.

Technical Microbiology | 6 ECTS

Recommended Previous Knowledge:
Bachelor with basic knowledge in microbiology and genetics

Theoretical Knowledge
After successfully finishing this module, students are able

a. to give an overview of genetic processes in the cell
b. to explain the application of industrial relevant biocatalysts
c. to explain and prove genetic differences between pro- and eukaryotes

Capabilities
After successfully finishing this module, students are able

a. to explain and use advanced molecular-biological methods
b. to recognize problems in interdisciplinary fields
Cell and Tissue Engineering | 6 ECTS

Recommended Previous Knowledge:
Knowledge of bioprocess engineering and process engineering at bachelor level

Theoretical Knowledge
After successful completion of the module the students:

- a. know the basic principles of cell and tissue culture
- b. know the relevant metabolic and physiological properties of animal and human cells
- c. are able to explain and describe the basic underlying principles of bioreactors for cell and tissue cultures, in contrast to microbial fermentations
- d. are able to explain the essential steps (unit operations) in downstream
- e. are able to explain, analyse and describe the kinetic relationships and significant litigation strategies for cell culture reactors

Capabilities
The students are able:

- a. to analyse and perform mathematical modelling to cellular metabolism at a higher level
- b. are able to develop process control strategies for cell culture systems

Molecular Modelling and Computational Fluid Dynamics | 6 ECTS

Recommended Previous Knowledge:
- Mathematics I-IV
- Basic knowledge in Fluid Mechanics
- Basic knowledge in chemical thermodynamics

Theoretical Knowledge
After successful completion of the module the students are able to:

- a. explain the basic principles of statistical thermodynamics (ensembles, simple systems)
- b. describe the main approaches in classical Molecular Modelling (Monte Carlo, Molecular Dynamics) in various ensembles
- c. discuss examples of computer programs in detail,
- d. evaluate the application of numerical simulations,
- e. list the possible start and boundary conditions for a numerical simulation.

Capabilities
The students are able to:

- a. set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,
- b. solve problems by molecular modelling,
- c. set up a numerical grid,
- d. perform a simple numerical simulation with OpenFoam,
- e. evaluate the result of a numerical simulation.
**Heterogeneous Catalysis | 6 ECTS**

**Recommended Previous Knowledge:**
Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes.

**Theoretical Knowledge**
The students are able to apply their knowledge to explain industrial catalytic processes as well as indicate different synthesis routes of established catalyst systems. They are capable to outline dis-/advantages of supported and full-catalysts with respect to their application. Students are able to identify analytical tools for specific catalytic applications.

**Capabilities**
After successful completion of the module, students are able to use their knowledge to identify suitable analytical tools for specific catalytic applications and to explain their choice. Moreover the students are able to choose and formulate suitable reactor systems for the current synthesis process. Students can apply their knowledge discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them.
Study package 2a – Chemical Process Engineering – WiSe

Process Systems Engineering and Transport Processes | 6 ECTS

Recommended Previous Knowledge:
- Fundamentals in Fluid Dynamics
- Fundamentals of Heat & Mass Transport
- Particle Technology
- Separation Technology
- Reactor Design and Operation
- Fundamentals of Process Control

Theoretical Knowledge
The students are able to describe the transport processes in single- and multiphase flows. They are able to explain the analogy between heat- and mass transfer as well as the limits of this analogy. The students are able to write down the main transport laws and their application as well as the limits of application.

Students are able to:

  a. describe how transport coefficients for heat- and mass transfer can be derived experimentally,
  b. define fundamentals of process synthesis and process control,
  c. present and explain the hierarchical method of Douglas regarding process synthesis,
  d. interpret heat recovery systems,
  e. explain the pinch point method,
  f. illustrate the interactions in process control systems.

Capabilities
Students are able to:

  a. use transport processes for the design of technical processes.
  b. utilize methods of process synthesis to develop a whole production process
  c. conduct a thermal analysis of a process regarding the heat and cooling demands
  d. utilize the pinch point method
  e. develop and evaluate a process control system

Special Areas of Process Engineering | 6 ECTS – Interfaces and Colloids, Chemical Kinetics and Environmental Analysis

Recommended Previous Knowledge:
The students should have passed the Bachelor modules "Process Engineering" successfully.

Theoretical Knowledge
Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering.

Students are able to explain technical dependencies and models in selected special areas of Process Engineering.

Capabilities
Students are able to apply basic methods in selected areas of process engineering.
### Applied Thermodynamics: Thermodynamic Properties for Industrial Applications | 6 ECTS

**Recommended Previous Knowledge:**
Thermodynamics III

**Theoretical Knowledge**
The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions.

**Capabilities**
The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes.

### Separation Technologies for Life Sciences | 6 ECTS

**Recommended Previous Knowledge:**
Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Chemical Engineering, Bioprocess Engineering
Basic knowledge in thermodynamics and in unit operations related to thermal separation processes

**Theoretical Knowledge**
On completion of the module, students are able to present an overview of the basic thermal process technology operations that are used, in particular, in the separation and purification of biochemically manufactured products. Students can describe chromatographic separation techniques and classic and new basic operations in thermal process technology and their areas of use. In their choice of separation operation students are able to take the specific properties and limitations of biomolecules into consideration. Using different phase diagrams, they can explain the principle behind the basic operation and its suitability for bioseparation problems.

**Capabilities**
On completion of the module, students are able to assess the separation processes for bio- and pharmaceutical products that have been dealt with for their suitability for a specific separation problem. They can use simulation software to establish the productivity and economic efficiency of bioseparation processes. In small groups they are able to jointly design a downstream process and to present their findings in plenary and summarize them in a joint report.
Research Project Process Engineering | 6 ECTS

Recommended Previous Knowledge:
Advanced state of knowledge in the master program of Process Engineering

Theoretical Knowledge
Students know current research topics of the institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related research.

Capabilities
Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alternative approaches with their own with regard to given criteria.

The student can choose the Professor related to his/her specialisation following this link: https://www.tuhh.de/alt/verfahrenstechnik/institutes.html.
Study packages 2b – Chemical Process Engineering – SoSe

**Heterogeneous Catalysis | 6 ECTS**

**Recommended Previous Knowledge:**
Content of the bachelor-modules “process technology”, as well as particle technology, fluid mechanics in process-technology and transport processes.

**Theoretical Knowledge**
The students are able to apply their knowledge to explain industrial catalytic processes as well as indicate different synthesis routes of established catalyst systems. They are capable to outline dis-/advantages of supported and full-catalysts with respect to their application. Students are able to identify analytical tools for specific catalytic applications.

**Capabilities**
After successful completion of the module, students are able to use their knowledge to identify suitable analytical tools for specific catalytic applications and to explain their choice. Moreover, the students are able to choose and formulate suitable reactor systems for the current synthesis process. Students can apply their knowledge discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them.

**High Pressure Chemical Engineering | 6 ECTS**

**Recommended Previous Knowledge:**

**Theoretical Knowledge**
After a successful completion of this module, students can:

- explain the influence of pressure on the properties of compounds, phase equilibria, and production processes,
- describe the thermodynamic fundamentals of separation processes with supercritical fluids,
- exemplify models for the description of solid extraction and countercurrent extraction,
- discuss parameters for optimization of processes with supercritical fluids.

**Capabilities**
After successful completion of this module, students are able to:

- compare separation processes with supercritical fluids and conventional solvents,
- assess the application potential of high-pressure processes at a given separation task,
- include high pressure methods in a given multistep industrial application,
- estimate economics of high-pressure processes in terms of investment and operating costs,
- perform an experiment with a high pressure apparatus under guidance,
- evaluate experimental results,
- prepare an experimental protocol.

**Waste and Energy | 6 ECTS**

**Recommended Previous Knowledge:**
Basics of process engineering

**Theoretical Knowledge**
Students are able to describe and explain in detail techniques, processes and concepts for treatment and energy recovery from wastes.

**Capabilities**
The students are able to select suitable processes for the treatment and energy recovery of wastes. They can evaluate the efforts and costs for processes and select economically feasible treatment Concepts. Students are able to evaluate alternatives even with incomplete information. Students are able to prepare systematic documentation of work results in form of reports, presentations and are able to defend their findings in a group.

**Molecular Modelling and Computational Fluid Dynamics | 6 ECTS**

**Recommended Previous Knowledge:**
- Mathematics I-IV
- Basic knowledge in Fluid Mechanics
- Basic knowledge in chemical thermodynamics

**Theoretical Knowledge**
After successful completion of the module the students are able to:

f. explain the basic principles of statistical thermodynamics (ensembles, simple systems)
g. describe the main approaches in classical Molecular Modelling (Monte Carlo, Molecular Dynamics) in various ensembles
h. discuss examples of computer programs in detail,
i. evaluate the application of numerical simulations,
j. list the possible start and boundary conditions for a numerical simulation.

**Capabilities**
The students are able to:

f. set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,
g. solve problems by molecular modelling,
h. set up a numerical grid,
i. perform a simple numerical simulation with OpenFoam,
j. evaluate the result of a numerical simulation.

**Research Project Process Engineering | 6 ECTS**

**Recommended Previous Knowledge:**
Advanced state of knowledge in the master program of Process Engineering

**Theoretical Knowledge**
Students know current research topics of the institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related research.

**Capabilities**
Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alternative approaches with their own with regard to given criteria.

The student can choose the Professor related to his/her specialisation following this link: [https://www.tuhh.de/alt/verfahrenstechnik/institutes.html](https://www.tuhh.de/alt/verfahrenstechnik/institutes.html).
Study package 3a – Environmental Process Engineering – WiSe

Bioresources and Biorefineries | 6 ECTS

**Recommended Previous Knowledge:**
Basics on engineering; basics of waste and energy management.

**Theoretical Knowledge**
Students can give an overview on principles and theories in the field’s bioresource management and biorefinery technology and can explain specialized terms and technologies.

**Capabilities**
Students are capable of applying knowledge and know-how in the field’s bioresource management and biorefinery technology in order to perform technical and regional-planning tasks. They are also able to discuss the links to waste management, energy management and biotechnology.

Rural Development and Resources Oriented Sanitation for different Climate Zones | 6 ECTS

**Recommended Previous Knowledge:**
Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation

**Theoretical Knowledge**
Students can describe resources oriented wastewater systems mainly based on source control in detail. They can comment on techniques designed for reuse of water, nutrients and soil conditioners.

Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world.

**Capabilities**
Students are able to design low-tech/low-cost sanitation, rural water supply, rainwater harvesting systems, measures for the rehabilitation of top soil quality combined with food and water security. Students can consult on the basics of soil building through “Holistic Planned Grazing” as developed by Allan Savory.

Waste Treatment Technologies | 6 ECTS

**Recommended Previous Knowledge:**
Chemical and biological basics

**Theoretical Knowledge**
The module aims possess knowledge concerning the planning of biological waste treatment plants. Students are able to explain the design and layout of anaerobic and aerobic waste treatment plants in detail, describe different techniques for waste gas treatment plants for biological waste treatment plants and explain different methods for waste analytics.

**Capabilities**
The students are able to discuss the compilation of design and layout of plants. They can critically evaluate techniques and quality control measurements. The students can recherché and evaluate literature and data connected to the tasks given in der module and plan additional tests. They are capable of reflecting and evaluating findings in the group.
Wastewater Treatment and Air Pollution Abatement | 6 ECTS

**Recommended Previous Knowledge:**
Basic knowledge of biology and chemistry and basic knowledge of solids process engineering and separation technology

**Theoretical Knowledge**
After successful completion of the module students are able to

a. name and explain biological processes for waste water treatment,

b. characterize waste water and sewage sludge

c. discuss legal regulations in the area of emissions and air quality

d. classify off gas treatment processes and to define their area of application.

**Capabilities**
The students are able to:

a. choose and design processes steps for the biological waste water treatment

b. combine processes for cleaning of off-gases depending on the pollutants contained in the gases

Special Areas of Process Engineering | 6 ECTS – Interfaces and Colloids, Chemical Kinetics and Environmental Analysis

**Recommended Previous Knowledge:**
The students should have passed the Bachelor modules "Process Engineering" successfully.

**Theoretical Knowledge**
Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering.

Students are able to explain technical dependencies and models in selected special areas of Process Engineering.

**Capabilities**
Students are able to apply basic methods in selected areas of process engineering.
**Study package 3b – Environmental Process Engineering – SoSe**

**Waste and Energy | 6 ECTS**

**Recommended Previous Knowledge:**
Basics of process engineering

**Theoretical Knowledge**
Students are able to describe and explain in detail techniques, processes and concepts for treatment and energy recovery from wastes.

**Capabilities**
The students are able to select suitable processes for the treatment and energy recovery of wastes. They can evaluate the efforts and costs for processes and select economically feasible treatment Concepts. Students are able to evaluate alternatives even with incomplete information. Students are able to prepare systematic documentation of work results in form of reports, presentations and are able to defend their findings in a group.

**Geochemical Engineering | 6 ECTS**

**Recommended Previous Knowledge:**
General and inorganic chemistry, organic chemistry, biology (basic knowledge)

**Theoretical Knowledge**
With the completion of this module students acquire profound knowledge of biogeochemical processes, the fate of pollutants in soil and groundwater, and techniques to deposit contaminated waste material. They are able to describe in principle the behaviour of chemicals in the environment. Students can explain and report the approach to remediate contaminated sites.

**Capabilities**
With the completion of this module students can apply the acquired theoretical knowledge to model cases of site pollution and critically assess the situation technically and conceptually. They are able to draw comparisons on different remediation strategies and techniques. Model projects can be devised and treated.

**Groundwater Modeling | 6 ECTS**

**Recommended Previous Knowledge:**
Groundwater hydrology; Hydromechanics

**Theoretical Knowledge**
Students are able to define typical aquifer types and the occurring flow and storage processes can be explained technically. They are able to derive the Darcy law and the mathematical description of flow processes as well as their solution. They are in a position to explain the physical background of well hydraulics. Fundamentals of solute transport can be reflected. They are able to use the flow and transport model MODFLOW/MT3D.

**Capabilities**
The students are able to build a concept model for ground water flow and to transfer this in a numerical flow model. They can use the model MODFLOW expertly and they are able to apply it for practical problems.

**Bioprocess and Biosystems Engineering | 6 ECTS**

**Recommended Previous Knowledge:**
Knowledge of bioprocess engineering and process engineering at bachelor level

**Theoretical Knowledge**
After completion of this module, participants will be able to:

a. differentiate between different kinds of bioreactors and describe their key features
b. identify and characterize the peripheral and control systems of bioreactors
c. depict integrated biosystems (bioprocesses including up- and downstream processing)
d. name different sterilization methods and evaluate those in terms of different applications
e. recall and define the advanced methods of modern systems-biological approaches
f. connect the multiple "omics"-methods and evaluate their application for biological questions
g. recall the fundamentals of modelling and simulation of biological networks and biotechnological processes and to discuss their methods
h. assess and apply methods and theories of genomics, transcriptomics, proteomics and metabolomics in order to quantify and optimize biological processes at molecular and process levels.

Capabilities
After completion of this module, participants will be able to:

a. describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess
b. plan and construct a bioreactor system including peripherals from lab to pilot plant scale
c. adapt a present bioreactor system to a new process and optimize it
d. develop concepts for integration of bioreactors into bioproduction processes
e. combine the different modelling methods into an overall modelling approach, to apply these methods to specific problems and to evaluate the achieved results critically
f. connect all process components of biotechnological processes for a holistic system view.

Molecular Modelling and Computational Fluid Dynamics | 6 ECTS

Recommended Previous Knowledge:
- Mathematics I-IV
- Basic knowledge in Fluid Mechanics
- Basic knowledge in chemical thermodynamics

Theoretical Knowledge
After successful completion of the module the students are able to:

a. explain the basic principles of statistical thermodynamics (ensembles, simple systems)
b. describe the main approaches in classical Molecular Modelling (Monte Carlo, Molecular Dynamics) in various ensembles
c. discuss examples of computer programs in detail,
d. evaluate the application of numerical simulations,
e. list the possible start and boundary conditions for a numerical simulation.

Capabilities
The students are able to:

a. set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,
b. solve problems by molecular modelling,
c. set up a numerical grid,
d. perform a simple numerical simulation with OpenFoam,
e. evaluate the result of a numerical simulation.