# Curriculum for Biomedical Engineering M.Sc.

## Content

BM=Specialisation Biomedicine; ME=Specialisation Medical Engineering

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<thead>
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<th>Course</th>
<th>Semesters</th>
<th>Page</th>
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</thead>
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<td>1st Sem. BM</td>
<td>2</td>
</tr>
<tr>
<td>2. Introduction to Medical Engineering</td>
<td>1st Sem. ME</td>
<td>3</td>
</tr>
<tr>
<td>3. Simulation</td>
<td>1st Sem.</td>
<td>4</td>
</tr>
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<td>4. Sensorics</td>
<td>1st Sem.</td>
<td>6</td>
</tr>
<tr>
<td>5. Modelling and Systems Theory</td>
<td>1st Sem.</td>
<td>8</td>
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<tr>
<td>6. Management competences</td>
<td>1st Sem.</td>
<td>10</td>
</tr>
<tr>
<td>7. Research practical biomedicine</td>
<td>2nd Sem. BM</td>
<td>11</td>
</tr>
<tr>
<td>8. Research practical medical engineering</td>
<td>2nd Sem. ME</td>
<td>12</td>
</tr>
<tr>
<td>9. Data management</td>
<td>2nd Sem. BM</td>
<td>13</td>
</tr>
<tr>
<td>10. Systembiologie</td>
<td>2nd Sem. BM</td>
<td>14</td>
</tr>
<tr>
<td>11. Medical Modelling</td>
<td>2nd Sem. ME</td>
<td>15</td>
</tr>
<tr>
<td>12. Signal processing</td>
<td>2nd Sem. ME</td>
<td>17</td>
</tr>
<tr>
<td>13. Advanced Medical Technologies</td>
<td>2nd Sem.</td>
<td>19</td>
</tr>
<tr>
<td>14. Electives part 1 and 2</td>
<td>2nd and 3rd Sem.</td>
<td>21</td>
</tr>
<tr>
<td>15. Thesis</td>
<td>2nd and 3rd Sem.</td>
<td>22</td>
</tr>
<tr>
<td>16. Oral Exam</td>
<td>3rd Sem.</td>
<td>23</td>
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</table>
## 1. Introduction to Biomedicine, 1st Sem. BM

### Introduction to Biomedicine

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits</th>
<th>Semester</th>
<th>Frequency of course</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Systembiological analysis of expression data</td>
<td>180 h</td>
<td>6</td>
<td>1</td>
<td>once a year</td>
<td>1 semester</td>
</tr>
<tr>
<td>b) Introduction into biomedicine</td>
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</table>

<table>
<thead>
<tr>
<th>Language</th>
<th>Contact hours</th>
<th>Self study</th>
<th>Class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>a) 2 SWS (22.5h)</td>
<td>a) 67.5</td>
<td>a) 12</td>
</tr>
<tr>
<td></td>
<td>b) 2 SWS (22.5h)</td>
<td>b) 67.5</td>
<td>b) 12</td>
</tr>
</tbody>
</table>

### 2. Learning outcome

#### Application (3):
- describe the range of approaches and methods in biomedicine
- understand the main principles of biomedicine especially in the field of expression analysis and its systembiological modelling as well as in the field of molecular therapies
- apply specific methods of gene expression analysis and mathematical modeling of biological processes via ordinary differential equations

#### Analysis (4) / Synthesis (5):
- evaluate and explain results in a scientific presentation
- determine parameters and settings required for successful performance of the expression analysis and the mathematical modeling
- determine robustness and noise sensitivity of the biomedical measurement system
- understand the basic principles of mathematical modelling of biological processes
- outline and present the ideas of scientific publications in the field of biomedicine and discuss their contents critically in relation to the state of the art

### 3. Content

#### a) From biological data to mathematical model:
- determine gene expression of stimulated and unstimulated eukaryotic cells by the appropriate methods
- quantitatively analyze the expression data using internal standards
- determine suitable parameters for mathematical modeling of the expression data
- mathematical modeling of the expression data using ordinary differential equations

#### b) Introduction into the principles of biomedicine
- recent developments in molecular therapy approaches

### 4. Teaching methods

- lecture, practical training,
- lecture, seminar

### 5. Prerequisites

- Basic knowledge of molecular biology and human biology
- Understanding of ordinary differential equations

### 6. Methods of assessment

- a) practical training and written report (50% each)
- b) introduction into biomedicine oral presentation (100%)

### 7. Applicability of module

- Mandatory module in BME

### 8. Person responsible for module /lecturer

- Margareta Müller

### 9. Literature

- a) Alberts, Molecular Biology of the Cell and script
- b) Alberts, Molecular Biology of the Cell and selected biomedical research publications
## 2. Introduction to Medical Engineering, 1st Sem. ME

### Introduction to medical engineering

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6</td>
<td>1</td>
<td>Once a year</td>
<td>1 Semester</td>
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</tbody>
</table>

#### Module

- a) Development of Blood pressure monitoring
- b) Introduction to medical Engineering

#### Teaching Language

- english

#### Contact hours

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<thead>
<tr>
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<th>a)</th>
<th>b)</th>
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<tbody>
<tr>
<td></td>
<td>2 SWS / 22,5 h</td>
<td>2 SWS / 22,5 h</td>
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#### Self-study

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<tr>
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<th>a)</th>
<th>b)</th>
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<tbody>
<tr>
<td></td>
<td>67,5 h</td>
<td>67,5 h</td>
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#### Class size

<table>
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<tr>
<th></th>
<th>a)</th>
<th>b)</th>
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<tbody>
<tr>
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<td>20</td>
<td>20</td>
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</table>

### Learning outcomes

On successful completion of this module you should be able to

#### Application (3):

- describe the range of applications and approaches in the field of Biomedical Engineering
- understand main principles in Biomedical Engineering especially in the field of modeling & simulation, measurement techniques and artificial organs
- apply methods of Biomedical Engineering to the specific application of blood pressure monitoring
- apply methods from electronics to tailor application specific solutions
- use standard software to analyze sound signals and design simple user interfaces

#### Analysis (4) / Synthesis (5):

- demonstrate and explain results in a scientific presentation
- determine parameters and settings required in electronic measurement systems
- determine robustness and noise sensitivity of a biomedical measurement system
- outline the ideas of relevant scientific publications, reproduce results and inspect for reproducibility
- understand mathematical problems in Biomedical Engineering and describe possible solutions to those

### Individual component content

#### a) From physiology to signal interpretation:

- Physiology of blood pressure
- Korotkoff method of blood pressure measurement
- Design of amplifiers
- Signal acquisition and analysis
- Simple interface programming

#### b) Overview of different fields of Biomedical Engineering:

- Physiological basis of organ systems
- Available measurements and their accuracy and robustness
- artificial organs e.g. artificial heart, kidney replacement, artificial limbs, cochlea implants, artificial retina
- modeling of organ systems
- optimization of therapeutic measures

### Teaching methods

- a) Lecture, Practical training
- b) Lecture, Seminar

### Prerequisites

Undergraduate programming, electronic circuits, signal analysis, :

- Physiology of organ system
- Signal acquisition, amplifier design, signal analysis

Basics of engineering and presentation skills:

- measurement devices
- engineering math
- scientific presentation

### Methods of assessment

- a) blood pressure monitor: 2 oral examinations on practical tasks (each 50%)
- b) Introduction to BioMedical Engineering: 1 presentation (100%)

### Applicability of module

Mandatory module in BME/elective in other study programs if places are available

### Person responsible for module/ lecturer

Knut Möller / Jan Zijlstra

### Reading list (Core texts and recommended texts)

### 3. Simulation, 1st Sem.

**Simulation**

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6</td>
<td>1</td>
<td>Once a year</td>
<td>1 Semester</td>
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</table>

#### Module

<table>
<thead>
<tr>
<th>Module</th>
<th>Teaching Language</th>
<th>Contact hours</th>
<th>Self-study</th>
<th>Class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Simulationstechnik (Simulation)</td>
<td>english</td>
<td>a) 2 SWS / 22.5 h</td>
<td>a) 67.5 h</td>
<td>a) 30</td>
</tr>
<tr>
<td>b) Computermathematik</td>
<td></td>
<td>b) 2 SWS / 22.5 h</td>
<td>b) 67.5 h</td>
<td>b) 30</td>
</tr>
</tbody>
</table>

#### Learning outcomes

On successful completion of this module you should be able to

**Application (3):**
- describe and generalize mathematical models for processes
- solve initial value problems numerically
- apply the Method of Lines to translate a partial differential equation to a system of ordinary differential equations
- apply methods of parameter identification to identify parameters of static and dynamic systems based on measured data
- implement dynamic systems in SIMULINK and design closed-loop controllers

**Analysis (4) / Synthesis (5):**
- calculate steady states and analyze their stability
- determine parameters in dynamical systems
- outline the ideas of relevant scientific publications, reproduce results and inspect for reproducibility
- understand mathematical problems and solve these by implementing appropriate algorithms in MATLAB
- compile graphical user interfaces and implement methods to prevent user based software errors.

#### Individual component content

**a) Ordinary differential equations:**
- Steady states, asymptotic stability
- Numerical solution with MATLAB ODE solvers
- Reaction kinetics: enzyme reactions, pseudo steady state hypothesis
- fitting ODE parameters
- Numerical solution of partial differential equations: Method of lines

**b) MATLAB/SIMULINK programming skills:**
- vector based calculus
- import, export and graphic representation of data and simulation results
- functions and scripts for automated execution of algorithms
- parameter identification using MATLAB functions
- compiling graphical user interfaces using MATLAB GUIDE
- toolboxes and blocksets in SIMULINK
- implementing dynamic systems in SIMULINK
- SIMULINK based controller design

#### Teaching methods

a) Lecture, MATLAB exercises
b) Lecture, MATLAB exercises

#### Prerequisites

**Undergraduate Mathematics:**
- Matrices: systems of linear equations, determinant;
- Calculus: (partial) derivatives, elementary differential equations

**Basics of text based programming:**
- Boolean algebra
- Basic algorithms (loops, conditions)
- Use of functions/methods, local and global variables

#### Methods of assessment

a) Simulation: 1 written examination (50%), 1 presentation (50%)
b) Computermathematic: 1 assignment (100%)

#### Applicability of module

Mandatory module in BME/elective in other study programs

#### Person responsible for module/ lecturer

Prof. Dr. Edgar Jäger / Dr. Jörn Kretschmer
<table>
<thead>
<tr>
<th>Reading list (Core texts and recommended texts)</th>
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<tbody>
<tr>
<td>MATLAB GUIDE toolbox tutorial:</td>
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4. Sensorics, 1st Sem.

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>a) Microcontroller Programming</td>
<td>180 h</td>
<td>6</td>
<td>1</td>
<td>Frequency of module</td>
<td>1 Semester</td>
</tr>
<tr>
<td>b) Sensorik</td>
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</tbody>
</table>

- Teaching Language | Contact hours | Self-study | Class size |
- English | 20 h | a) 70 h | a) 30 |
- | 2 SWS / 22,5 h | b) 67,5 h | b) 30 |

2 Learning outcomes

On successful completion of this module you should be able to

a) Application (3):
- apply bitwise operators to access individual pins
- employ interrupt service routines in order to react to events
- diagnose programming errors by using the debugger
- apply print/scan customization to direct input/output to specific hardware

Analysis (4):
- appraise algorithms by simulating external signals

b) Application (3):
- calculate the transfer functions of various sensor interfaces
- develop methods of signal processing of biomedical signals
- design biomedical measurement systems

Analysis (4):
- analyse the transfer functions of sensor interfaces
- examine biomedical measurement systems

3 Individual component content

a) C Basics:
- Local/global variables
- Projects consisting of several source files
- Preprocessor directives
- Console output/keyboard input
- Pointers
- Bitwise operators
- Digital I/O, Interrupts
- Analog-to-Digital Conversion
- RS232 communication, I2C bus, customizing printf/scanf, LCD output

b) Biomedical sensors
- General biomedical signal processing
- Origin and characteristics of biomedical signals
- Biopotential amplifiers
- Analog signal processing
- Digital signal processing
- General requirements for safety
- Electrocardiogram
- Electroencephalogram
- Electromyogram
- Invasive and noninvasive blood pressure measurement
- Infrared temperature measurement
- Ultrasound measurement systems
- Magnetic resonance imaging
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| 4 | **Teaching methods**  
a) Blended learning: Online material, tutorials, presence date  
b) Lecture, student's projects |
| 5 | **Prerequisites**  
a) Basics of text based programming  
b) Basics of electrical engineering and electronics, basics in anatomy and electrophysiology |
| 6 | **Methods of assessment**  
a) Microcontroller programming: elaboration assignments  
b) 1 written examination (70%), 1 presentation (30%) |
| 7 | **Applicability of module**  
Mandatory module in BME/elective in other study programs |
| 8 | **Person responsible for module/ lecturer**  
Prof. Dr. Bernhard Vondenbusch / Prof. Dr. Edgar Jäger |
| 9 | **Literature**  
(Core texts and recommended texts)  
http://publications.gbdirect.co.uk/c_book/  
## Modelling and Systems Theory, 1st Sem.

### Modelling and systems theory

<table>
<thead>
<tr>
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<th>Workload</th>
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<th>Semester</th>
<th>Frequency of course</th>
<th>Duration</th>
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<td>Module</td>
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<tr>
<td></td>
<td>a) modeling</td>
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<td></td>
<td>b) systems theory</td>
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<tr>
<td>2</td>
<td>Language</td>
<td></td>
<td>Contact hours</td>
<td>Self study</td>
<td>Class size</td>
</tr>
<tr>
<td></td>
<td>english</td>
<td></td>
<td>a) 2 SWS / 22,5 h</td>
<td>a) 37,5 h</td>
<td>a) 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) 2 SWS / 22,5 h</td>
<td>b) 37,5 h</td>
<td>30</td>
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</table>

### Learning outcome

#### Knowledge (1):
- Upon successful completion of the module you should be able to:
  - Know the terminology and basic principles of control theory

#### Understanding (2):
- Upon successful completion of the module you should be able to:
  - Understand modeling (for) in the context of controlled systems and processes
  - Understand the difference between open and closed loop control and (are) be able to illustrate the mathematical principles of controlled systems in Laplace and time scale.
  - Design a speed and position controlled system

#### Application (3):
- Upon successful completion of the module you should be able to:
  - Mathematically describe power systems with elastically coupled mechanical structures
  - Determine the stability of open and closed loop systems
  - Establish mathematical models (ordinary differential equations) of different controlled systems

#### Analysis (4):
- Upon successful completion of the module you should be able to:
  - Analyze the statistical and dynamical behavior of controlled systems in both time and frequency domain and determine their characteristics and physical parameters
  - Determine the resulting behavior of controlled systems for different inputs in the time domain and transform them into the frequency domain
  - Construct a P-Controller as well as a cascading P- and PI-Controller
  - Evaluate the quality of a controlled system and its dynamical behavior
  - Graph a Bode-diagram of the frequency domain of controlled systems
  - Analyze the systems behavior using the Nyquist theorem and determine the amplification factor of a controlled system

### Content

- a) and b:
  - Modeling of power systems and mechanical transmission elements
  - Laplace-transformation
  - Input and output signals in time and frequency domain
  - Behavior of controlled systems in the time domain establishment of characteristics and physical parameters
  - Pole zero plot
  - Transfer elements and their transfer functions
  - Block diagram
  - Frequency response, Bode diagram, Nyquist plot
  - Stability parameters, Hurwitz criterion, central limiting value theorem
  - Linear controlled systems, Nyquist method
  - P-/PI control

### Teaching methods

- a) lecture
- b) lecture

### Prerequisites

- a) and b:
  - Basics of measurement and control theory, technical mechanics 1 and 2, dynamics, mathematics for engineers, physics

### Methods of assessment

- One written exam

### Applicability of module

- Mandatory module in BME/elective in other study programs

### Person responsible for module/lecturer

- Prof. Dr. Ketterer
| Literature  
a) & b) |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>H. Lutz,</td>
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<td>O. Föllinger</td>
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<td>R. Isermann</td>
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<td>H. Unbehauen</td>
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<td>S. Zacher</td>
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<thead>
<tr>
<th>Module Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Semester</th>
<th>Frequency of course</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180 h</td>
<td>6</td>
<td>1</td>
<td>once a year</td>
<td>1 semester</td>
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</table>

<table>
<thead>
<tr>
<th>Module</th>
<th>Language</th>
<th>Contact hours</th>
<th>Self-study</th>
<th>Class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Project management</td>
<td>English</td>
<td>2 SWS (22.5h)</td>
<td>a) 67.5h</td>
<td>a) 24</td>
</tr>
<tr>
<td>b) Human machine interface or experimental design</td>
<td></td>
<td>2 SWS (22.5h)</td>
<td>b) 67.5h</td>
<td>b) 24</td>
</tr>
<tr>
<td>c) Language or any other course with management content</td>
<td></td>
<td>2 SWS (22.5h)</td>
<td>c) 67.5h</td>
<td>c) 24</td>
</tr>
</tbody>
</table>

2 Learning outcome
On successful completion of this module you should be able to

**Comprehension (2) / Application (3):**
- a) understand the criteria that defined a project (SMART) and the differences between project and process
- b) describe and understand the different approaches to project management
- c) describe and understand the tools for planning and steering of projects

**Analysis (4) / Synthesis (5):**
- a) understand and apply the basic principles of scientific writing in the generation of a scientific/experimental paper
- b) gain management competences depending on content of course

3 Content
- a) from idea to successful completion of a project:
  - Project ideas and start –up, time scale and project structure, risk management and decision techniques, content of grant applications, and contracts, documentation, tools of project management (e.g. SWOT analysis, magic triangle, etc.)
- b) experimental from data to scientific publication
  - scientific writings the core objective, exercises are done with the important field of human machine interfaces
- c) depends on course chosen

4 Teaching methods
- a) lecture,
- b) lecture, seminar
- c) depends on course chosen

5 Prerequisites
Basic knowledge of literature search
Understanding of scientific publications

6 Methods of assessment
- a) written exam
- b) written paper (50%) and oral presentation (50%)
- c) depends on course chosen

7 Applicability of module
Mandatory module in BME/ elective in other study programs

8 Person responsible for module / lecturer
Margareta Müller

9 Literature
## Research practical biomedicine, 2nd Sem. BM

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credits</th>
<th>Semester</th>
<th>Frequency of course</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6</td>
<td>2</td>
<td>once a year</td>
<td>1 semester</td>
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### Module
Forschungspraktikum

### Language
English

### Contact hours
2 SWS (22,5h)

### Self study
157,5

### Class size
20 in groups of one or 2 students

### Learning outcome
On successful completion of this module you should be able to

**Analysis (4):**
- Plan and perform scientific investigations in the field of biomedicine
- Perform a focused literature research on the chosen research topic, evaluate and summarize the relevant state of the art

**Synthesis (5):**
- Apply methods of biomedical research to a specific project
- Analyze and evaluate your data, perform statistical analysis of data

**Evaluation (6):**
- Evaluate different approaches to the solution of your experimental
- Describe your results in a scientific report comparable to a research publication
- Summarize and explain results in a scientific (oral) presentation

### Content
From project description to scientific publication:
- Specification of project, especially formulation of a clear objective
- Summary of the state of the art
- Selection and realization of appropriate methods
- Perform experiments to obtain significant results
- Critical discussion of the relevance of the obtained results
- Formulation of a proper conclusion
- Short presentation highlighting the main findings

### Teaching methods
Lecture, practical training, presentation

### Prerequisites
Dependent on the topic chosen including basic knowledge of molecular and cell biology, selected biomedical methods, scientific writing and presentation

### Methods of assessment
- a) Research (50%)
- b) Written report (30%)
- c) Presentation (20%)

### Applicability of module
Mandatory module in BME/elective in other study programs

### Person responsible for module / lecturer
Prof. Dr. Margareta Müller

### Literature
Alberts, Molecular Biology of the Cell and selected biomedical research publications dependent on the topic chosen
8. Research practical medical engineering, 2nd Sem. ME

<table>
<thead>
<tr>
<th>Module code</th>
<th>Workload</th>
<th>Credits/CP</th>
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<tbody>
<tr>
<td>Forschungspraktikum</td>
<td>180 h</td>
<td>6</td>
<td>2</td>
<td>Once a year</td>
<td>1 Semester</td>
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</tbody>
</table>

| Learning outcomes |  
|---|---
| **Analysis (4):** |  
| - plan and perform scientific investigations in the field of Biomedical Engineering |  
| - perform a focused literature research, evaluate and summarize the relevant state of the art |  
| **Synthesis (5):** |  
| - apply methods of Biomedical Engineering to a specific application |  
| - perform statistical analysis on experimental data |  
| **Evaluation (6):** |  
| - evaluate the quality of different approaches, |  
| - describe your work in a scientific report comparable to reports published on international conferences |  
| - summarize and explain results in a scientific presentation |  

| Individual component content |  
|---|---
| From project description to scientific publication: |  
| - specification of project, especially formulation of a clear objective |  
| - Summarize the state of the art |  
| - selection and realization of appropriate methods |  
| - perform experiments to obtain significant results |  
| - discussion and critical review of the relevance of your obtained solution |  
| - formulation of a proper conclusion |  
| - short presentation of your research highlighting the main findings |  

| Teaching methods |  
|---|---
| lecture, practical training, presentations |  

| Prerequisites |  
|---|---
| Undergraduate programming, electronic circuits, signal analysis |  
| - basic understanding of medical concepts |  
| - Signal acquisition, signal analysis |  
| - optimization, model design Scientific writing and presentation skills: |  

| Methods of assessment |  
|---|---
| - research (50%) |  
| - written report (30%) |  
| - presentation (20%) |  

| Applicability of module |  
|---|---
| Mandatory module in BME/elective in other study programs |  

| Person responsible for module/ lecturer |  
|---|---
| Prof. Dr. Knut Möller |  

| Literature |  
|---|---
| Reading list (Core texts and recommended texts) |  
| Special scientific papers to be searched in relevant databases depending on the subject of research |
### Data management, 2nd Sem. BM

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6</td>
<td>2. semester</td>
<td>yearly</td>
<td>1 semester</td>
</tr>
</tbody>
</table>

#### Module
- a) Datenbanksysteme
- b) Statistik

#### Teaching Language
- German or English

#### Contact hours
- a) 2 SWS / 22.5 h
- b) 2 SWS / 22.5 h

#### Self-study
- a) 67.5 h
- b) 65.5 h

#### Class size
- a) 20 students
- b) 20 students

### Learning outcomes

Upon successful completion of the module the students are able to:

**Analysis (4):**
- carry out database queries in several important databases
- apply p value adjustment in multiple testing

**Synthesis (5):**
- summarise biological information for biomedical problems
- explain the results of unsupervised and supervised statistical learning methods

**Evaluation (6):**
- assess the information contained in biological databases
- validate the results of supervised statistical learning methods

### Individual component content

- a) Biological databases, protein sequences, similarity searches, protein domains, protein structure, enzyme kinetics, mathematical models, biological networks
- b) Multiple testing, hierarchical clustering, partitioning, principal component analysis, multidimensional scaling, performance measures, feature selection, discriminant analysis, generalized partial least squares, k-nearest neighbours, decision trees, random forest, support vector machines

### Teaching methods
- a) and b) Lecture with exercises

### Prerequisites

Module Einführung in die Biomedizin should be completed, basic knowledge in mathematics and statistics

### Methods of assessment

- a) Written report (during semester, 3 LP)
- b) Written report (during semester, 3 LP)

### Applicability of module

Mandatory module in BME/elective in other study programs

### Person responsible for module/lecturer

Prof. Kohl

### Literature

(Core texts and recommended texts)
## 10. Systembiologie, 2nd Sem. BM

### Systembiologie

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Bioinformatik</td>
<td>180 h</td>
<td>6</td>
<td>2. semester</td>
<td>yearly</td>
<td>1 semester</td>
</tr>
<tr>
<td>b) Systembiologie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching Language</th>
<th>Contact hours</th>
<th>Self-study</th>
<th>Class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>German or English</td>
<td>a) 2 SWS / 22.5 h</td>
<td>a) 67.5 h</td>
<td>a) 20 students</td>
</tr>
<tr>
<td>b) 2 SWS / 22.5 h</td>
<td>b) 65.5 h</td>
<td>b) 20 students</td>
<td></td>
</tr>
</tbody>
</table>

#### 2 Learning outcomes

After visiting this module, students are able to

**Analysis (4):**
- carry out parameter estimation in systems biology models
- model biochemical reactions
- execute pairwise sequence alignments

**Synthesis (5):**
- explain models for molecular events
- explain sequence motifs and profiles

**Evaluation (6):**
- compare systems biology models
- describe scoring schemes

#### 3 Individual component content

- a) Pairwise alignment of sequences, distances and similarity measures, sequence motifs, sequence profiles, scoring schemes, FASTA, BLAST, extensions of BLAST
- b) Basic mathematics, excitable systems, stochastic differential equation, FitzHugh-Nagumo model, continuous models, models for molecular events, modelling of biochemical reactions, dynamic models of gene regulation, parameter estimation

#### 4 Teaching methods

- a) and b) Lecture with exercises

#### 5 Prerequisites

Module Einführung in die Biomedizin should be completed, basic knowledge in mathematics and statistics

#### 6 Methods of assessment

- a) Written exam (50%, 3 LP)
- b) Written report (during semester, 50%, 3 LP)

#### 7 Applicability of module

Mandatory module in the master course Biomedical Engineering, electoral module for other master courses

#### 8 Person responsible for module/ lecturer

Module: Prof. Kohl
Lectures: Prof. Kohl, contract lecturer

#### 9 Literature

(Core texts and recommended texts)
# 11. Medical Modelling, 2nd Sem. ME

## Module Overview

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Physiological Modeling</td>
<td>180 h</td>
<td>6</td>
<td>2</td>
<td>Once a year</td>
<td>1 Semester</td>
</tr>
<tr>
<td>b) System Identification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Teaching Language
- Physiological Modeling: English
- System Identification: English

### Contact Hours
- a) 2 SWS / 22.5 h
- b) 2 SWS / 22.5 h

### Self-study
- a) 67.5 h
- b) 67.5 h

### Class size
- a) 20
- b) 20

## Learning Outcomes

### Comprehension (2) / Application (3):
- understand the concept of system identification
- describe different approaches to prove identifiability
- understand the importance of identifiability in model based therapy in Medicine

### Analysis (4) / Synthesis (5):
- compare different modeling approaches
- analyze properties of model formulations e.g. computational complexity, stability, identifiability
- develop own models and derive formal mathematical representations
- understand mathematical problems and solve these by implementing appropriate algorithms in MATLAB
- combine approaches on different levels to "multi-level" models
- derive simple approaches for model-based optimization in medical applications

### Evaluation (6):
- demonstrate and explain results in a scientific presentation
- determine model parameters in dynamical systems
- analyze robustness of system, identify sensitivity on parameter settings.

## Individual Component Content

### a) From physiology to mathematical representations:
- Physiology of gas exchange, pulmonary mechanics, cardio-vascular systems
- Modeling basics, system equations, transforms
- Mathematical representations
- Sensitivity analysis
- hierarchically structured models

### b) From mathematical representations to therapeutic decisions:
- Signal acquisition and evaluation
- System identification, structural, practical identifiability
- identification in hierarchies of models

## Teaching Methods

### a) Lecture, practical training
### b) Lecture, practical training

## Prerequisites

- Undergraduate programming, electronic circuits, signal analysis:
  - Physiology of organ systems
  - Signal acquisition, amplifier design, signal analysis

Basics of engineering and presentation skills:
- measurement devices
- engineering math
- scientific presentation

## Methods of Assessment

### a) physiological modeling: 1 written paper (60%), 1 oral presentation (40%)
### b) system identification: homework assignments, final exam (100%)

## Applicability of Module

Mandatory module in BME/elective in other study programs

## Person Responsible for Module/ Lecturer

Prof. Dr. Knut Möller
Literature (Core texts and recommended texts)


### Signal processing

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits/CP</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Image processing, Computer Graphics, Biosignal-Processing</td>
<td>180 h</td>
<td>6</td>
<td>Once a year</td>
<td>1 Semester</td>
</tr>
</tbody>
</table>

#### Learning outcomes

On successful completion of this module you should be able to

**a)**

**Application (3):**
- apply different methods of image processing
- apply different tools of image processing

**Analysis (4):**
- realize application possibilities of image processing
- assess results of image processing
- optimize methods of image processing

**b)**

**Application (3):**
- design a system for digital signal processing
- apply various window functions during discrete Fourier transform
- calculate parameters of digital filters
- apply different methods for coding / decoding of biosignals
- design systems for pattern recognition

**Analysis (4):**
- analyze the transfer functions of discrete systems in time and frequency domain
- assess results of a discrete Fourier transform and optimize the result
- optimize digital filters
- optimize systems for problem dependant pattern recognition

#### Individual component content

**a)**
- Digitalization, histogram, Fourier-Transform, filtering, texture, classification, 3D-imaging, segmentation methods, colour quantification, data compression methods, JPEG, Wavelet-Transform, Radon-Transform

**b)**
- Digital Signal Processors
- Sampling and analog-digital/digital-analog conversion
- Discrete signals and systems
- Z-Transform, Discrete Fourier Transform
- Design of digital filters (FIR/IIR)
- Coding and decoding of signals
- Methods of pattern recognition

#### Teaching methods

**a)** seminar
**b)** Lecture, student's projects

#### Prerequisites

**a)** Basic Mathematics
**b)** Basics of electrical engineering and electronics

#### Methods of assessment

**a)** Presentation & summary paper
**b)** 1 written examination (70%), 1 presentation (30%)

#### Applicability of module

Mandatory module in BME/elective in other study programs

#### Person responsible for module/ lecturer

Module: Prof. Dr. U. Busolt
Lecturer: Prof. Dr. U. Busolt / Prof. Dr. Bernhard Vondenbusch
<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Core texts and recommended texts)</td>
</tr>
</tbody>
</table>
### Advanced Medical Technologies, 2nd Sem.

**Workload** | 180 h  
 Credits/CP | 6  
 Semester | 1  
 Frequency of module | Once a year  
 Duration | 1 Semester  

<table>
<thead>
<tr>
<th>Module</th>
<th>Teaching Language</th>
<th>Contact hours</th>
<th>Self-study</th>
<th>Class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Minimal Invasive Medicine / Technologies</td>
<td>English</td>
<td>a) 2 SWS / 22.5 h</td>
<td>a) 67.5 h</td>
<td>a) 30</td>
</tr>
<tr>
<td>b) Artificial Organs</td>
<td></td>
<td>b) 2 SWS / 22.5 h</td>
<td>b) 67.5 h</td>
<td>b) 30</td>
</tr>
</tbody>
</table>

### Learning outcomes

On successful completion of this module you should be able to

**Application (3):**
- understand how to use Artif. Org. in an optimal manner (machine and device)
- decide upon parameters like external blood flow, pressures, etc..
- provide ideas for further development of Artif. Org.
- discuss features of minimally invasive diagnostic and surgical techniques with surgeons

**Analysis (4):**
- understand basics in mass transfer of most important components
- identify shortcomings of currently available surgical instrumentation
- analyse the requirements for instruments and equipment needed to implement new techniques

**Synthesis (5):**
- develop ideas for the technical implementation of new techniques

### Individual component content

**a) Minimally Invasive Med.:**
- Basic techniques of minimally invasive medicine (e.g. laparoscopy, endoscopy)
- Technical requirements: instruments, endoscopy, electrosurgery, navigation, manipulator systems, diagnostic systems
- Advanced optical methods in diagnosis and treatment
- Recent developments: NOTES, ....

**b) Artificial Organs:**
- Principles of membrane Processes
- Manufacturing of Membranes / Modules
- Basics about individual processes (machines,..)

### Teaching methods

**a)** Lecture, Presentations, Excursion (Endoscopy department or Manufacturer)
**b)** Lecture, Exercises, Excursion to Manufacturer of Art. Organs and Machines for Appl.

### Prerequisites

**a) Minimal Invasive Medicine / Technologies**
- Basics of medical nomenclature and human anatomy
- Basic knowledge of surgical techniques and instrumentation
- Basic knowledge in optics, electricity and mechanics

**b) Process Engineering:**
- Mass Balances, Concentrations,..
- Basics in Diffusion, Convection, Phase Equilibria...
- Basics in fluid dynamic (laminar flow, dimensionless numbers, etc.)

### Methods of assessment

**a)** 1 written examination (50%)
**b)** 1 written examination (50%)

### Applicability of module

Mandatory module in BME/elective in other study programs

### Person responsible for module/ lecturer

Module: Prof. Dr. Manfred Raff
Lecture: Prof. Dr. Manfred Raff / Dr. habil. Ludger Schnieder
9 | Literature
---
## Electives part 1 and 2, 2nd and 3rd Sem.

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits</th>
<th>Semester</th>
<th>Frequency of module</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 courses comprising at least 9 credits</td>
<td>330 h</td>
<td>9</td>
<td>2nd and 3rd semester</td>
<td>twice a year</td>
<td>1 semester</td>
</tr>
</tbody>
</table>

### Language
German or English

### Contact hours
Dependent upon course chosen

### Self study
Dependent upon course chosen

### Class Size
Dependent upon course chosen

### Learning outcome
The modules allow the students to acquire in depth knowledge / consolidate existing knowledge in the field of medical technology, biomedicine and scientific competences. The detailed learning outcome depends upon the course chosen and can be found in the respective module description.

### Content
Dependent upon the course chosen.

### Teaching methods
Dependent upon the course chosen.

### Prerequisite
Dependent upon the course chosen.

### Assessment methods
Dependent upon the course chosen.
At least 4 courses amounting to at least 8 credits must be completed with a graded assessment (Prüfungsleistung/PL).

### Applicability of module
Mandatory module in BME/elective in other study programs.

### Person responsible for module/lecturer
Module: Dean of study course
Lecturer: dependent upon the course chosen

### Literature
Dependent upon the course chosen

<table>
<thead>
<tr>
<th>Module</th>
<th>Workload</th>
<th>Credits</th>
<th>Semester</th>
<th>Frequency of course</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Thesis</td>
<td>720 h</td>
<td>24 (22/2)</td>
<td>3</td>
<td>each semester</td>
<td>1 semester</td>
</tr>
<tr>
<td>b) Thesis Seminar</td>
<td>Language</td>
<td>Contact hours</td>
<td>Self study</td>
<td>Class size</td>
<td></td>
</tr>
<tr>
<td>German or English</td>
<td>a) 22 h</td>
<td>b) 2SWS (22.5h)</td>
<td>677.5</td>
<td>a) 24 in group sizes of one</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) 24 S</td>
<td></td>
</tr>
</tbody>
</table>

2 Learning outcome

The thesis project can be done as a research project at the HFU or in a company. Students can also choose a thesis project abroad to gain additional social and language competence.

On successful completion of this module you should be able to

Application (3):
- organize and plan a scientific project independently
- chose the appropriate methods for a scientific project on the basis of the current scientific knowledge
- implement a thesis report summarizing a research project
- analyze and presents defined topics of higher complexity based on current scientific knowledge and methods

Analysis (4):
- critically analyse and evaluate a scientific project and include the results of this analysis in the future development of the project
- critically discuss a scientific project on the basis of current knowledge
- select the key results of a project die(?) and analyze and present them in the context of current scientific knowledge and literature.

3 Content
a) scientific realization and summary of a chosen thesis project
b) Presentation of the thesis project

4 Teaching methods
a) master-thesis
b) presentation

5 Prerequisites
Dependent on the topics chosen

6 Methods of assessment
a) 1 thesis (80%)
b) 1 presentation (20%)

7 Applicability of module
Mandatory module in BME

8 Person responsible for module / lecturer
Dean of study course
Primary supervisor: HFU professors and staff,
Secondary supervisor: HFU professors and staff, visiting lecturer, external supervisor

9 Literature
Dependent on the topic chosen
### Oral Exam, 3rd Sem.

<table>
<thead>
<tr>
<th><strong>Oral Exam</strong></th>
<th><strong>Workload</strong></th>
<th><strong>Credits</strong></th>
<th><strong>Semester</strong></th>
<th><strong>Frequency of course</strong></th>
<th><strong>Duration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 h</td>
<td>3</td>
<td>3</td>
<td>twice a year</td>
<td>1 semester</td>
</tr>
<tr>
<td><strong>1 Module</strong></td>
<td>Language</td>
<td>Contact hours</td>
<td>Self study</td>
<td>Class size</td>
<td></td>
</tr>
<tr>
<td>Oral exam</td>
<td>English</td>
<td>0.5h</td>
<td>89.5h</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>2 Learning outcome</strong></td>
<td>On successful completion of this module you should be able to:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Comprehension (2):</strong></td>
<td>Reproduce a broad spectrum of study related knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Describe methods of scientific work and studies</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Understand the selected fields of science and engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Application (3):</strong></td>
<td>select and apply appropriate methods and instruments for defined scientific questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analysis (4):</strong></td>
<td>independently comprehend and describe a defined topic of science or engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Synthesis (5):</strong></td>
<td>independently research and structure a defined topic of science and/or engineering to orally present it in a short comprehensive way and discuss it on the background of the state of the art</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3 Content</strong></td>
<td>The content includes the knowledge of all module of the 3 semester master course, and consists of at least two modules of the lecturers involved in the exam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4 Teaching methods</strong></td>
<td>preparation for self study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5 Prerequisites</strong></td>
<td>Maximally 2 module exams of the 3 semester master course can be open</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6 Methods of assessment</strong></td>
<td>Oral exam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7 Applicability of module</strong></td>
<td>Mandatory module in BME</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>8 Person responsible for module /lecturer</strong></td>
<td>Module: dean of study course</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lecturer: all HFU professors of the study course BME</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>9 Literature</strong></td>
<td>is given by the lecturer of the selected topics</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>