TECHNISCHE HOCHSCHULE DEGGENDORF

Module Guide
Life Science Informatics

Faculty Computer Science
Examination regulations 31.03.2021
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Table of Contents

LSI-01 Mandatory Elective Course (FWP)

Module code	LSI-01
Module coordination	Dr. Stefan Fischer
Course number and name	Mandatory Elective Course LSI-01-1 Informatics LSI-01-1 Informatics (FWP-1) LSI-01-2 Biomedicine LSI-01-2 Biomedicine (FWP-2)
Lecturers	Dr. Stefan Fischer Prof. Dr. Melanie Kappelmann-Fenzl Prof. Dr. Phillipp Torkler
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	compulsory course, required course
Level	Postgraduate
Semester periods per week (SWS)	16
ECTS	5
Workload	Time of attendance: 180 hours self-study: 135 hours virtual learning: 135 hours Total: 450 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

In LSI both students from biomedicine and informatics fields come together. Primary goal in this course is to learn the fundamentals of informatics and molecular biology to get everyone to an even level before the main courses start.

Biomedical research is currently using a variety of computer-based analyses to analyze genes that are predictive for the prognosis or therapy response of a disease ('personalized medicine'). After completing the Informatics and Biomedicine module, students will have obtained the following learning competencies:

Biomedicine:

Professional competences

After succesfully completing the module students will be:

- familiar with basic concepts of Anatomy, Physiology, Biochemistry, Metabolism, Cell Biology and Genetics
- able to basically describe and discuss the human body on anatomical, cellular and molecular level

Methodological competence

After succesfully completing the module students will be:

- aware of the relations of the above mentioned fields in context with the human body, health and disease

Social competence

After succesfully completing the module students will have:

- the capacity of discourse about the influence of molecular alterations on health and disease
- the ability to discuss medical issues with professionals and non-professionals

(Introduction to) Informatics:

After successful accomplishment of (Introduction to) Informatics the students:

Professional & Methodological competence:

- are able to work with Linux based operating systems
- know the purpose and responsibilties of operating systems
- know the fundamentals of administrating a Linux based operating system

- can write small programs using the Python programming language
- are familiar with built-in objects of Python
- know how to structure a program into modules

Social competence:

After succesfully completing the module students will have:

- the capacity of discourse about different kind of OS
- the ability to discuss linux and python related issues with professionals and non-professionals

Applicability in this and other Programs

Informatics I, Life Science I+II, Biomedical Data Analysis

Entrance Requirements

None

Learning Content

Biomedicine:

1 Introduction into Anatomy and Physiology
2 Introduction into Molecular Cell Biology
3 Basic metabolic events
4 Basic genetic mechanisms
5 Tissues/Cancer/Stem cells

(Introduction to) Informatics:

- Introduction
  - 1.1 Definition
  - 1.2 Short History of Computers
  - 1.3 Binary System
  - 1.4 Encoding and Decoding
- Operating systems
  - 2.1 Role of Operating Systems
  - 2.2 GNU/Linux and Free Software
  - 2.3 Linux Command Line
  - 2.3.1 Basic Operations
  - 2.3.2 Manipulating Files And Directories
  - 2.3.3 Text Editing usig Vim

    - 2.3.4 Permissions
    - 2.3.5 Package Management
    - 2.3.6 Environments
    - 2.3.7 Processes
- Introduction to Python
    - 3.1 Python Interpreter
    - 3.2 Strings
    - 3.3 Lists
    - 3.4 Dictionaries
    - 3.5 If-Statements
    - 3.6 Loops
    - 3.7 Functions
    - 3.8 Modules
    - 3.9 Exceptions

Teaching Methods

Seminar-like class (virtual/live/recorded) with Moodle blended learning tools (in iLearn).

Biomedicine:

This module consists of lectures, discussions and student tasks about biomedical topics. Students will get introduction into biomedical relevant topics which will be discussed or deepened via exercises to sharpen a life scientific view also on medical issues.

(Introduction to) Informatics:

No extra tools.

Recommended Literature

Biomedicine:

- Bruce Alberts, Alexander Johnson, Peter Walter, Julian Lewis, MartinRaff, Keith Roberts: Molecular Biology of the Cell (Englisch) GebundeneAusgabe, 2. Dezember 2014; ISBN-13: 9780815344643; ISBN-10:0815344643
- Neil A. Campbell, [et al.]: Biology: A Global Approach, Global Edition, 11th Edition, Pearson 2018; ISBN-13: 9781292170435
- Stephen R. Bolsover [et al.]: Cell biology : a short course 2nd ed.; ISBN0-471-26393-1
- Erin C. Amerman, Human anatomy & physiology (English), Ebook, 2019, ISBN: 9781292260174

- Elaine Nicpon Marieb, Human anatomy & physiology (English), Ebook, ISBN: 9781292260938

(Introduction to) Informatics:

- Lutz, Mark. Learning Python: Powerful Object-Oriented Programming. O'Reilly Media, Inc., 2013.
- Shotts, William. The Linux Command Line: A Complete Introduction. No Starch Press, 2019.

LSI-02 Life Science I

Module code	LSI-02
Module coordination	Prof. Dr. Melanie Kappelmann-Fenzl
Course number and name	LSI-02-1 Life Science I
Lecturers	Ines Böhme Prof. Dr. Melanie Kappelmann-Fenzl Franziska Thiele
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

The “Life Science I” module aims at providing an in depth understanding of the relevant aspects of molecular biology. In order to analyze biomedical data professionally, one needs a deep understanding of molecular biological and biochemical processes, which are conveyed within this module.

After completing the Life Science I module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- understand the genetic mechanisms of living organisms and the consequences of genetic alterations
- understand signaling pathways and their repercussions on cell systems
- gain deep knowledge about manipulating/ modifying living systems in the lab and understand the purpose and readout of genetic engineering

Methodological competence

After successfully completing the module, students will:

- be able to differentiate between genetics, transcriptomics and proteomics and have deep insights into their biomedical relevance
- be familiar with genetic engineering methods and experimental procedures and the significance of their results

Applicability in this and other Programs

Biomedical Data Analysis, Sequencing Technologies, Life Science II

Entrance Requirements

Advantageous: Basic knowledge in Molecular Biology

Learning Content

1 Molecular genetics
  1.1 How cells read the genome
  1.2 Control of gene expression
2 Cell Signaling
3 Genetic engineering

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including exercises and interactive discussions on current topics and publications. The lecture part will prepare students' basic knowledge on biomedical objectives and the exercises as well as the interactive discussions will practice students’ critical thinking skills.

Excursion (3 days): Friedrich Alexander University Erlangen-Nürnberg, Institute of Biochemistry, Molecular Oncology, Genetical Engineering

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work:

- Bruce Alberts, Alexander Johnson, Peter Walter, Julian Lewis, Martin Raff, Keith Roberts: Molecular Biology of the Cell (Englisch) Gebundene Ausgabe – 2. Dezember 2014; ISBN-13: 9780815344643; ISBN-10: 0815344643
- Stephen R. Bolsover [et al.]: Cell biology : a short course 2 nd ed.; ISBN 0-471-26393-1

LSI-03 Informatics I

Module code	LSI-03
Module coordination	Gökçe Aydos
Course number and name	LSI-03-1 Informatics I
Lecturer	Gökçe Aydos
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

The purpose of the course is for you (the student) to learn to:

(Part 1: Unix)

- describe what fundamental Unix environment tools do
- use Unix shell commands to carry out tasks like
  - inspecting, moving, copying, deleting files and folders
  - consulting documentation
  - applying a chain of data processing commands on an input data (piping)

- implement shell scripts for automating tasks on a Unix system, e.g., file management and text processing
- apply regular expressions on text to extract relevant information
- understand the advantage of git, Github, cloud computing and carry out basic git and cloud computing tasks

(Part 2: Python)

- use the the following tools of programming to create applications:
  - expressions, conditionals, functions
  - loops
  - data structures like lists, dictionaries, sets
- select the right data structure for a given data processing task

(In general)

- breakdown programs into various components, explain what these components do
- make sense of typical programming error outputs and find a fix
- classify a problem based on if the problem can be solved more efficiently with the Unix shell or Python
- evaluate someone else's work and give constructive feedback (e.g, in context of peer-assessed exercises)

Applicability in this and other Programs

Biomedical Data Analysis; Informatics II; Data management, Data analysis and Data mining, Bioinformatics: Algorithms and Data Structures; Data visualization

Entrance Requirements

- Computer science fundamentals (e.g., information, hardware, software, operating systems, shells, algorithms)

Learning Content

Part 1: The Unix workbench

- Unix and command line basics
- Working with Unix
- Bash programming
- Git & Github & cloud computing

Part 2: Programming with Python (in context of interactive programming)

- Statements, expressions, variables

- Functions, logic, conditionals
- Event-driven programming, local/global variables
- Canvas, drawing, timers
- Lists, keyboard input, the basics of modeling motion
- Mouse input, list methods, dictionaries
- Classes and object-oriented programming
- Basic game physics, sprites
- Sets and animation

Teaching Methods

- Flipped classroom
- Labs with feedback sessions
- Pair programming
- Mini projects

Recommended Literature

- The Unix workbench - Coursera
- Interactive programming with Python 1 - Coursera
- Interactive programming with Python 2 - Coursera
- Joyner, Introduction to Computing, 2016, ISBN: 1-260-08227-X

LSI-04 Biostatistics I

Module code	LSI-04
Module coordination	Prof. Dr. Melanie Kappelmann-Fenzl
Course number and name	LSI-04-1 Biostatistics I
Lecturers	Prof. Dr. Melanie Kappelmann-Fenzl Dr. Meik Kunz
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

The
Biostatistics I
module aims at providing an in depth understanding of the relevant aspects of statistics in terms of biomedical data analysis. In order to analyze biomedical data professionally, one needs in-depth biostatistical knowhow, which is conveyed within this module.

After completing the Biostatistics I module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- have learned how to use the free statistics language R and how to apply the language to biological data sets
- be able to use statistical methods such as descriptive statistics, parametric and non-parametric two-sample tests, chi-square tests, correlation analysis, linear regression analysis and ANOVA.

Methodological competence

After successfully completing the module, students will:

- be safe in dealing with R
- be able to use R for statistical testing of biomedical data
- be familiar with the Bioconductor R packages and their properties and contents

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on developing statistical data analysis.
- Working together with fellow-students in small groups on designing and developing biostatistical analysis methods on biomedical datasets.

Applicability in this and other Programs

Biomedical Data Analysis; Bioinformatics: Algorithms and Data Structures; Data visualization

Entrance Requirements

Advantageous: Basic knowledge in R and Statistics

Learning Content

1 Basics and Concepts in Biostatistics
2 DNA and RNA Analysis
3 Protein Analysis- Hidden Markov Models
4 Descriptive Statistics
5 Statistic Testing
6 Diagnostic Testing, Meta Analysis

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including practical exercises. The lecture part will prepare students' basic knowledge on biostatistical objectives and the practical exercises will practice students’ gained knowledge in biostatistical analysis using the software R.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work

- Motulsky, Harvey, M.D.: Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking, 2014;
- Andy Field: Discovering Statistics Using R; 2012; ISBN-13: 978-1446200469

LSI-05 Sequencing Technologies

Module code	LSI-05
Module coordination	Prof. Dr. Melanie Kappelmann-Fenzl
Course number and name	LSI-05-1 Sequencing Technologies
Lecturer	Prof. Dr. Melanie Kappelmann-Fenzl
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	oral ex. 30 min.
Weight	5/90
Language of Instruction	English

Module Objective

The
Sequencing Technologies
module aims at providing an in depth understanding of the current Sequencing Technologies and their advantages and disadvantages. In order to analyze biomedical data professionally, one needs to understand the different experimental setups of commonly used NGS methods, which are conveyed within this module.

After completing the Sequencing Technologies module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- have learned how to prepare samples for NGS applications.
- know about common methods of NGS and understand their technology and are able to computationally handle NGS raw data.
- know about the advantages and disadvantages of each sequencing method.

Methodological competence

After successfully completing the module, students will:

- know about the impact of experimental procedures on sample quality.
- know which key data regarding quality and quantity are important for successful sequencing.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on technical and methodical principals of Sequencing technologies
- Working together with fellow-students in small groups on designing and developing professional presentations of literature research results of different NGS applications.
- Team building by collaborative project work.

Applicability in this and other Programs

Biomedical Data Analysis; master seminar, master thesis

Entrance Requirements

Advantageous: Module LSI-01
Introduction to Biomedicine

Learning Content

1 Experimental setup for NGS applications
2 Sequencing instruments
3 Illumina Sequencers
4 PacBio sequencers
5 Minion sequencers
6 Sequencing data preparation
7 Sequencing data

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including visualization of sequencing technologies. The lecture part will prepare students' basic knowledge on common NGS methods and their applications in research and medicine. Basic practical knowledge in library preparation workflows will be gained by experimental work in the laboratory.

Guest lectures: Illumina, Dr. Silvio Scheel; Dr. Mohren and Dr. Hamberger, Pathology and Cytology, Deggendorf

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work:

- Jianping Xu: Next-Generation Sequencing: Current Technologies and Applications; 2014; ISBN-13: 978-1908230331

LSI-06 Biomedical Data Analysis

Module code	LSI-06
Module coordination	Prof. Dr. Phillipp Torkler
Course number and name	LSI-06-1 Biomedical Data Analysis
Lecturers	Prof. Dr. Melanie Kappelmann-Fenzl Prof. Dr. Phillipp Torkler
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written student research project
Weight	5/90
Language of Instruction	English

Module Objective

This interdisciplinary module combines knowledge from the fields of informatics, statistics and molecular biology.

The
Biomedical Data Analysis
module shows the students the practical application of computer-aided biomedical data analysis and enables them to carry it out independently. This module is an interdisciplinary tutorial in which the students perform the NGS data analysis workflow by themselves under professional instruction.

After completing the Biomedical Data Analysis module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- have learned how to manage NGS data.
- be familiar with file formats and their usage in the different analysis approaches.
- know about common data analysis workflows and be able to interpret and visualize the achieved results.

Methodological competence

After successfully completing the module, students will:

- be able to perform quality control on sequencing data.
- be able to perform mapping procedures.
- be able to create genome indices and know the relevance of a reference genome.
- be able to perform NGS data analysis in terms of RNA-Seq data.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on performing biomedical data analysis.
- Working together with fellow-students in small groups on designing and developing NGS data analysis workflows.
- Team building by interactive working groups.

Applicability in this and other Programs

master seminar, master thesis

Entrance Requirements

Advantageous: Module LSI-01:
Introduction to Informatics and Biomedicine
, Basic knowledge in R, Basic knowledge in Statistics

Learning Content

1 Introduction to Biomedical Data Analysis
2 Reproducible Research

3 Technical Setup
  3.1 Conda/Bioconca
  3.2 Environments / Virtual Machines / Containers
  3.3 Notebooks / Jupyterlab / Markdown
4 Manual RNA-seq Data Analysis
  4.1 NGS File Formats
  4.2 Quality Control
  4.3 Adapter Trimming
  4.4 Index Generation and Read Alignment
  4.5 Feature Counting
  4.6 Differential Expression Analysis
5 Workflow Managers
  5.1 Concept of Worflow Managers and Their Benefits
  5.2 Introduction to Snakemake
  5.3 RNA-seq Analysis Using Snakemake

Teaching Methods

Tutorial, practical exercises, application examples

The module consists of an interactive theoretical part with blended learning components. Within the tutorial the students use example NGS datasets to perform the biomedical data analysis workflow. In the practical part of the tutorial the students should learn to find solutions to problems independently by discussions and research work.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work

- The Biostars Handbook: Bioinformatics Data Analysis Guide; 2019; https://www.biostarhandbook.com/

LSI-07 Life Science II

Module code	LSI-07
Module coordination	Dr. Stefan Fischer
Course number and name	LSI-07-1 Life Science II
Lecturers	Dr. Stefan Fischer Prof. Dr. Melanie Kappelmann-Fenzl
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

The
Life Science II
module builds on the knowledge from
Life Science I
and aims at providing an in depth understanding of the relevant aspects of molecular based diseases with a special focus on molecular oncology. In order to understand the approaches of personalized medicine and targeted therapy the students should have a

broad as well as profound knowledge about the ongoing biochemical processes resulting in disease development and progression.

The practice of medicine, especially in the disciplines of Pathology and human Genetics is increasingly reliant on Genomic technology. The aim of this module is to increase the knowledge and capability of the students using genetic data allowing them to engage confidently with the scientific concepts of Molecular Pathology and Genomic Medicine.

After completing the
Life Science II
module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- be able to explain how genetic variation is involved in human disease and the development of cancer.
- understand how genetic variation can be a major determinant of patient treatment.

Methodological competence

After successfully completing the module, students will:

- be able to interprete NGS data in the context of germline mutations that cause human genetic disease, and somatic mutations involved in cancer.
- be able to interprete NGS data in the context of gene expression analysis and understand the relevance of gene set enrichment analysis as well as gene ontology classifications

Social competence

After successfully completing the module, students will:

- be confident in critically evaluate molecular pathology & diagnostics.
- b e able to discuss molecular feature of different kind of diseases

Applicability in this and other Programs

Data vizualisation, master seminar, master thesis

Entrance Requirements

Recommended or advantageous:

Module LSI-02:

Life Science I

Learning Content

Molecular basis of human disease

1 Molecular Pathology
2 Molecular Oncology

Teaching Methods

Seminar-like classes, Laboratory practical course

The module consists of a theoretical lecture part and practical part in the laboratory with blended learning components, including interactive discussions on current topics and publications as well as the execution of practical biochemical experiments. The lecture part will prepare students' in-depth knowledge on the molecular basis of human disease. The practical part will give in dephth insights into the exoperimental procedure of cell culture, nucleic acids and protein analytics.

Guest lecture: Prof. Dr. Michael Rehli, Epigenetics Data Analysis (Dept. Internal Medicine III, University Hospital Regensburg), Dr. Silvio Scheel (Illumina), Prof. Dr. Calus Hellerbrand, Molecular Pathology (University of Erlangen-Nürnberg, Insitute of Biochemistry), Prof. Dr. Anja Bosserhoff, Good Scientific Practice (University of Erlangen-Nürnberg, Insitute of Biochemistry), Dr. Alexandra Hamberger and Dr. Mohren, Molecular Diagnostics (Insitute of Pathology, Deggendorf), Dr. Josef Scheiber, Bioinformatics (BioVariance)

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work

- Bruce Alberts, Alexander Johnson, Peter Walter, Julian Lewis, MartinRaff, Keith Roberts: Molecular Biology of the Cell (Englisch) GebundeneAusgabe 2. Dezember 2014; ISBN-13: 9780815344643; ISBN-10:0815344643
- William B. Coleman, Gregory J. Tsongalis: Molecular Pathology: The Molecular Basis of Human Disease, 2 nd edition, 2017, ISBN-13: 978-0128027615

LSI-08 Informatics II

Module code	LSI-08
Module coordination	Gökçe Aydos
Course number and name	LSI-08-1 Informatics II
Lecturer	Gökçe Aydos
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

After successful accomplishment the students can:

- Professional competences
  - outline fundamental features of the Python programming language
  - understand the advantages of object-oriented and functional programming
  - know different request types to access web resources
  - list useful libraries from the standard library
- Methodological competences
  - implement programs for string processing

    - leverage the interactive interpreter for short computing tasks
    - use object-oriented programming to breakdown a program into classes
    - use functional programming to write shorter code
    - implement programs for interacting with web APIs
    - carry out simple image processing tasks
    - leverage Numpy to conveniently work with matrices
    - use an unknown library by reading its documentation
- Social competences
    - cooperate in a pair programming setting
    - evaluate someone else?s work and give constructive feedback (e.g., in context of peer-assessed exercises)

Applicability in this and other Programs

- Data mining and machine learning
- Bioinformatics algorithms and data structures
- Data visualization

Entrance Requirements

- Computer science fundamentals (e.g., information, hardware, software, operating systems, shells, algorithms)
- Fundamental programming tools (e.g, control flow, data structures, functions)

Learning Content

Most of the contents are based on the course
CS41: The Python Programming Language
from Stanford University.

- Python basics:
    - Interactive interpreter
    - Comments
    - Variables and types
    - Numbers and Booleans
    - Strings and lists
    - Console I/O
    - Control Flow
    - Loops
    - Functions

    - Assignment Expressions
- Data structures:
    - list
    - dict
    - tuple
    - set
- Object-oriented Python:
    - errors and exceptions
    - easier to ask for forgiveness than permission (EAFP) vs look before you leap (LBYL)
    - data model
    - classes
    - exceptions as classes
- Functions:
    - namespaces and scope
    - Python Functions
    - (variadic) arguments
    - Parameter ordering
- Functional programming:
    - meaning
    - first-class functions
    - lambda s
    - iterators and generators
    - map and filter
    - decorators
- Python & the Web:
    - HTTP
    - requests library
    - working with images
    - creating a web interface for your app using Flask library
- Numpy:
    - what is a matrix?
    - why are matrices useful?
    - n-dimensional array ndarray
    - axes and shapes
    - matrix operations
    - statistical methods
    - parameter fitting example
- Standard library and third party libraries

Teaching Methods

- flipped classroom
- labs with feedback sessions
- pair programming

Recommended Literature

- CS41 course reader
- The Python Tutorial

LSI-09 Biostatistics II

Module code	LSI-09
Module coordination	Prof. Dr. Melanie Kappelmann-Fenzl
Course number and name	LSI-09-1 Biostatistics II
Lecturers	Prof. Dr. Melanie Kappelmann-Fenzl Dr. Meik Kunz
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

The
Biostatistics II
module aims at providing an in depth understanding of the relevant aspects of statistics in terms of biomedical data analysis. In order to analyze biomedical data professionally, one needs in-depth biostatistical know-how, which is conveyed within this module.

After completing the Biostatistics II module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- be confident in advanced R programming.
- be able to identify different types of data, and how it can be collected.
- be able to recognize and design experiments.
- know how to summarize data numerically and graphically using R.
- understand the difference between point and interval estimation.
- be able to determine and perform correct statistical tests.
- know how to conclude and interpret the results from statistical tests.
- be familiar with inferential statistics including parametric and nonparametric methods.

Methodological competence

After successfully completing the module, students will:

- be able to write programming scripts in R.
- be able to use R for advanced statistical testing of biomedical data.
- be confident in data visualization in R.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on developing statistical data analysis.
- Working together with fellow-students in small groups on designing and developing biostatistical analysis methods on biomedical datasets.

Applicability in this and other Programs

Bioinformatics: Algorithms and Data Structures; Data visualization, master seminar, master thesis

Entrance Requirements

Recommended or advantageous:

Module: LSI-04
Biostatistics I

Learning Content

1 Linear regression; Logistic regression
2 Survival analysis; Multivariate regression
3 Stepwise regression; SVM, GBM
4 Regularized regression I+II (Lasso, Ridge, Elastic net)
5 Dimension reduction I+II (PCA, MDS, t-SNE, SOM)
6 ClusteringI+II (kNN, k-means, ...)

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including practical exercises. The lecture part will prepare students' basic knowledge on biostatistical objectives and the practical exercises will practice students’ gained knowledge in biostatistical analysis using the software R.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work

- Motulsky, Harvey, M.D.: Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking, 2017;
- Andy Field: Discovering Statistics Using R; 2012; ISBN-13: 978-1446200469

LSI-10 Data Mining and Machine Learning

Module code	LSI-10
Module coordination	Prof. Dr. Phillipp Torkler
Course number and name	LSI-10-1 Data Mining and Machine Learning
Lecturers	Prof. Dr. Melanie Kappelmann-Fenzl Prof. Dr. Phillipp Torkler
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

Within the
Data
Analysis module, the students will acquire fundamental knowledge of the techniques and applications of data analysis and machine learning. Data analysis is a mixture of developments in particular in the fields of machine learning, statistical learning and computer science. The course covers the theoretical fundamentals but concentrates on the application of machine learning methods with Python.

After completing the
Data Mining & Machine Learning
module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- know the fundamentals of machine learning as well as common pitfalls and obstacles.
- be familiar with the usage of Python, scikit-learn, pandas and matplotlib for analyzing data sets.
- be able to compare, evaluate and select machine learning methods.
- be familiar with regression, classification and clustering methods and know how to apply them.

Methodological competence

After successfully completing the module, students will:

- know how to use Jupyter Lab to perform and report data analysis projects.
- be able to select and apply appropriate data analysis techniques.
- be able to interpret the results.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on data analysis exercises.

Applicability in this and other Programs

Data Visualization, Biomedical Data Analysis, Master Seminar, Master Thesis

Entrance Requirements

Recommended or advantageous:

Module: LSI-03
Informatics I

Module: LSI-04
Biostatistics I

Learning Content

1 Introduction
  1.1 Goals of Machine Learning, Definitions and General Concepts
  1.2 Technical Introduction: NumPy, SciPy, scikit-learn, pandas and matplotlib
2 Supervised Learning
  2.1 Regression (e.g.)
  2.1.1 Linear Regression, Multiple Linear Regression
  2.1.2 Regression Trees
  2.2 Classification (e.g.)
  2.2.1 k-Nearest Neighbor
  2.2.2 Decision Trees
  2.2.3 Multinomial and Gaussian Naive Bayes
3 Unsupervised Learning (e.g.)
  3.1 k-means and EM-algorithm
  3.2 Hierarchical Clustering
4 Model Assessment & Evaluation
  4.1 Confusion Matrix, Performance Measurements
  4.2 ROC Curves, Precision-Recall Curves
  4.3 Cross-validation: k-fold, LOOCV, nested CV
  4.4 Bootstrapping
5 Ensemble Methods
6 Data Preprocessing
7 Introduction to Deep Learning

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including practical exercises. The lecture part will prepare students' basic knowledge on data analysis objectives and the practical exercises will practice students' gained knowledge in data analysis using Python.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Lecture notes are available online.

Literature:

- Bishop, Christopher M. Pattern Recognition and Machine Learning. Springer, 2006
- Géron, Aurélien. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. O'Reilly Media, Inc., 2022.

LSI-11 Bioinformatics - Algorithms and Data Structures

Module code	LSI-11
Module coordination	Prof. Dr. Phillipp Torkler
Course number and name	LSI-11-1 Bioinformatics - Algorithms and Data Structures
Lecturers	Prof. Dr. Melanie Kappelmann-Fenzl Prof. Dr. Phillipp Torkler
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	5/90
Language of Instruction	English

Module Objective

Within the
Bioinformatics - Algorithms and Data Structures
module the students will acquire fundamental knowledge of the techniques, opportunities and applications of bioinformatic algorithms. The module provides the algorithmic background for programs used in bioinformatic and biomedical data analysis.

After completing the Bioinformatics module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- understand essential bioinformatic algorithms and will know their advances and limitations.
- know how to develop, describe and implement algorithms.
- understand how the analysis of biological sequences leads to biological knowledge.

Methodological competence

After successfully completing the module, students will:

- be able to formulate biological problems or models as algorithmic problems.
- be able to implement algorithms based on algorithmic descriptions.
- be familiar with the usage of bioinformatic programs.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups.
- Team building by interactive project groups.

Applicability in this and other Programs

Biomedical Data Analysis, Sequencing Technologies, Data Visualization, Master Seminar, Master Thesis

Entrance Requirements

Recommended or advantageous:

Module: LSI-03
Informatics I

Module: LSI-04
Biostatistics I

Learning Content

1 Introduction to Biological Sequence Analysis
2 Exact String Matching
3 Pairwise Sequence Alignments
  3.1 Sequence Similarity/Cost Functions
  3.2 Substitution Matrices
  3.3 Alignment Graphs and Dynamic Programming
  3.4 Global, Local, End-Gap Alignments
  3.5 Gotoh Algorithm
4 BLAST
5 Index Data Structures
  5.1 Suffix Tries
  5.2 Suffix Trees
  5.3 Suffix Arrays
6 Multiple Sequence Alignments

Teaching Methods

Seminar-like classes, application examples

The module consists of a lecture part with blended learning components, including practical exercises. The lecture part will prepare students' knowledge on bioinformatic algorithms and data structures and the practical exercises expose students to the application and implementation of bioinformatic algorithms.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Lecture notes are available online.

Literature:

- Compeau, Phillip, et al. Bioinformatics Algorithms: An Active Learning Approach, 2nd Ed, Active Learning Publishers, 2014
- Durbin, Richard, et al. Biological sequence analysis: probabilistic models of proteins and nucleic acids. Cambridge university press, 1998

LSI-12 Data Visualization

Module code	LSI-12
Module coordination	Prof. Dr. Phillipp Torkler
Course number and name	LSI-12-1 Data Visualization
Lecturers	Prof. Dr. Phillipp Torkler Prof. Dr. Javier Valdes
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 45 hours virtual learning: 45 hours Total: 150 hours
Type of Examination	written student research project
Weight	5/90
Language of Instruction	English

Module Objective

Data Visualization
is the graphic representation of a data analysis to achieve clear and effective communication of results and insights. Complex ideas are presented in charts and graphs with the goal of quickly and easily disseminating key, actionable information. Data visualization is an essential part of data science and analytics, especially when working with large, complicated data sets like sequencing data. The visualization tells a story, whether as a stand-along graph or combined with other graphs, charts and design elements in an infographic or dashboard.

After completing the Data Visualization module, students will have obtained the following learning competencies:

Professional competence

After successfully completing the module, students will:

- know the data visualization principles.
- be familiar with file formats and their usage in the different analysis approaches.
- know about common data analysis workflows and be able to interpret and visualize the achieved results.

Methodological competence

After successfully completing the module, students will:

- know how to use ggplot2 in R to create custom plots.
- know how to use matplotlib and Python to create custom plots.

Social competence

- Interdisciplinary and interpersonal collaboration when working together in small groups on developing R and Python scripts for data analysis and data visualization.
- Working together with fellow-students in small groups on designing and developing biostatistical validation of biomedical datasets within R and/or Python.

Applicability in this and other Programs

master seminar, master thesis

Entrance Requirements

Recommended or advantageous:

Basic Knowledge in R

Module: LSI-04
Biostatistics I

Learning Content

1 R Packages for data visualization
2 Open access visualization tools

3 Matplotlib and other Python packages for data visualization
4 Theoretical Background
5 Perception And Interpretation

Teaching Methods

Tutorial, practical exercises, application examples

The module consists of an interactive theoretical part with blended learning components. Within the tutorial the students use example NGS datasets to perform the biomedical data visualization. In the practical part of the tutorial the students should learn to find various visualization tools, possibilities and methods and discuss their advantages and disadvantages to represent statisitical significance.

Remarks

The iLearn teaching and learning platform provides students with additional literature references and learning material to prepare for the lectures.

Recommended Literature

Detailed lecture notes are available online for preparation and follow-up work

- The Biostars Handbook: Bioinformatics Data Analysis Guide; 2019; https://www.biostarhandbook.com/

LSI-13 Master Thesis

Module code	LSI-13
Module coordination	Prof. Dr. Melanie Kappelmann-Fenzl
Course number and name	LSI-13-1 Master Thesis LSI-13-2 Master Kolloquium LSI-13-3 Master Seminar
Lecturers	Dr. Stefan Fischer Prof. Dr. Melanie Kappelmann-Fenzl Prof. Dr. Phillipp Torkler
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Postgraduate
Semester periods per week (SWS)	6
ECTS	30
Workload	Time of attendance: 90 hours self-study: 780 hours virtual learning: 30 hours Total: 900 hours
Type of Examination	master thesis
Weight	30/90
Language of Instruction	English

Module Objective

By producing a Master's Thesis the students should demonstrate their ability to apply the knowledge and skills acquired during the study course, in an independently written scientific work on complex tasks. They thus demonstrate that they have successfully completed their Master's levels studies and acquired the capacity for independent scientific work.

Entrance Requirements

According to the paragraph 8 of the Study and Examination Regulations, those students who have collected at least 40 ECTS credits may register for the Master's Thesis.

Learning Content

The Master's Thesis is a written report in a form of a scientific paper. It describes the scientific findings, as well as the way leading to these findings. It contains justifications for decisions regarding chosen methods for the thesis and discarded alternatives. The student’s own substantial contribution to the achieved results has to be evident. In addition, the student presents his work in a colloquium, in which the scientific quality and the scientific independence of his achievements are evaluated. The work on the Master’s Thesis is supervised by any of the instructors within the study course (professors or lecturers) or an external instructor. The Master’s Thesis can be written on any subject or topic related to the content of any of the modules of the study course. The students can suggest the topics for their Master’s Theses according to their research or practice preferences. The preparation time of a Master’s Thesis according to the regulations is 6 (six) months. However, an extension up to a maximum of 8 months from the subscription date is possible (§11 APO). As a general rule, the size of the thesis should not exceed 70 pages.

Teaching Methods

Students perform an independent supervised scientific research work.

Recommended Literature

Recommendations and instructions of writing a master's thesis (available through iLearn).