Description of the modules in BioMex

Status: April 2024

Continuously evolving, the programme provides teaching from the following competence clusters and already offers the following modules:

Competence Cluster: Biotechnology and Biomedicine
Module BT1: Molecular Biology and Molecular Biotechnology (3 ECTS)

Content:

The self-studying course Molecular Biology and Molecular Biotechnology is designed to provide individuals with a comprehensive understanding of the fundamental principles, techniques, and applications of molecular biology and molecular biotechnology. The Course is based on a Blended-Learning-Concept and integrates also practical training units in the laboratory.

Based on the blended learning approach, self-organized online learning activities are combined with seminar-based online-face-to-face-teaching to enable a more flexible and individualized learning experience. Students can acquire the theoretical background with the help of text-sections, videos and questions for self-monitoring, regardless of time and place - whenever and wherever the student sees the opportunity to study. In addition, Online-Tutorials are offered at regular time-intervals, in which students can review together with the lecturers what they have learned so far.

Learning practical skills is particularly important in molecular biology and molecular biotechnology. For this reason, the course also offers the opportunity to learn the basic techniques of molecular biology in laboratories.

The course is based on learning units in the Open-OLAT learning management system. This gives students the opportunity to work through the course content individually.

The course takes into account different levels of prior knowledge, starting with the basics of molecular biology and moving on to advanced topics and current research.

Learning Outcomes:

After completing the module, students will be able to

- understand the structure and function of cells
- reproduce the basic cellular processes and place them in a molecular biological context
- know and assign basic terms of molecular biology and reproduce them in a question-related manner
- describe classical and modern methods of molecular biology and genetic engineering and analyse their results
- reproduce the basics of classical genetics
- understand the basic principles of molecular biology and apply them theoretically to solve problems in everyday laboratory work
- explain the interaction and function of macromolecules (Proteins, DNA, RNA)
- describe the molecular mechanisms of replication, transcription and translation and place them in the context of the transfer of genetic information and regulatory gene expression
- contrast the mechanisms of gene regulation in prokaryotic and eukaryotic cells
- know mutations and classify their effects on the organism and describe repair mechanisms
- characterize mechanisms of recombination (homologous recombination, sequence-specific recombination and transposition)
- describe epigenetic changes and analyse their effects on gene regulation
- describe RNAi and CRISPR as naturally occurring mechanisms and to understand them also as a molecular biological method
- know the basic methods of molecular biology and molecular biotechnology such as gel electrophoresis, PCR, cloning techniques and sequencing methods and apply them practically in the laboratory

Competence Cluster: Biotechnology and Biomedicine
Module BT2: Biostatistics and Data Literacy (3 ECTS)

Content:

In this course an introduction into biostatistics and data literacy is given. Statistics is the discipline that covers how to gather, display, review, and analyse data and how to draw conclusions from data. Statistics is therefore important in all areas of empirical research which is based on observed data. Biomedical research is an empirical science. The analysis of data is essential for valid conclusions and any recommendation in evidence-based medicine. Therefore, data literacy, that is the ability to read, write and communicate data, and the ability to carry out statistical analyses are important. Biostatistics is the area of statistics where data from life sciences including medicine are analysed.

We start with a brief introduction into the free and open-source software package R. Knowledge of software such as R is crucial to carry out statistical analyses and therefore for professional practice.

In chapter 2, descriptive statistics and methods for exploratory data analysis are presented. Descriptive statistics provides tools to describe properties of observed data, whereas inferential statistics is used to infer properties of a population, mainly using estimation and by testing hypotheses. The main part of this course deals with inferential (also called inductive) statistics. We describe random sampling and randomization. Then, estimation, confidence intervals and hypothesis tests are introduced, before these methods are presented for different types of data such as categorical, continuous and time-to-event data.

Since biostatisticians often have to work with small sample sizes, a special focus is on exact permutation tests and the bootstrap. Correlation, regression models and the analysis of variance are also covered. We briefly introduce some basic methods to deal with multiple testing problems. In addition, we give an overview on clinical trials including interim analyses, and discuss a case study in detail.

In all chapters, example data are used together with R code to illustrate the methods. In the last chapter the topic data literacy is discussed and illustrated. For example, it is shown how graphs are – regrettably – used to distort reality. Bayesian methods are not covered because this is an introductory course. Recommendations for further reading are given.

The main learning objective is the knowledge of commonly used statistical methods, both in descriptive and inferential statistics. Students should understand the different methods, should be competent to choose an appropriate method for a given problem, and should have the ability to carry out these analyses with the software R.

Learning Outcomes:

After studying this course you should

- know and understand commonly used statistical methods;
- within descriptive statistics you should be able to characterize a data set using measures of location and spread as well as with appropriate graphics;
- within inferential statistics you should understand the concepts of estimation, confidence intervals and statistical tests;
- you should know the assumptions of the different methods;
- you should be competent to choose an appropriate method for a given problem and for different types of data,
- to carry out the analysis with the software R, and
- to understand and interpret R output.
- Students should know some basic features of clinical trials, and
- have the ability to read, write and communicate data.

Competence Cluster: Pharmaceutical Chemistry and Pharmaceutical Technology
Module PT1: Pharmaceutical Chemistry and Pharmacology (3 ECTS)

Content:

Medicines have been used by humans (and other animals) since the birth of the mankind. Humans have learnt that eating some plants, drinking some teas, putting smashed leaves on an open wound would have facilitated the healing.
Plants do the same things, they protect themselves from bacteria, fungi, other predators by biochemically synthesizing small molecules, called secondary metabolites, which act as 'antibiotics' and protect the plant from the hostile environment.
One of the most impressive man's inventions has been the idea of using the same secondary metabolites produced by plants and yeast to cure man's infection. The discovery of penicillin, in 1927 by Fleming is a milestone in the progress of mankind. The life expectancy and life's
quality of those for whom penicillin become available increased enormously, and this gave impulse to the birth of the modern pharmacology and pharmaceutical chemistry.

Today we have several hundreds of unique active molecules which constitute the ingredients of medicines used and effective against a vast array of diseases, from infections to cancer, from metabolic diseases to psychiatric disorders. Nevertheless, the need of new, more active, more available medicines is higher than ever. Anti-infective drugs are facing the threats of resistance. New zoonotic infections continuously appear. We are realizing that 'diseases' that we are used to call 'cancer', 'depression', 'cardiac insufficiency', are constituted by a myriad of different conditions for which targeted medicines are necessary and sought. We are, as well, realizing that our genetic background, the presence of Single Nucleotide Polymorphisms (SNP) may change the individual response to the same drug, and that the old paradigm that one single drug can cure millions of people seems no longer true.
In a word, we still need to discovery new and more active medicines.

The journey to a new medicine is very long. It requires time and money. But on top of it, it requires knowledge, intuition, perseverance. And it requires the involvement of many disciplines from biochemistry to process chemistry, from pharmaceutical technology to clinical medicine and toxicology. Nevertheless, all of this finds its roots in the deep understanding of the molecular mechanism of action of drugs, and on the deep understanding on how small chemical modifications may improve the biological effect and reducing the side-effect, the toxicity, the low bioavailability of a given drug. Pharmaceutical Chemistry and Pharmacology are the disciplines which study the mechanism of action of drugs at a molecular level and the structure-activity relationships. Their basic knowledge is a pre-requisite for every scientist and technician who aspires to be part of the heartbreaking journey of drug discovery.

This module is directed to everyone who has a basic knowledge of:

- Physiology
- Human Pathology
- Biochemistry
- Cellular biology
- Chemistry
- Organic chemistry including nomenclature of heterocycle compounds.

An entry assessment of the previous knowledge will be offered, not mandatory but highly suggested.

Learning Outcomes:

The learning objectives of the module can be listed as follow:

- Understand the process of drug discovery and development. Realize the difference between preclinical and clinical research. Understand the main reason for attrition and failure in drug discovery.
- Understanding the basic principles of pharmacology and their experimental basis: Define pharmacology and its scope, including drug classification, mechanisms of action, and pharmacokinetics/pharmacodynamics principles.
- Describe drug-receptor interactions: Explain how drugs interact with receptors to produce pharmacological effects, including agonists, antagonists, and allosteric modulators.
- Explain drug absorption, distribution, metabolism, and excretion (ADME): Describe the processes involved in the ADME of drugs in the body and how these processes influence drug bioavailability and efficacy.
- Identify common drug classes and their therapeutic uses: Classify drugs based on their pharmacological properties and therapeutic indications, including examples of drugs in each class and their clinical applications.
- Understand the principles of drug dosage and administration: Calculate drug dosages based on patient factors such as weight, age, and renal/hepatic function, and describe various routes of drug administration and their advantages/disadvantages.
- Explain the mechanisms of drug action in major organ systems: Describe how drugs affect the central nervous, cardiovascular, respiratory, gastrointestinal, and endocrine systems, including specific drug classes used to treat disorders in each system.
- Understand the principles of drug toxicology and adverse drug reactions (ADR): Identify common mechanisms of drug toxicity and factors influencing ADRs, including patient variability, drug-drug interactions, and idiosyncratic reactions.
- Describe the role of pharmaceutical chemistry in drug discovery and development: Explain the process of drug discovery, including target identification, lead compound optimization, preclinical testing, and clinical trials, and discuss the importance of medicinal chemistry in rational drug design.
- Discuss current trends and challenges in pharmacology and pharmaceutical chemistry: Identify emerging drug targets, novel drug delivery systems, and regulatory issues affecting the pharmaceutical industry, and evaluate the ethical and social implications of pharmacological research and drug use.
- Apply critical thinking and problem-solving skills to pharmacological case studies: Analyze clinical scenarios involving drug therapy, including patient assessment, drug selection, monitoring parameters, and patient education, and develop evidence-based treatment plans

Competence Cluster: Innovation Management and Intercultural Cooperation
Module IM1: Innovation Management (3 ECTS)

Content:

This interdisciplinary module on Innovation Management and Sustainable Development is designed to equip students with the knowledge, skills, and tools necessary to develop innovative solutions aligned with the Sustainable Development Goals (SDGs). Through a blend of theoretical concepts, practical exercises, and collaborative projects, students will explore the principles of innovation, problem-solving, evidence-based argumentation, and effective presentation techniques. Emphasis will be placed on fostering creativity, critical thinking, and ethical decision-making in the context of addressing real-world challenges.

Learning Outcomes:

Upon successful completion of this course, students will be able to:

- Analyze and evaluate the role of innovation in addressing global challenges, with a focus on the Sustainable Development Goals (SDGs).
- Apply problem-solving techniques to identify, analyze, and prioritize societal problems that can be addressed through innovative solutions.
- Utilize evidence-based reasoning to support arguments and decisions related to innovation management and sustainable development.
- Develop and present coherent and persuasive arguments for innovative solutions, considering ethical and social implications.

(to be continued)