Imaging techniques in biomedicine and translational research approaches	
Module code	**mlsImaging-01a**
Abbreviated title	Imaging
Module components	Lectures, seminars
When	Semesters 2+3
Module coordinator/ Organisers	C.-C. Glüer Radiology and Neuroradiology ***3rd semester electives***: Experimental Trauma Surgery (Regen. Medicine), Dermatology (Epithelial barrier functions), Neurology (Neurosciences), IKMB (Metabolomics), University Cancer Center Schleswig-Holstein [UCCSH] (Molecular Diagnostics), IfE (Cardiovascular epidemiology), IKMB (Metabolomics)
Lecturers	Imaging (elective semesters 2+3): S. Tiwari, **C.-C. Glüer**, **M. Both**, and colleagues (Radiology) ***Electives 3rd semester*:** **a. Regenerative medicine and tissue engineering**: S. Fuchs (Experimental trauma surgery) **b. Epithelial barrier functions:** J. Harder (Dermatology) **c. Clinical, molecular and diagnostic neurosciences**: F. Leypoldt (Neurology and Clinical Chemistry), G. Kuhlenbäumer, C. Stürner (Neurology) **d. Molecular Diagnostics**: S. Lipinski (UCCSH), L. Bastian, C. Baldus, M. Brüggemann, C. Pott (Klinik für Innere Medizin II) **e. Cardiovascular epidemiology**: W. Lieb (IfE) **f. Metabolomics:** K. Aden (IKMB)
Contact hours	Semester 2: Lecture Imaging 1 CH Seminar Imaging 1 CH Semester 3: Lecture Imaging 1 CH Seminar Imaging 2 CH Semester 3 elective: Lecture 1 CH Seminar 2 CH
Workload Total: 240 h	Lecture semester 2: 30 h Attendance time 14 h, preparation 10 h, revision 6 h Seminar semester 2: 60 h Attendance time 14 h, preparation 14 h, revision 32 h Lecture semester 3: 30 h Attendance time 14 h, preparation 6 h, revision 10 h Seminar semester 3: 60 h Attendance time 26 h, preparation 24 h, revision 10 h Elective semester 3 lecture: 30 h Attendance time 14 h, preparation 6, revision 10 h Elective semester 3 seminar: 30 h Attendance time 26 h, preparation 4 h
Credit points	8 (sem. 2 lecture = 1 CP, sem. 2 seminar = 2 CP, sem. 3 lecture = 1 CP, sem. 3 seminar = 2 CP; 3rd-sem. elective lecture + seminar = 1 CP each)
Requirements	-

Expected outcome	**Tracing disease through time** Knowledge: Students - are familiar with analytical techniques (e.g. genetic, biochemical, chemical) and approaches used for the study of ancient biomolecules, diets and diseases - understand how specimens are recovered from field situations, archived sources and collections - have a basic knowledge of human osteology, paleopathology, epidemiology - have gained an understanding of historical events as an important factor in disease etiology and epidemiology - have acquired insights not only into the health status in past societies but also into how new diseases emerge in present-day populations. Skills: Students - can demonstrate the use of analytical methods for the investigation of ancient biomolecules, diets and diseases - can apply basic osteological methods - can perform literature research and give presentations on a specific topic in front of their peers. Competencies: Students - can assess the importance of the interrelations between environmental and societal conditions that contribute to the onset and human impact of disease through time - recognize which key questions need to be asked for investigating scientific problems concerning disease spreading geographically and chronologically and can formulate them accordingly. Electives 3rd semester **a. Regenerative medicine and tissue engineering** Knowledge: Students - are familiar with the principles and potential fields of application of tissue engineering and regenerative medicine including the use of adult stem cells, biomaterials, bioactive molecules. - can define different cellular and molecular mechanisms in tissue repair - understand 3-D cultures. Skills: Students - can define and isolate adult stem cells in cell cultures in the laboratory - can handle co-culture models in the laboratory - can apply models to study angiogenesis and wound repair - can apply methods to evaluate repair mechanisms. Competencies: Students - are able to apply interdisciplinary approaches to support tissue regeneration - can develop translational strategies. **b. Epithelial barrier functions: Molecular interaction epithelium – environment** Knowledge: Students - are familiar with the importance of epithelia as physiological barrier against potentially detrimental environmental factors - understand the molecular mechanisms of epithelia for protecting the integrity of their barrier function. Skills: Students can associate disruptions of the epithelial barrier with specific

	disease manifestations. Competencies: Students - can assess the impact of epithelial barrier disruptions for specific disease manifestations - are able to understand scientific papers, to evaluate and discuss them critically with colleagues. **c. Clinical, molecular and diagnostic neurosciences** Knowledge: Students - have a general understanding of clinical assessment, clinical syndromes, major categories of neurological diseases and diagnostic procedures - have a general understanding of molecular mechanisms underlying neurological disease, their disease models and techniques used in studying them. Skills: Students - are able to apply disease models to human diseases and develop them into translational research - are able to critically discuss relevant scientific publications and draw conclusions for own research projects. - can perform literature research self-reliantly. Competencies: Students - are able to select suitable methods to address specific neuroscientific questions - are able to communicate with clinical neurologists. **d. Molecular diagnostics** Knowledge: Students - understand which influence molecular biology has on state-of-the-art diagnostic methods in medicine, with a particular view to cancer - can explain what precision/personalized medicine is and why this requires particular diagnostic tools - have a good understand of current immunotherapy approaches (e.g. immune checkpoint inhibitors) - are familiar with the theoretical background of basic diagnostic approaches in molecular biology - understand the workflow from sample processing to treatment recommendation. Skills: Students - can conduct a set series of diagnostic routines including samples preparation (e.g. extraction of nucleic acids from blood and tissues, quality check, qPCR, ddPCR, exome sequencing) - can apply software (self-programmed and software packages) to analyse data resulting from sample processing - can use quality control measures to ensure correct sample processing and error eradication in data analysis - are able to establish complete documentation of sample processing and data analysis, case based.

	Competences: Students - can establish connections between theoretical knowledge in molecular biology and determined tumour samples to arrive at the best suitable diagnostic approaches for individual samples. - can use gene data bases for extracting relevant information for a given data set of a processed tumour sample with regard to formulating potential treatment suggestions. - are able to transfer case knowledge onto a meta level for further research in precision medicine. **f. Metabolomics**: Knowledge: Students - understand the key concepts of metabolomics, metabolism, metabolites, and metabolic networks - are familiar with basic principles of metabolomics analytical tools (nuclear magnetic resonance (NMR) spectroscopy and hyphenated mass spectrometry) and workflows in metabolomics research - are familiar with basic principles of high-dimensional statistics/machine learning data analysis in metabolomics. Skills: Students - can prepare samples for NMR spectroscopy - can preprocess NMR spectroscopic data - can perform basic statistical data analysis with metabolomics data (e.g. hypothesis testing) - can write R code for selected analysis tasks Competencies: Students - are able to identify metabolites from NMR spectra - are aware of advantages/disadvantages of specific metabolomics analytical tools - are able to select suitable statistical methods for specific research questions in metabolomics.
Content	**Imaging** Lectures: Technical principles (X-ray, magnetic resonance, nuclear medicine, sonography, optical techniques); contrast media, molecular markers and reporters; image processing (acquisition, reconstruction, processing, parametrisation, quantification); examples for clinical/preclinical imaging structured by organs and diseases; quality standards, design and execution of preclinical/clinical studies using imaging techniques; quality assurance; criteria for evidence-based assessment of diagnostic studies (e.g. Oxford criteria) Seminars: Discussion of merits/shortcomings of selected scientific publications ***Electives 3rd semester*** **a. Regenerative medicine and tissue engineering** Lecture: Definitions of and examples for regenerative medicine and tissue engineering; interdisciplinary approaches in regenerative medicine; adult stem cells; biocompatibility and functionality of implant materials, bioactive molecules,

	vascularisation as key issue for tissue repair, co-culture models, models for studying angiogenesis, inflammation and tissue repair Seminar: Discussions of scientific papers on tissue engineering and regenerative medicine with integrated lab experience in experiments using techniques introduced in both lecture and seminar. **b. Epithelial barrier functions: Molecular interaction epithelium – environment** Lecture: Structure and cellular components of epithelia (skin, intestine and respiratory tract); physical barrier functions; strategies for identification and differentiation of pathogenic micro-organisms and members of the commensal microbiota; extracellular and intracellular effector mechanisms for controlling microbial growth; provision of mediators for activation and recruitment of effector cells. Seminar: Hypothesis formulation and discussion (e.g. how can dysregulation of the epithelial barrier lead to epithelial infectious and inflammatory diseases?); discussion of scientific papers, presentation of current research results **c. Clinical, molecular and diagnostic neurosciences** Lecture: Clinical diagnostic techniques, movement/neurodegenerative disorders, neuroimmunology, neurovascular diseases, peripheral nervous system, neuroscience of pain, neuroscience of epilepsy. Seminar: Presentation of scientific articles by the students followed by critical group discussion. **d. Molecular diagnostics:** Lecture: Somatic cancer mutations and driver genes, concept of personalized medicine, classes of biomarkers, diagnostic tools: qPCR, ddPR, panel diagnostics; data analysis and interpretation: limits of detection, SNP analysis, databases; practicalities in medicine: health insurance coverage and diagnostics, time-sensitivity, patient-based science. Lab seminar: Workflow and methods in a diagnostic lab, conducting lab diagnostics Computer seminar: Data analysis using bioinformatics and databases. **e. Cardiovascular epidemiology** Lecture: Epidemiological methods and study designs; contribution of cohort studies to cardiovascular epidemiology; global burden of cardiovascular disease; traditional and novel risk factors (including genomic and metabolomic markers); assessment of new biomarkers and their performance; concepts of screening and risk prediction; subclinical cardiovascular disease; various forms of clinical manifestations of cardiovascular disease (e.g. stroke, myocardial infarction, heart failure) Seminars: Discussion of scientific papers and important concepts of cardiovascular epidemiology **f. Metabolomics** Lecture: Overview of metabolomics and its different applications, important aspects of metabolomics study design, introduction to metabolomics analytical

	tools (NMR spectroscopy and hyphenated mass spectrometry) and metabolite identification, introduction to metabolomics data preprocessing, statistics and bioinformatics data analysis in metabolomics and interpretation of results in biomedical context Analysis seminar: Preparing samples for NMR spectroscopy (practical lab work), metabolite identification from NMR spectra, computer-based analysis of data in R, writing R code for individual data analysis routines.
Module evaluation/ exam	**Graded** Oral exam
Media used	PPT presentations, handouts, textbooks, example experiments
Literature	**Imaging** Bushberg J T, Seibert A, Leitholdt E M, Boone J M, The Essential Physics of Medical Imaging (Wolters Kluwer 4th edition, 2020) Tian J, Molecular Imaging – Fundamentals and Applications (Springer 2013) Pomper MG, Gelovani JG, Molecular Imaging in Oncology (Informa Healthcare 2008) [still valid] Suetens P, Fundamentals of Medical Imaging (Cambridge University Press 3rd edition, 2017) Current scientific publications **a. Regenerative medicine and tissue engineering** von Blitterswijk C, de Boer J, Tissue Engineering (Elsevier 3rd edition, 2022) Current scientific papers **b. Epithelial barrier functions** Kabelitz D, Schröder J-M, Mechanisms of Epithelial Defense (Karger 2005) [still valid] Gallo R, Hooper L, Epithelial antimicrobial defence of the skin and intestine (Nature Reviews Immunology, vol. 12, July 2012) Leiva-Juarez M M, Kolls J K, Evans S E, Lung epithelial cells: therapeutically inducible effetors of antimicrobial defense (Mucosal Immunology, vol. 11, no. 1, January 2018) Current scientific publications **c. Clinical, molecular and diagnostic neurosciences** Kandel E R, Kessell T M, Siegelbaum S A, Principles of Neural Science (McGraw Hill 6th edition, 2021) Ropper A, Samuels M, Klein J, Prasad S, Adams and Victor's Principles of Neurology (McGraw Hill 11th edition, 2019) Research and review articles **d. Molecular diagnostics** William Coleman, Gregory Tsongalis: The Molecular Basis of Human Disease (Academic Press, 2nd edition, 2017) Gregory Tsongalis: Advances in Molecular Pathology, volume 4-1 (Elsevier 2021) Bailey M et al.: Comprehensive Characterization of Cancer Driver Genes and Mutations (Cell, Volume 173, Issue 2, 2018)

	e. Cardiovascular epidemiology Rothman K, Epidemiology - An introduction (OUP 2nd edition, 2012) [still valid] Oleckno WA, Epidemiology: Concepts and Methods (Waveland Press Inc. 2008) [still valid] Current scientific publications **f. Metabolomics** Gowda, GA Nagana, and Daniel Raftery, eds. NMR-based Metabolomics: Methods and Protocols. Humana Press, 2019. Cavanagh, John, et al. Protein NMR spectroscopy: principles and practice. Elsevier, 1995. Wehrens, Ron, and Reza Salek, eds. Metabolomics: practical guide to design and analysis. CRC Press, 2019. James, Gareth, et al. An introduction to statistical learning. Vol. 112. New York: springer, 2013. Review and research articles