Module Handbook

Medical Sciences - Cardiovascular Research

Master of Science
One-year programme

University of Freiburg
Medical Faculty

Version 1, July 2023

universität freiburg

Content

1. Short description of the programme

Subject	*Medical Sciences - Cardiovascular Research*
Degree	Master of Science (MSc)
Form of programme	Full-time
Type of programme	Consecutive
Standard period of study	2 semesters
University	University of Freiburg
Faculty	Medical Faculty
Institute	Institute for Experimental Cardiovascular Medicine
Homepage	www.MSc-MedSci.uni-freiburg.de/cardiovascular
Language	English
Requirements for application	4-year BSc [240 ECTS] or MSc or equivalent degree in life sciences, natural sciences, bio-/ engineering, mathematics, computer sciences, human/ veterinary medicine, medical sciences, or similar subject
Start of the programme	Winter term

2. Contact details

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3. Objectives of the programme

The English-language one-year Master's programme in *Medical Sciences - Cardiovascular Research* will serve to educate small cohorts of basic scientists (initially 6 per annum) in medically relevant content, with the aim of training the next generation of translational scientists. This programme will enable candidates to communicate across real or perceived boundaries between basic science and medicine, by becoming familiar with vocabulary, concepts, and key approaches, and by developing an awareness of the opportunities and limitations of medical practice in general, and of cardiovascular medicine in particular.

The research-oriented course of study aims to recruit excellent national and international students with a 4-year 'honours' BSc (≥240 ECTS), an MSc or equivalent degrees in life sciences, natural sciences, bio-/ engineering, mathematics, computer sciences, medicine, medical sciences, or similar. This consecutive programme leads to a Master of Science (MSc) degree offered by the Faculty of Medicine, and organised by the Institute for Experimental Cardiovascular Medicine (IEKM).

The programme lasts one year and accounts for a total of 60 ECTS. It has been designed to offer a broad knowledge-base in cardiovascular medicine, and the opportunity to specialise in a subset of cardiovascular research. The one-year curriculum is divided into two parts: the first consisting of a taught course to develop breadth and depth of understanding in the subject matter and in advanced laboratory and clinical techniques; the second dedicated to implementing an individual research project (= MSc Thesis).

In the first term, students engage in various study modules with components lasting up to three weeks. Module components cover theoretical and practical aspects, with a mix of seminars, tutorials, practical classes, and demonstrations including clinical shadowing. Students will receive a comprehensive introduction to cardiovascular anatomy, physiology, molecular/ cell biology, biochemistry, and biophysics. This is followed by an exploration of pathology and pharmacology, as well as imaging and diagnostics relevant for examining the heart and vessels. A clinical module addresses cardiology and cardiovascular surgery, followed by biomathematics, biostatistics, and Federation of European Laboratory Animal Science Associations (FELASA) accredited laboratory animal education and skills training. This taught term therefore combines a thorough grounding in general aspects of cardiovascular system structure and function with clinical insight into diagnosis and treatment of heart and vessel diseases, as well as exposure to 'wet- and dry-lab' basic and clinical work.

By the end of the first term, students will have obtained solid knowledge and competences, qualifying them to independently plan and carry out an experimental research project, to choose and apply appropriate methodological approaches, and to critically evaluate scientific findings in the context of other published data. These skills will be honed during the MSc Thesis research project in the second term. The thesis forms a major programme component, entailing a coordinated 20-week research project supervised by two principal investigators.

The key qualification goals of the interdisciplinary MSc in *Medical Sciences - Cardiovascular Research* are as follows.

Professional and interdisciplinary competences

Our graduates will:

- have a sound understanding of cardiovascular science, ranging from anatomical and physiological insight to cardiovascular diseases and clinical cardiovascular medicine;

- gain solid knowledge and skills in addressing medical research ethics and implementing good scientific practice;
- be capable of gathering, analysing, and critically assessing information from a variety of different sources;
- be able to use critical thinking and analytical skills to explore problems, propose solutions, critically evaluate results, and identify and design follow-up research and/ or alternatives;
- have advanced English language skills, including scientific and medical vocabulary relevant for the subject, and be able to clearly and succinctly present scientific thoughts and findings orally and in writing.

Practical research skills

Graduates:

- are capable of critically evaluating published reports, identifying open research questions, and formulating experimentally testable hypotheses;
- have sophisticated practical skills and familiarity with a broad range of techniques in the medical sciences, combined with awareness of good scientific practice in laboratory work;
- are capable of critically scrutinising the suitability of experimental approaches for investigating questions related to medical sciences. Based on broad exposure to state-of-the-art research approaches and on a broad network of peers, they are also able to identify additional methods and techniques and to combine them in a meaningful way to make complex scientific questions accessible;
- can independently plan and conduct experiments to answer scientific questions as part of their own research project. They have the ability to evaluate the relevance of results of their experiments;
- will be able to perform quantitative and qualitative analysis of the data obtained;
- are able to answer scientific questions competently in discussions, and to communicate with experts across a range of specialities in the field.

Personal development and future profession

Graduates:

- acquire the practical and technical skills required for conducting advanced and independent research, such as towards a PhD;
- will have an understanding of ethical reasoning and moral issues related to medical research and clinical practice, and apply this understanding to assess current and future ethical issues responsibly;
- will acquire general abilities, such as time- and conflict-management, coping with stressful situations and tight deadlines, and critical thinking skills, as well as social competence and the ability to work in a team, during their MSc Thesis work. In addition, as members of an international study programme working in internationally composed research groups, they also gain interpersonal, intercultural, and communication skills;
- gain qualities that improve their chances in a competitive employment market, including personal responsibility, sound judgment, and initiative to navigate a complex professional environment;
- will be aware of the need for engagement with the wider community and be capable of reflecting on the role of science and medical research in society;
- are able to work in a variety of careers, including biomedical and related sciences, research and development in academia and industry, education, and scientific publishing.

In conclusion, upon successful completion of the Master's programme, students will be well prepared to engage in demanding, advanced research and/ or pursue a career in the public or private sector.

4. Curriculum

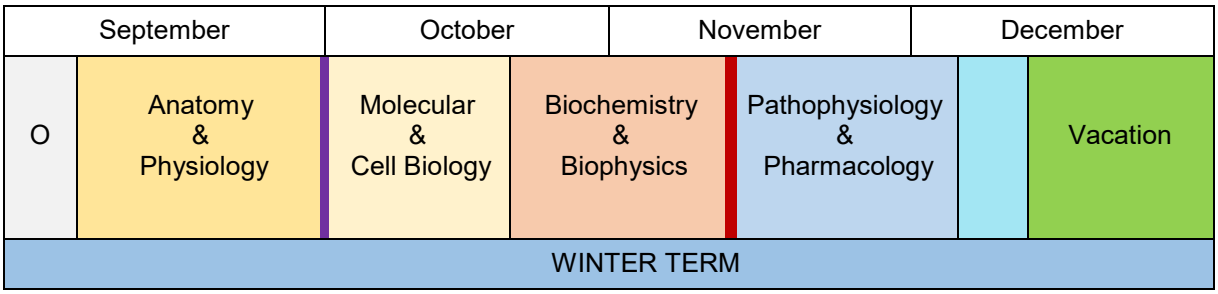
4.1 Overview by Modules

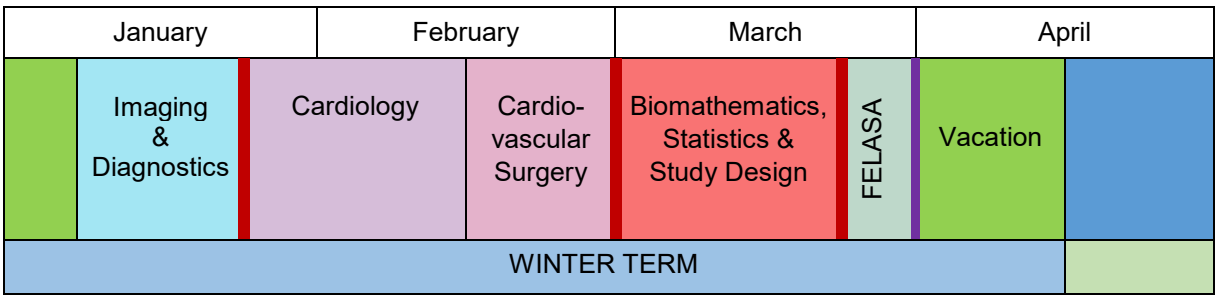
Module Code	Module Title	Term	ECTS
Compulsory modules combining lectures, seminars, practical classes			**∑ 29**
MS-01	**The Cardiovascular System**		**∑ 10**
01.1	Introduction to Cardiovascular Medicine	1	1
01.2	Anatomy & Physiology	1	3
01.3	Molecular & Cell Biology	1	3
01.4	Biochemistry & Biophysics	1	3
MS-02	**Cardiovascular Disease**		**∑ 6**
02.1	Pathophysiology & Pharmacology	1	3
02.2	Biomedical Imaging & Diagnostics	1	3
MS-03	**Cardiovascular Medicine**		**∑ 5**
03.1	Cardiology & Cardiovascular Research	1	3
03.2	Cardiovascular Surgery	1	2
MS-04	**Methods In Experimental Cardiovascular Research**		**∑ 8**
04.1	Biomathematics, Statistics & Study Design	1	3
04.2	FELASA course	1	2
04.3	Student-led seminars	1	1
04.4	Transferable skill courses	1+2	2
Compulsory master thesis			**∑ 31**
MS-05	**MSc Thesis**		**∑ 31**
05.1	MSc Thesis	2	28+2
05.2	Science Days	2	1
			∑ 60

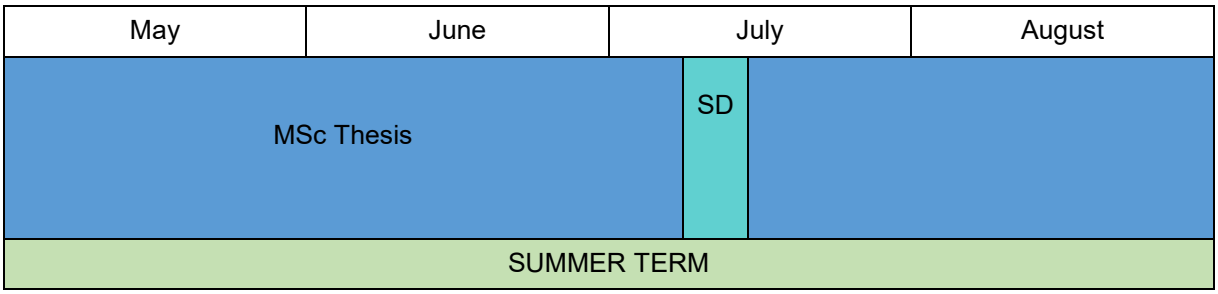
4.2 Module components and module directors

Module components	Module directors; institutions
Introduction to Cardiovascular Medicine	Peter Kohl; Institute for Experimental Cardiovascular Medicine (IEKM)
	Hannah Kappler; Department of Congenital Heart Defects and Pediatric Cardiology
Anatomy & Physiology	Franka Arden; Institute of Anatomy and Cell Biology
	Peter Kohl; IEKM
Molecular & Cell Biology	Oliver Schilling; Institute for Surgical Pathology
	Franziska Schneider-Warme; IEKM
Biochemistry & Biophysics	Tilman Brummer; Institute for Molecular Medicine and Cell Research
	Rémi Peyronnet; IEKM
Pathophysiology & Pharmacology	Eva Rog-Zielinska; IEKM
	Achim Lother; Institute of Experimental and Clinical Pharmacology and Toxicology
Biomedical Imaging & Diagnostics	Callum Zgierski-Johnston; IEKM
	Christopher Schlett; Clinic of Radiology, Section for Cardiovascular Radiology
Cardiology & Cardiovascular Research	Ingo Hilgendorf; Department of Cardiology and Angiology
	Nadine Gauchel; Department of Cardiology and Angiology
Cardiovascular Surgery	David Schibilsky; Department of Cardiovascular Surgery
	Maximilian Kreibich; Department of Cardiovascular Surgery
Biomathematics, Statistics & Study Design	Viviane Timmermann; IEKM
	Rémi Peyronnet; IEKM
FELASA Course	Rita Sanchez-Brandelik; Medical Faculty
	Susanne Tulke; IEKM
Student-led Seminar	Peter Kohl; IEKM
	Susanne Tulke; IEKM
Transferable Skills	Susanne Tulke; IEKM
	Callum Zgierski-Johnston; IEKM
MSc Thesis	Peter Kohl; IEKM
	Susanne Tulke; IEKM
	Project Advisors; various
Science Days	Callum Zgierski-Johnston; IEKM
	Susanne Tulke; IEKM

4.3 Timeline of the Master's programme







Key: O= Orientation week; SD= Science Days

Module examination (= Modulabschlussprüfung)

Intermediate evaluation (= Teilmodulzwischenprüfung)

4.4 Programme coordination and supervision

The Course Director will have 1:1 meetings with each student at the four- and eight-months time-points to assess student progress and address any academic queries or concerns. In addition, the Course Coordinator will have 1:1 meetings at the two- and six-months time-points, and be available throughout the programme, to discuss any issues regarding course organisation or non-academic concerns.

MSc Thesis work will be supported by a thesis committee. This will consist of the primary supervisor of the project and a secondary supervisor from a different academic background (aiming for representation of preclinical and clinical science). The thesis committee will convene during the Science Days to assess progress and provide feedback on thesis progress, and during the assessment of the final thesis.

4.5 Evaluations and module examinations

Evaluations (= Studienleistungen) are not graded and thus are pass/ fail performance and/ or progress assessments. They may include records of attendance of the respective courses, presentations, protocols, and written or oral tasks, which help assess the learning progress of students.

Examinations (= Prüfungsleistungen) in the form of oral or written examinations will be conducted at the end of modules and will be graded. Written examinations usually last 60-180 minutes. Oral examinations usually last 10-45 minutes.

Key	
Evaluation (pass/ fail)	A = attendance (minimum required: 85%); T = written or oral task; P = presentation
Examination (graded)	W = written; O = oral; P = presentation; MSc = MSc Thesis

4.6 Grading system

Performance in examinations will be assessed as the performance out of 100. Percentages will be documented and transformed into grades according to the scheme below. The final grade will be calculated as follows: one half constitutes the weighted grade of the MSc Thesis (written thesis grade multiplied by 0.8, plus the oral defence grade multiplied by 0.2), the other half is the average of marks obtained in examinations during term 1.

Percentage	Grade
≥95%	1.0
≥91%, <95%	1.3
≥87% <91%	1.7
≥83% <87%	2.0
≥79% <83%	2.3
≥75% <79%	2.7
≥71% <75%	3.0
≥67% <71%	3.3
≥63% <67%	3.7
≥60% <63%	4.0
<60%	5.0

The final grade is:

with an average of up to 1.5:	very good	(sehr gut)
with an average of 1.6 to 2.5:	good	(gut)
with an average of 2.6 to 3.5:	satisfactory	(befriedigend)
with an average of 3.6 to 4.0:	sufficient	(ausreichend)
with an average above 4.0:	not sufficient	(nicht ausreichend)

4.7 Types of course work

Seminars
Seminars are interactive exchanges, based on faculty-led presentations that introduce new content and provide breadth. Students are expected to post-process seminars.

Tutorials
Tutorials 'flip' the classroom, in that students contribute substantially and actively to presentations and discussions. They facilitate thought-processes and application of prior knowledge to increase depth of understanding. Students are expected to prepare in advance for tutorials.

Practical classes
Practical classes provide hands-on opportunities for students to try tools and techniques, to experiment, to obtain and analyse data, and to apply previously acquired knowledge. Usually no specific preparation is needed, and a protocol is generated as an output.

Demonstrations
Demonstrations give hands-off instructions to students, for example, in human anatomy dissections, advanced experiments or techniques, and clinical shadowing on wards and in operating theatres. Usually no specific preparation is needed by students, and content is followed up in discussions at seminars or tutorials.

As the different types of course work require a varying range of pre- or post-processing, student workload is determined by differential factors to take into account self-study time needed. Factors are: Seminars: 1.3; tutorials: 1.7; practical classes: 0.8; demonstrations: 0.6.

5. Module Descriptions

5.1 Modules

Module MS-01 The Cardiovascular System										ECTS ∑ 10
Module Components/ Study Subjects	***Type of Course***					***Time in Class***	***Total Workload***	***ECTS***	***Evaluation***	***Examination***
	Seminar	*Tutorial*	*Practical Class*	*Demonstration*	*Other Activities*					
01.1 Introduction to Cardiovascular Medicine	X			X	X	25 h	25 h	1	A	
01.2 Anatomy & Physiology	X	X	X	X		68 h	90 h	3	A; T	
01.3 Molecular & Cell Biology	X	X	X			62 h	90 h	3	A	W
01.4 Biochemistry & Biophysics	X	X	X			64 h	90 h	3	A	

01.1 Introduction to Cardiovascular Medicine			ECTS: 1
Module directors	*Prof Dr Peter Kohl, Dr Hannah Kappler*		
Workload	*Total workload: 25 h*	*Time in class: 25 h*	*Self-study: /*
Duration/ Frequency	*1 week/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, discussion rounds, demonstrations* *Other: extracurricular activities*		
Content	This module component will introduce the MSc course and its participants to one-another. Basic principles of scientific working, with emphasis on critical reading and assessment of scientific communications, will be explored together with good scientific practice. Furthermore, ethical aspects of basic science, translational studies, and clinical research will be surveyed. Students will be given insight into different perspectives of cardiovascular research from clinical and basic science points of view, including possibilities and limitations of modern cardiovascular medicine.		
Objectives	Students will: - enhance their ability to critically read, understand, and constructively discuss scientific publications;		

	- obtain knowledge of key aspects of good scientific practice, and tools to communicate across disciplines in the field of cardiovascular science; - become aware of opportunities, feasibility, and limitations of different types of cardiovascular research.
Evaluation	Students participate in at least 85% of all scheduled course content. Attendance will be documented.
Examination	*None*
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*None*
Literature	

01.2 Anatomy & Physiology			**ECTS: 3**
Module directors	*Dr Franka Arden (Anatomy); Prof Dr Peter Kohl (Physiology)*		
Workload	*Total workload: 90 h*	*Time in class: 68 h*	*Self-study: 22 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, demonstrations, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	Anatomy: - General principles and terminology used in human anatomy; - Microscopic anatomy of cardiovascular cells and tissues, including introduction to basic microscopy techniques; - Macroscopic anatomy of heart and vessels; - Developmental changes in cardiovascular anatomy and perinatal changes in systemic circulation; - Structure and function of coronary circulation and cardiac innervation; - Anatomy of the respiratory system and interaction with circulation. Physiology: - General principles of excitable and contractile cell function; - Cardiac electrical activity and electro-mechanical coupling; - Cardiac mechanical activity and mechano-electric feedback; - (Auto-)regulation of circulatory function and adaptation to changes in demand; - Oxygen transport. Practical skills: - Hands-on auscultation, blood pressure measurement, basic sonography, ECG recording (Einthoven leads), microscopic evaluation of cardiovascular tissue;		

	- Demonstration of human cardiac anatomy: dissection.
Objectives	**To provide an anatomically based understanding of normal cardio-vascular function.** Students will: - obtain active knowledge of general principles and terminology required to explore anatomy and physiology of the cardiovascular system; - be able to explain and interrelate cardiac structure and electro-mechanical function; - comprehend vascular structures and blood components relevant for circulatory system function; - appreciate the relevance of inter-organ communication in auto-regulation of blood flow; - be familiar with basic techniques for microscopic and macroscopic investigation of cardiovascular structure, and for assessment of basic cardiovascular electrical and mechanical function.
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented. Assessment of learning progress: at the end of the module component, students will sit an oral test consisting of a combination of closed- and open-ended questions, including labelling tasks and short thought experiments. Content of the test will focus on key elements of this module component featured in seminars and additionally discussed in detail in practical classes and/ or tutorials. The assessment will not be formally graded as content will be re-visited in more detail in subsequent study modules (the pass level is 65 out of 100 points).
Examination	*None*
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Participation in preceding module component.*
Literature	*Anatomy:* Paulsen F, Böckers T & Waschke J. *Sobotta Anatomy Textbook.* Elsevier 2018. ISBN: 9780702067600. *Physiology:* Hall JE & Hall ME. *Guyton and Hall Textbook of Medical Physiology.* Elsevier 2020. ISBN: 9780323597128. Kohl P & Helmes M. The heart. In: Petersen O (ed) *Lecture Notes: Human Physiology.* Blackwell Publishing 2006, 335-371. ISBN: 9781405136518.

01.3 Molecular & Cell Biology			ECTS: 3
Module directors	*Prof Dr Oliver Schilling (Molecular Biology); Dr Franziska Schneider-Warme (Cell Biology)*		
Workload	*Total workload: 90 h*	*Time in class: 62 h*	*Self-study: 28 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	Cellular structures and processes: - Overview of eukaryotic cell organization and of key organelle structure and function; - Mitosis, cell division, cellular differentiation, and pluripotency; - Key metabolic pathways; - Principles of inflammatory response & types of cell death; - Integration of cells in tissue. Molecular components and concepts: - Classes and function of biomolecules, central dogma of molecular biology; - Gene expression regulation, epigenetic concepts; - Ion channels, cell surface receptors, cell-cell contacts; - Components of the extracellular matrix. Applications: - Model systems, including animal models for cardiac research; - Introduction to optogenetics. Practical skills: - DNA preparation, protein separation and detection, cell culture and transfection.		
Objectives	**To provide a basic understanding of cellular physiology in general, and its relevance for cardiovascular systems in particular.** Students will: - be able to associate classes of biomolecules with their functions; - be capable of identifying cellular and subcellular structures and understand their corresponding functions; - comprehend general concepts and terminology in molecular and cell biology; - understand key mechanisms of gene expression control; - have an overview of common experimental techniques in molecular and cell biology; - understand basic principles of biological signal transduction; - be able to explain cell biological foundations of pathophysiological processes in cardiovascular diseases such as myocardial infarction.		

Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.
Examination	At the end of module component 01.4, students will sit a written exam consisting of a combination of closed- and open-ended questions, including single choice questions, labelling tasks, short thought experiments, and text questions requiring brief essay-style answers. Content of the exam will focus on key elements of module components 01.3 and 01.4 featured in seminars and additionally discussed in detail in practical classes and/ or tutorials. The assessment will be graded.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Successful completion of preceding module components.*
Literature	Alberts B, Johnson A, Lewis J, Morgan D & Raff M. *Molecular Biology of the Cell.* 6th rev. ed., Garland Science, Taylor & Francis 2014. ISBN: 9780815345244

01.4 Biochemistry & Biophysics			**ECTS: 3**
Module directors	*Prof Dr Tilman Brummer (Biochemistry), Dr Rémi Peyronnet (Biophysics)*		
Workload	*Total workload: 90 h*	*Time in class: 64 h*	*Self-study: 26 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	Biochemical signalling: - Definitions, terminology, main principles of signalling elements and circuitry, overview of major signalling pathways, *e.g.* RTK/RAS/MAPK, PI3K/AKT/mTOR, cell adhesion and developmental pathways (Wnt, Hippo, etc.), and signalling pathways involved in inflammation; - Key techniques: Western blotting, immunoprecipitation, consideration of antibody choice and validation, protein arrays, enzymatic assays. Biophysics: - Biophysics and Biomechanics: definitions, terminology, and main concepts; - Key techniques used to assess passive and active mechanics and electrics; - Active and passive mechanics of vasculature and the heart; - Electrical *vs*. mechanical stimulation in the heart - Most common mechanical alterations in the context of cardiac diseases		

	and link with electrical disturbances; - Main mechano-sensors and mechano-transduction pathways in health and disease. Practical classes and skills: - Mechanical activation and inflammation; - Application and control of mechanical stimuli; - Using fluorescence microscopy to follow live protein complex dynamics during the early steps of inflammation; - Western blot analysis of inflammasome activation; - Application and control of mechanical stimuli (stretch, fluid shear, stress) to cardiac non-myocytes and observation of calcium responses, measurement of different hydrogels; - Preparation and analysis of primary cell culture lysate contents.
Objectives	**To provide students with an overview of essential biochemical and biophysical signalling pathways.** Students will: - gain a general understanding of key biochemical signalling pathways; - know the drivers, controllers and regulators of cardiac passive and active electrical and mechanical properties; - appreciate interrelation between mechanical stimuli, mechano-sensor proteins, and downstream signalling effects on cell and tissue function; - be introduced to and observe techniques to assess and control cell and tissue mechanical environment; - be able to interpret Western blot data and validate antibodies.
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.
Examination	At the end of this module component, students will sit a written exam consisting of a combination of closed- and open-ended questions, including single choice questions, labelling tasks, short thought experiments, and text questions requiring brief essay-style answers. Content of the exam will focus on key elements of module components 01.3 and 01.4 featured in seminars and additionally discussed in detail in practical classes and/ or tutorials. The assessment will be graded.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Participation in preceding module components.*
Literature	<u>*Biochemical signalling*</u>: Alberts B, Johnson A, Lewis J, Morgan D & Raff M*. Molecular Biology of the Cell.* 6th rev. ed., Garland Science, Taylor & Francis 2014. ISBN: 9780815345244 <u>*Biophysics*</u>: Hoskins PR, Lawford PV and Doyle BJ*. Cardiovascular biomechanics.* Springer 2017. ISBN: 9783319464077

Module MS-02 Cardiovascular Disease	ECTS ∑ 6

Module Components/ Study Subjects	Type of Course: Seminar	Tutorial	Practical Class	Demonstration	Other Activities	Time in Class	Total Workload	ECTS	Evaluation	Examination
02.1 Pathophysiology & Pharmacology	X	X	X			58 h	90 h	3	A	W
02.2 Biomedical Imaging & Diagnostics	X		X	X		69 h	90 h	3	A; P	

02.1 Pathophysiology & Pharmacology			ECTS: 3
Module directors	*Dr Eva Rog-Zielinska (Pathophysiology); Dr Achim Lother (Pharmacology)*		
Workload	*Total workload: 90 h*	*Time in class: 58 h*	*Self-study: 32 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, self-study* *Optional component: student-led seminar (see module components 04.3)*		
Content	Pathophysiology: - An overview of the cellular basis of the most common structural and functional disorders of the heart (congenital, acquired, systemic); - Multi-scale overview of common pathological phenotypes (gene mis-regulation, ultrastructural changes, metabolic disorders, mechanical and electrical malfunctions); - Blood pressure regulation and the interplay of cardiac pathologies with other body systems (vasculature, kidneys, liver); - Overview of the current state of basic research on some of the most common heart diseases; - Emerging trends in treatment of cardiac pathologies (cell-based therapies). Pharmacology: - General principles of pharmacology, including pharmacodynamics and -kinetics; - Overview of intra- and extracellular signalling cascades relevant for pharmacotherapy (hormone systems, ligands, receptors, enzymes); - Compounds relevant in the prevention and treatment of cardiovascular		

	disease according to current guidelines; - Potential problems of pharmacotherapy: adverse effects, drug-drug interactions, metabolites; - Principles of preclinical and clinical drug development. Practical skills: - Light microscopy-based evaluation of healthy and diseased cardiac tissue; - Contraction assessment in living cardiomyocytes in normal and pathological settings and upon pharmacological intervention; - Assessment of gene regulation using qRT-PCR and reporter gene assays.
Objectives	**To provide a solid basis for a comprehensive understanding of cardiovascular disease and its pharmacological treatment.** Students will: - have active knowledge of the prevalence of various cardiac pathologies, and of main characteristics of the most commonly seen types of cardiac diseases; - be able to explain the mechanisms associated with structural, functional, and molecular pathological changes seen during heart disease; - be familiar with general principles of pharmacology; - have an active knowledge of relevant compounds used in guideline-directed medical therapy of cardiovascular disease, including their mechanisms of action; - comprehend principles of emerging cardiac therapies.
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.
Examination	At the end of the module component 02.2, students will sit a written exam consisting of a combination of closed- and open-ended questions, including single choice questions, labelling tasks, short thought experiments, and text questions requiring brief essay-style answers. Content of the exam will focus on key elements of the module components 02.1 and 02.2 featured in seminars and additionally discussed in detail in practical classes and/ or tutorials. The assessment will be graded.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Successful completion of preceding module.*
Literature	*Pathophysiology:* Zipes DP, Libby P, Bonow RO & Tomaselli D*. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine.* Elsevier 2005. ISBN: 071260479X Chapters: 19-22, 27-29, 35-37, 39-40, 44, 50-54, 56-57, 59 *Pharmacology:* Brunton L, Knollmann B & Hilal-Dandan R. *Goodman & Gilman's: The pharmacological basis of therapeutics.* McGraw Hill 2017. ISBN: 9781259584732

02.2 Biomedical Imaging & Diagnostics			**ECTS: 3**
Module directors	*Dr Callum Zgierski-Johnston (Pre-clinical), Prof Dr Christopher Schlett (Clinical)*		
Workload	*Total workload: 90 h*	*Time in class: 69 h*	*Self-study: 21 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, practical classes, demonstrations, project, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	This module component will provide an introduction to language, methods, and tools for preclinical and clinical imaging covering: - General principles and terminology; - Sample processing and tissue labelling for optical imaging; - Working principles and advantages/ disadvantages of preclinical imaging methods including: ultrasound, macroscopy, bioluminescence imaging, brightfield, fluorescence, confocal, light-sheet, multiphoton, and electron microscopy; - Working principles and advantages/ disadvantages of clinical imaging methods such as gating strategies, computed tomography (CT) including photon-counting CT, magnetic resonance imaging (MRI), ultrasound, Doppler ultrasonography, single photon emission computed tomography (SPECT), positron emission tomography (PET); - Approaches for image processing and registration; - Identification of electrical and mechanical disorders of the cardiovascular system using structural and functional imaging; - Application and clinical value of the different clinical imaging modalities in the context of different cardiovascular diseases.		
Objectives	Students will be: - able to identify the most appropriate imaging method for addressing a given research question or for diagnosing a given medical condition, based on weighing imaging requirements and utility/ limitations of existing methods; - aware of the entire imaging analysis pipeline from sample preparation and processing including labelling, through to imaging and image processing; - able to recognise anatomical structures in clinical images; - familiar with image processing techniques for segmentation of cardiovascular structures; - understand potential and limitations of the different clinical imaging modalities.		

Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented. In addition, students will be expected to implement and give a presentation on a hands-on project involving research into a disease state, 3D image segmentation, model generation, and 3D printing.
Examination	Structured assessment: at the end of this module component, students will sit a written exam consisting of a combination of closed- and open-ended questions, including single choice questions, labelling tasks, short thought experiments, and text questions requiring brief essay-style answers. Content of exam will focus on key elements of the module components 02.1 and 02.2 featured in seminars and additionally discussed in detail in practical classes and/ or tutorials. The assessment will be graded.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Successful completion of preceding module components.*
Literature	As there is no suitable single textbook, this module with provide tailor-made handouts, including copies of relevant publications.

Module MS-03 **Cardiovascular Medicine**	ECTS ∑ 5

Module Components/ Study Subjects	Type of Course					Time in Class	Total Workload	ECTS	Evaluation	Examination
	Seminar	Tutorial	Practical Class	Demonstration	Other Activities					
03.1 Cardiology & Cardiovascular Research	X	X	X	X		79 h	90 h	3	A	O
03.2 Cardiovascular Surgery	X	X	X	X		43 h	60 h	2	A	

03.1 Cardiology & Cardiovascular Research			**ECTS: 3**
Module directors	*PD Dr Ingo Hilgendorf; Dr Nadine Gauchel*		
Workload	*Total workload: 90 h*	*Time in class: 79 h*	*Self-study: 11 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, clinical demonstrations, self-study* *Optional component: student-led seminar (see module components 04.3)*		
Content	Theoretical insight into different cardiovascular diseases (listed below) will be obtained in seminars. Medical cases are observed and discussed in the clinical setting, and students will be trained in key hands-on skills in the field of cardiology. Vascular diseases: - Coronary artery disease; - Peripheral artery disease; - Venous thromboembolism. Cardiomyopathies: - Ischaemic cardiomyopathy; - Genetic/ metabolic cardiomyopathies; - Heart failure - diagnostics and therapeutic options. Critical Care: - Cardiogenic shock; - Cardiac arrest. Clinical Electrophysiology: - Atrial fibrillation; - Ventricular arrhythmias;		

	- Pacemaker therapies. Practical skills: - Hands-on echocardiography and vascular duplex sonography, ECG recording, central venous catheter techniques, and their clinical interpretation; - Basic life support (resuscitation training). Seminar series 'Introduction to cardiovascular research at Freiburg': This series will introduce the different cardiovascular research groups in Freiburg, their research focus, state-of-the-art techniques and methodologies, including an introduction to the utility and limitations of the various biological model systems used. Students will be presented with MSc Thesis project offers from interested laboratories.
Objectives	**To provide a basic understanding of the clinical utility of diagnostics, conventional, and interventional therapies in cardiology.** Students are expected to: - gain active knowledge about the most relevant cardiovascular diseases; - be able to recognise typical symptoms of cardiovascular diseases; - possess an overview of diagnostic options in cardiovascular medicine and when to use which; - understand therapeutic options and goals in cardiovascular medicine (medication, interventions); - perform venous punctures; - record an ECG and analyse it; - perform ultrasound sonography of heart and vessels; - be able to perform basic life support. After attending the seminar series 'Introduction to cardiovascular research at Freiburg', students should: - have an overview of available MSc Thesis projects; - be able to make an informed choice about which research group they want to join to commence their MSc Thesis project; - be aware of animal models in cardiovascular research, their scope, utility, and limitations.
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.
Examination	At the end of the module component 03.2, students undergo a structured oral exam. This will comprise key elements of the content of the module components 03.1 and 03.2.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Successful completion of preceding modules.*
Literature	Camm AJ, Lüscher TF, Maurer G and Serruys PW. *The ESC Textbook of Cardiovascular Medicine.* Oxford Medicine, 2019. ISBN: 9780198784906

03.2 Cardiovascular Surgery			ECTS: 2
Module directors	*PD Dr David Schibilsky; PD Dr Maximilian Kreibich*		
Workload	*Total workload: 60 h*	*Time in class: 43 h*	*Self-study: 17 h*
Duration/ Frequency	*2 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, demonstrations, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	This module component will address historical roots of surgery, highlight milestones of the development of thoracic and cardiovascular interventions, provide an overview of current state-of-the-art cardiovascular invasive procedures and their interrelation with minimally-invasive approaches, and highlight emerging directions in the field. Specifically, students will be introduced to: - Symptoms, diagnosis, indications and treatment options for coronary artery disease (*e.g.* bypass grafting), valve diseases, and diseases of the aorta; - Ventricular assist device implantation, total artificial heart, and heart transplantation; - Modern approaches to managing congenital heart defects; - Emergency interventions. These topics will be featured in seminars and demonstrations (shadowing in the operating room [OR] and on the intensive care ward). In terms of hands-on skills, students will be introduced to basics of hygiene in the OR, obtain practical skills in cutting and suturing, and conduct a class on cardiac perfusion using a slaughterhouse pig heart. Beyond clinical content, students will visit a start-up company developing novel resuscitation approaches, to familiarise themselves with the framework of academia-industry-interrelations.		
Objectives	**To provide an overview of cardiovascular pathologies and understanding of principles of surgical treatments.** Students will: - acquire knowledge of cardiovascular disease entities amenable to surgical therapy, and required diagnostics; - be introduced to general principles of cardiovascular surgery and the use of medical products in this context; - become familiar with basic hygiene requirements and obtain hands-on skills in basic surgical techniques.		
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.		

Examination	At the end of this module, students undergo a structured oral exam. This will comprise key elements of the module components 03.1 and 03.2.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Successful completion of preceding module components.*
Literature	Moorjani N, Viola N & Ohril SK. *Key Questions in Cardiac Surgery.* TFM Publishing Ltd 2011. ISBN: 9781903378694 Cohn LH & Adams DH. *Cardiac Surgery in the Adult.* McGraw-Hill 2017. ISBN: 9780071844871

Module MS-04 **Methods in Experimental Cardiovascular Medicine**	ECTS ∑ 8

Module components/ Study Subjects	Type of Course					Time in Class	Total Workload	ECTS	Evaluation	Examination
	Seminar	Tutorial	Practical Class	Demonstration	Other Activities					
04.1 Biomathematics, Statistics & Study Design	X	X	X			53 h	90 h	3	A	O
04.2 FELASA course	X	X	X			40 h	60 h	2	A; T	
04.3 Student-led seminar	X				X	6 h	30 h	1	A; P	
04.4 Transferable skills	X	X	X		X	50 h	60 h	2	A	

04.1 Biomathematics, Statistics, & Study Design			**ECTS: 3**
Module directors	*Dr Viviane Timmermann (Biomathematics); Dr Rémi Peyronnet (Statistics & Study Design)*		
Workload	*Total workload: 90 h*	*Time in class: 53 h*	*Self-study: 27 h*
Duration/ Frequency	*3 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, tutorials, practical classes, demonstrations, self-study* *Optional component: student-led seminar (see module component 04.3)*		
Content	Biomathematics: - Mathematical model of Hodgkin and Huxley, and their adaptation to the heart by Noble; - Ordinary differential equations; - Markov models of ion channels; - Models of cell contraction; - Electro-mechanical and mechano-electrical coupling models; - Numerical methods; - Optimization methods (*e.g.*, simplex algorithm or gradient-based algorithms). Statistics and Study Design: - Descriptive statistics, graphical data exploration; - Probability and distributions; - Hypothesis testing;		

	- Regression and correlation: linear regression models (including ANalysis Of VAriance), logistic regression models, survival analysis (including Kaplan-Meier curves and Cox regression); - Planning of experiments, sample size calculations; - Interpretation of results and replication; - Hierarchical statistics and pseudo-replication. Practical skills: - Scientific computing: Introduction to Python; implementation of a heart cell action potential model and incorporation of specific channels into existing cardiac cell models; - Statistics: Practical data examples and exercises using the free software R; implementation of statistical methods for dual and multiple comparisons; - Study planning: Exemplary assessment of sample size for the student's chosen MSc project.
Objectives	**To provide mathematical methods for scientific computing and statistics/ study design.** Students can: - describe and discuss the Hodgkin-Huxley and Noble models of cell electrophysiology; - compare different mathematical methods for modelling cardiac cell functions; - select and apply biostatistical techniques required for data analysis; - describe how to design an experimental study and how to calculate the experimental animal numbers.
Evaluation	Students participate in at least 85% of scheduled course content. Attendance will be documented.
Examination	At the end of the module component, students will be tested in an oral exam. Based on the Hodgkin-Huxley formalism, students will be examined on their understanding of the mathematical description of cardiac cell biology and applications in the context of the heart. It is expected that students are able to use that understanding to generate algorithms executed by a computer. Further, students will be tested on their logical thinking, knowledge, and application of biostatistical methods. They are expected to be able to calculate statistical sample sizes for a given experimental example, giving a rationale and explanation of the used statistical methods.
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*Participation in preceding modules.*
Literature	*Biomathematics:* Keener, and Sneyd. *Mathematical Physiology I: Cellular Physiology*. 2009. ISBN: 9780387758473 Keener, and Sneyd. *Mathematical Physiology II: Systems Physiology*, 2010. ISBN: 9780387793887

	Statistics and Study Design: Dalgaard P. *Introductory Statistics with R.* Springer, 2nd edition, 2008. ISBN: 9780387790541

04.2 FELASA course			**ECTS: 2**
Module directors	*Dr Rita Sanchez-Brandelik, Dr Susanne Tulke*		
Workload	*Total workload: 60 h*	*Time in class: 40 h*	*Self-study: 20 h*
Duration/ Frequency	*1-2 weeks/ annually*		
Language	*English*		
Forms of teaching and learning	*Lectures, practical classes.*		
Content	Course with 20 h theory and 20 h practice, according to FELASA type A certified by GV-SOLAS: - Ethical and legal principles of animal experiments (Animal Welfare Act); - Alternatives to animal experiments; - Biology, nutrition, husbandry, anaesthesia, euthanasia, recognition of pain/ stress assessment, surgical interventions, genetics (creation of genetically modified animals, embryo transfer, cryopreservation), hygiene management, immunisation, infectious diseases/ zoonoses, allergies. Practical skills: - Mouse/ rat handling, sample/ blood collection, euthanasia, necropsy, suture techniques, basic surgical techniques, anaesthesia.		
Objectives	Working with animals in science requires a profound understanding of the legal and ethical framework, species-specific expertise, and technical knowledge. This course teaches the basics of laboratory animal science as an introduction, and it serves as a building block for obtaining official permission to work on research projects with animals.		
Evaluation	Attendance of lectures and practical classes. Written pass/ fail exam at the end of the course.		
Examination	*None*		
Usability	*MSc Medical Sciences*		
Prerequisites	*None*		
Recommendations	*Successful completion of preceding module components.*		
Literature	*Course script*		

04.3 Student-led seminar			ECTS: 1
Module directors	*Prof Dr Peter Kohl, Dr Susanne Tulke*		
Workload	*Total workload: 30 h*	*Time in class: 6 h*	*Self-study: 24 h*
Duration/ Frequency	*1 term/ annually*		
Language	*English*		
Forms of teaching and learning	*Student-led seminar: each student picks one topic (based on interest/ expertise) where they run teaching (usually a 30 min block within a Seminar or a Tutorial, followed by feedback; to be coordinated with the respective module directors).*		
Content	Content will depend on the module and topic of the student-led seminar, but will often relate to previous research experience of the student.		
Objectives	Through active involvement in teaching, students will improve their scientific, presentation, and didactic skills. By participating in other students' seminars, they will broaden their horizons, gain a deeper understanding of the respective topic, and engage in scientific discourse.		
Evaluation	Students hold a seminar within one of the taught module components. Assignment to specific module components will be conducted in nought week (module 01.1), and agreed upon with target module directors.		
Examination	*None*		
Usability	*MSc Medical Sciences*		
Prerequisites	*None*		
Recommendations	*Successful completion of preceding module components.*		
Literature			

04.4 Transferable Skill Courses			ECTS: 2
Module directors	*Dr Susanne Tulke, Dr Callum Zgierski-Johnston*		
Workload	*Total workload: 60 h*	*Time in class: 50 h*	*Self-study: 10 h*
Duration/ Frequency	*continuous/ annually*		
Language	*English*		
Forms of teaching and learning	*Depends on the type of course selected*: *lecture, seminars, presentations, hands-on training*		

Content	- CRC distinguished lecturer seminar series: monthly seminars with internationally renowned invited speakers who present their current research. After these talks, students have the opportunity to interact with the speaker in 'meet the speaker' sessions for trainees, to engage in networking and scientific discussions. Contact time 16 h *p.a*. - International dimension of biomedical research: seminars presenting the international scope of medical research and reflecting on global, international and intercultural dimensions of/ differences in medical research organisation. Contact time 2 h *p.a*. - Courses on: - Good scientific practice - Research data management - Presentation skills
Objectives	The courses offered within the transferable skills module component will impart knowledge and skills outside of the thematic focus of the MSc programme, and be relevant for the students' interdisciplinary skills- and personal development. Students will: - learn about state-of-the-art research projects and techniques around the world, engage in discussions about current research and networking with renowned scientists; - discover international aspects of biomedical research and be aware of associated opportunities and challenges; - be familiar with rules and concepts of good scientific practice; - learn about the FAIR principles (findable, accessible, interoperable, and reusable) of research data management - obtain knowledge and practical skills in poster and oral presentation.
Evaluation	Attendance and completion of training courses will be monitored. Depending on the course, this can include oral presentations, hands-on training or similar. Students participate in at least 85% of scheduled course content. This module component is not graded (pass/ fail based on confirmed attendance of at least 85% of scheduled course content/ course completion).
Examination	*None*
Usability	*MSc Medical Sciences*
Prerequisites	*None*
Recommendations	*None*
Literature	

Module MS-05 MSc Thesis	ECTS ∑ 31

Module Components/ Study Subjects	Type of Course: Seminar	Tutorial	Practical Class	Demonstration	Other Activities	Time in Class	Total Workload	ECTS	Evaluation	Examination
05.1 MSc Thesis	**Project + defence**						800 h	28+2		MSc; P
05.2 Science Days	**X**				**X**		30 h	1	A; P	

05.1 MSc Thesis	ECTS: 28+2
Module directors	*Prof Dr Peter Kohl, Dr Susanne Tulke, Project advisors*
Workload	*Total workload: 800 h*
Duration/ Frequency	*20 weeks/ annually*
Language	*English*
Forms of teaching and learning	*Practical research project in a laboratory, including reading of research papers, development of experimental approach, data gathering and analysis, presentation of progress reports, and writing of an MSc Thesis.* *The MSc Thesis module component comprises a 20-week research project with both practical work, writing and oral defence of the thesis.*
Content	To complete their studies, students are required to complete an independent research project and prepare an MSc Thesis in a student-selected laboratory within the given period of time. A surplus of project offers will be introduced within the seminar series 'Introduction to cardiovascular research at Freiburg' in module component 03.1 for the students to choose from. Students will conduct their experimental work under the guidance of experienced scientists, on a current problem from the field of cardiovascular research. They will obtain hands-on skills in methods required to address the problem of the MSc Thesis, and apply them independently. In addition to the practical work, the design of experiments or studies (sequence of work steps, inclusion of control groups or control experiments, statistical planning), the documentation, presentation and interpretation of the collected data, as well as their oral and written presentation are required. Projects will be in line with ongoing research in Freiburg-based cardiovascular research teams. They will be supervised by two thesis advisors: the host group leader (primary advisor) and an additional principal investigator from another team (secondary advisor with a different academic background). The MSc Thesis will be concluded with a written thesis

	formatted like a scientific paper and an oral defence. Both in the practical and in the written/oral part of the MSc Thesis, emphasis is on the compliance with good scientific practice, integrity, and honesty. Scientific content is depending on the project.
Objectives	After successful completion of the MSc Thesis, students have acquired sound practical knowledge in a subset of state-of-the-art methods for cardiovascular research. They are familiar with current scientific questions and recent publications in their field. They are skilled in collecting and analysing scientific data, and in writing a scientific report. In addition to specific research expertise, students acquire soft skills such as time- and project-management, working in international, interdisciplinary teams, English communication and writing skills, as well as adherence to rules of good scientific practice. With successful completion of the MSc Thesis, students demonstrate their scientific ability and show that they are prepared to independently tackle challenging research projects, such as in subsequent PhD thesis work. As a result of their MSc experience, students should be able to analyse published reports, develop own research project ideas, design and perform appropriate experiments, obtain, analyse, and publish data. They should be efficient in presenting their research in oral and written form, and in engaging in a scientific discourse about their subject of study. In addition, they will be able to make an informed decision on their further career path.
Evaluation	*None*
Examination	General regulations: Students are required to submit – after 20 weeks of work – one electronic (PDF) and three printed copies of their thesis to the office of the MSc programme. They also prepare and give an oral presentation of their results. Upon the student's written application, and with the primary supervisor's support, the examination board may grant an extension of the submission deadline of up to 8 weeks. Examination: The written MSc Thesis is evaluated by two examiners: the primary thesis advisor and a referee who is not the secondary advisor. The oral defence is evaluated by three examiners: the primary and secondary advisors, and the referee. Upon successful completion of the module component examination MSc Thesis, the student obtains 30 ECTS. The grades for written thesis (28 ECTS) and oral defence (2 ECTS) are weighted 0.8 and 0.2, respectively, and together form the grade for the MSc Thesis. The MSc Thesis' grade is weighted according to ECTS and thus constitutes half of the final grade of the entire programme (the other half is the average of marks obtained in examinations in term 1).
Usability	*MSc Medical Sciences*
Prerequisites	*Successful completion of preceding modules in term 1.*

Recommendations	*Students should contact the PI in whose laboratory they would wish to do your MSc Thesis as soon as possible after introduction of available projects in Module component 03.1 of the course.*
Literature	*To be specified by the primary thesis advisor*

05.2 Science Days			**ECTS: 1**
Module directors	*Dr Callum Zgierski-Johnston; Dr Susanne Tulke*		
Workload	*Total workload: 30 h*	*Time in class: 14 h*	*Self-study: 16 h*
Duration/ Frequency	*2 days/ annually*		
Language	*English*		
Forms of teaching and learning	*Seminars, students' presentations, other activities*		
Content	Cardiovascular science, with a scientific focus depending on MSc Theses of students enrolled. A keynote speaker, selected by the students from international leaders in cardiovascular research, will address the area of excellence they work in. The Science Days will feature oral presentations by all trainees and presentations by/ discussions with alumni of the course, a student-selected keynote lecture, and training of presentation skills. Students present talks on their ongoing MSc Thesis (mid-term report). As part of transferrable skills training, students will additionally give brief (4 min) lectures on *ad hoc* topics. Lectures will be video-taped; students will receive detailed professional feedback on presentation style, slides, *etc*. After revision, students will present their short lecture again, this time in 3 min.		
Objectives	Training of organisation and presentation skills, and discussion of MSc Thesis content and progress.		
Evaluation	Successful participation in the Science Days requires attendance and presentation of a 20 minutes talk with 10 minutes discussion on the MSc Thesis, plus two mini-lectures for the skills session. This module component is not graded (pass/ fail).		
Examination	*None*		
Usability	*MSc Medical Sciences*		
Prerequisites	*None*		
Recommendations	*Successful completion of preceding module components.*		
Literature			