Course Package

Bioengineering Technologies – Q3 + Q4

Name module	BET Biomedical Membranes & Artificial Organs - Q3 + Q4
Educational programme	MSc Biomedical Engineering
Period	Second semester (quartiles Q3 + Q4)
Study load	30 ECTS
Coordinator	J. Huttenhuis

BET Biomedical Membranes & Artificial Organs			
Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
		Biomedical Membranes & Artificial Organs 201400284 (5 EC)	**Microphysiological systems 202300079** (5 EC)
		Bionanotechnology 193400111 (5 EC)	**3D Bioprinting 202100080** (5 EC)
		Electives: choose 5 EC	***Electives: choose 5 EC***
		Advanced Organic Chemistry – 201900123 (5 EC)	**Topics in Human Anatomy; Physiology and Movement Disorders – 202200365** (5 EC)
		Biomedical Signal Acquisition - 191210720 (5 EC)	**Clinical Chemistry - 193640050** (5 EC)
		Development of Artificial Internal Organs - 202001409 (5 EC)	**Tissue Engineering* - 201600327 (5 EC)**

Required preliminary knowledge: Fundamental knowledge and concepts from Cell Biology; Biochemistry; Chemistry (both inorganic and organic chemistry, standard techniques); Biology; Biomaterials and Cell Material Interactions; Basic anatomy and Physiology; Cell Culture and Molecular Biological; Laboratory experience is of eminent importance; Thermodynamics; Biomechanics.

*Mandatory preliminary knowledge: ‘Intro to BET’ and ‘Applied Cell Biology’ are mandatory courses you have to have passed.

Quartile 3

201400284 - Biomedical membranes & (bio) artificial organs

The course covers biomedical applications where the (bio) artificial membrane plays a crucial role. Main topics are: membrane preparation and characterization, drug delivery, blood purification-dialysis, blood oxygenation, bio-artificial kidney, bio-artificial pancreas, bio-artificial liver and tissue engineering. The course combines theory, assignments as well as experiments.

193400111 - Bionanotechnology

Bionanotechnology is a field of research and applications that sits at the interface between nanotechnology on the one hand and life sciences on the other.

This course includes:
An introduction into the field of bionanotechnology field.
Basics of nanobiology, including structure and function of DNA/RNA, DNA supercoiling, chromatin structure, structure and function of proteins, lipids, membranes, molecular motors, biological cells (Biological) nanoparticles, including gene therapy and DNA nanoparticles, inorganica and iron oxide nanoparticles, quantum dots, the unfamiliar world at the nanoscale, molecular interactions, Brownian motion, and diffusion.
Methods and techniques to study biology at the nanoscale, including fluorescence microscopy and other fluorescence-based technoniques, nanoscopy methods, scanning probe microscopy (AFM), single molecule force spectroscopy, elasticity mapping, optical tweezers, magnetic tweezers.

Writing of a comprehensive essay on the applications of nanobiotechnology, based on a short literature study.

Electives: choose 5 EC

201900123 - Advanced Organic Chemistry

- Reacive groups, competing mechanisms;
- Structures of amino acids and proteins;
- Peptides and their chemical synthesis;
- Orthogonal chemistry;
- Protein modification;
- Chemistry on surfaces;
- Cell surface engineering;
- Protein arrays, protein sensors
- Antifouling and bio-activation of biomaterials.

191210720 - Biomedical Signal Acquisition

The electrochemical detection methods form a beautiful comprehensive part of this course: starting from electrochemical processes at an electrode and the subsequent mass transport phenomena result in the three basic operational principles (potentiometry, amperometry and conductometry). When the relation between the variable to be determined (ionic species and/or its concentration) and the measured quantity (voltage, current or conductance) is known, the relevant examples follow: the oxygen electrode (Clark electrode), the carbon dioxide sensor (Severinghaus principle) and the pH sensors (glass electrode). Additionally, other chemical biosensors like the glucose sensor, and biosensors based on optical detection principles are treated. The treatment of physical sensor systems is guided by the biomedical application: blood pressure and flow, lung volume and capacity. A bridge to the course Lab-on-a-Chip is formed by some examples of micro Total Analysis Systems, of which the detector is based on one of the mentioned sensor principles.

This course is open for TM, MBE, APH, NANO and EE students. General knowledge from your bachelor programs is required. For TM students, this course bridges the gap between biophysiology and biomedical signal processing and -analysis. This course consists of 12 lectures, where you actively participate in discussions to reach the learning objectives. You will write your critical review paper in teams of two students to train and improve your knowledge and understanding via the original papers you have to review. Moreover, a 4-hr practical project concerning synchronous sensor data retrieval into a computer is one of the instructional modes of this course.

202001409 - Development of Artificial Internal Organs

The course will introduce you to the development of medical devices for the support or replacement of the internal organs heart, lungs, and kidneys, and it will incorporate the interaction between blood and the medical device, fundamentals of hemodynamics and the anatomy and physiology of the natural organ in comparison to the artificial organ.

The development process of artificial organs as medical devices will be the leading topic throughout the course, covering the user and design requirement specifications, risk analysis, design and usability, verification and validation testing, and documentation relevant for market approval.

Quartile 4

202300079 - **Microphysiological systems**

Microphysiological Systems (MPS) are miniaturized 3D cell culture platforms, such as spheroids, organoids, bioprinted tissues and organs-on-chips. MPS are used as investigational and predictive tools in (patho-)biology, pharmacology, toxicology, and efficacy assessments, and are essential, for example, for understanding mechanisms of disease and for accelerating drug development. This course will instruct students how to develop MPS and related technologies from conceptualization to validation, with an intentional emphasis on organs-on-chip technologies. Identifying MPS applications and routes towards implementation of MPS are major learning goals, which will be explained from both academic and industrial perspectives. The course will focus on understanding the relevance and development steps involved in establishing more physiologically realistic model systems, particularly with regard to developing organs-on-chip platforms. Lectures focusing on organ models will be provided, including liver, brain, kidney, heart, lung, and articular joint tissues. Furthermore, it will be discussed how key functions of organs/tissues can be emulated, including biochemical, electrical and/or mechanical features. In parallel, technologies that are used for designing, fabricating, and validating MPS will be discussed in depth, with the perspective of applying the knowledge in a project/practical exercises. The interaction between organ/tissue systems will be a key concept to be addressed in group brainstorming sessions, to enable student-directed active learning on systemic-like and complex disease models. In turn, this will enable students to identify and conceptualize organ/tissue elements to mimic in a MPS, envisioning an end application as model of (diseased/damaged) organs or tissues, such as the heart, the kidney, cartilage and blood vessels. Lastly, the combination of in vitro and in silico model systems will also be a main topic for discussion, to broaden the perspectives on technology complementarity. The advantages and bottlenecks of using MPS will be debated, to provide potential directions for further developments of these advanced technological platforms.

202100080 - 3D Bioprinting

As with all areas of additive manufacturing, 3D bioprinting has seen tremendous progress and developments in the last decade. 3D bioprinting combines advanced 3D fabrication techniques with biological systems to create designed tissue constructs, which can be applied for tissue engineering, as 3D in vitro biological models, or for other applications. This course will provide the student with fundamental insights on important aspects of 3D bioprinting, with a particular emphasis on extrusion bioprinting. Topics include bio-ink development, rheology of 3D bioprinting, inclusion of cells and 4D bioprinting, tissue engineering and translation, biohybrid robotics, and ethics.

The content that is covered in the course includes:

- Introduction, different methodologies for 3D biofabrication, from medical imaging to G-code to print, complexity in tissues
- Current limitations and main challenges in tissue engineering and 3D biofabrication
- Bio-inks; tissue derived matrices, biomaterial properties design, multiscale functional materials; crosslinking strategies
- Rheology of bio-inks, printability, embedded printing
- Inclusion of cells, tissue remodeling, 4D bioprinting
- Challenge lecture 1: write a 2-page proposal describing a new optimal 3D bioprinting procedure to produce a patterned construct with a complex shape.
- Tissue engineering, translation, in-clinic and in-vivo printing
- Biohybrid robotics
- Environmental, economic, and ethical implications of biofabrication
- Practical: Convert a filament printer into an extrusion hydrogel printer. Investigate the relationship between hydrogel rheological properties and printability.

Electives: choose 5 EC

202200365 - Topics in Human Anatomy, Physiology and Movement Disorders

This course will focus at different topics in the field of human anatomy and physiology with a focus on sport injuries and sport physiology. Next to that there will be a focus on gait analysis and movement disorders in patients with stroke, SCI and amputations. Lectures and one more practical course will be used alternatively. In addition, guest speakers who are experts in the field of rehabilitation will provide one or more lectures. The course will be examined by a written exam.

202400641 - Biochemistry

Biochemistry is the study of the chemistry of life processes. With this course, we aim to unravel with students the chemistry of life. Topics included are: Protein composition and structure, protein purification, identification and characterization methods; enzyme kinetics and catalysis; DNA, RNA and flow of genetic information; DNA replication, repair and recombination; RNA and protein synthesis; membrane channels and pumps; signal transduction pathways; sensory, immune and molecular motor systems; metabolic pathways including glycolysis, gluconeogenesis, citric acid cycle, oxidative phosphorylation, pentose phosphate; glycogen, fatty acid and protein metabolism.

202100252 - Technology for assessment of performance in sports

This course will focus at different techniques and methods to assess performance and identify injury risk in sports. It will cover biomechanical and physiological variables that can be measured in the laboratory setting as well as in the real world. It will provide the basic principles of biomechanics as well as exercise physiology as well an elaborate discussion of how these can be measured as well as estimated using advanced laboratory systems as well as wearable equipment. Furthermore, it will discuss models to estimate optimal workload for performance enhancement and models for injury prevention. Novel data analysis techniques will be introduced and applied to single and multi-level data streams for cyclical as well as non-cyclical data. Students will have the theoretical background to asses performance in sports, know which technique to apply when and how, and know the data analysis techniques to analyze and meaningfully interpret data to benefit sports performance or decrease injury risk.

Topics that will be addressed are:

- Principles of biomechanics and exercise physiology;
- Performance in a broader context. How does performance relate to capacity?;
- Movement analysis techniques for performance enhancement and injury prevention;
- Inertial sensor systems and wearable technology for movement analysis;
- Models for chronic versus acute work load;
- Models for injury risk estimation;
- Use of data science in sports and technology.

There will be guest lectures on interaction technology in sports and the use of advanced data analysis techniques as well as the integration of other variables (e.g. psychological variables) by athletes/coaches to asses changes in performance and injury risk.

201600327 - Tissue Engineering

The course 'Tissue Engineering' provides students with both basic knowledge as well as state-of-the-art examples of the field of regenerative medicine and tissue engineering in particular. The course will rely on the text book: Tissue Engineering 2nd edition (ISBN13: 9780124201453), which will be available as a downloadable e-book.

The course will be composed of multiple lectures that will cover all essential Tissue Engineering topics, which will be followed by a practical assignment. At the start of the course students will have the opportunity to an non-committal entrance exam, which reveal the presence and gaps in the students' knowledge. The depth and extent of the following lectures will be adjusted based on this preliminary test. Lectures will detail on cells source (stem cell vs mature cell), extracellular matrix (natural and engineered), Growth factors (tissue formation and controlled release), construct vascularization (methods and approaches), types of tissue engineering (Top-down vs Bottom-up), and advanced enabling technologies (microtechnology and 3D bioprinting). Internationally leading scientist will perform guest lectures on specific topics. For each lecture a set of questions will be provided via which the students can test their grasp of the topic's content. Lectures will take place over a period of 4 weeks. Every other week there is a dedicated opportunity for discussion on the content and questions of the past lectures. The lectures will be followed by an individual written exam that will count for 40% of the final grade. During these first 4 weeks the student will also work on an assignment, which will be presented by the student. This assignment will count for 10% of the final grade, which will be based on a presentation. This assignment revolves around the formation of a well-argued opinion on the relevance and translatability of a recently published solution that aims to solve an key challenge within the field.

Students will subsequently gain practical experience via lab work that will be performed in a subgroup format. Students will be able to choose between two practical assignments, which are either mostly biological or mostly engineering. Assignment one focusses on the decellularization of a tissue, which will be recellularized to form an engineering tissue. Assignment two focusses on the 3D printing of a designer construct that will be seeded with cells to generate an engineered tissue. For both assignments students will have the choice to engineer liver, skeletal, or heart tissue. The students will be allowed to design their own experiments within the boundaries of the practically feasible. Experts researchers will act as mentors for the experimental design. Students will present their design, which will provide the basis for a go or no-go (revision) decision to proceed with the experimental lab work. Lab work will count for 50% of the final grade, which will be based on an oral presentation, which will be assessed on design, scientific accuracy, data interpretation, originality, contextualization, and future perspective.