Teaching Chemistry in the New Bachelor "*Regenerative Medicine and Technology*"

Supporting Information

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Maastricht University

SYLLABUS

Track: Regenerative Medicine and Technology

Molecular Basis of Life

RMT1001

Academic year: 2024–2025

Faculty of Health, Medicine and Life Sciences

Regenerative Medicine and Technology

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Introduction

Course background, context

The course 'The Molecular Basis of Life' relies on the students' existing knowledge and understanding of biology and chemistry. It aims to provide insight into the structure and function of living and non-living matter. New concepts are introduced in the context of regenerative medicine and directly applied in solving problems and addressing challenges in the field. The period partly focuses on the structure and function of living tissues. The emphasis is on how cells interact with biologically relevant molecules, such as growth factors and extracellular matrix molecules, and how their interplay determines tissue development and homeostasis. The role of stem cells and their potency will be introduced in the context of these processes. Distinctions are made between several cell types and tissues (bone, cartilage) that highlight the structure-function relationship. Basic chemistry concepts are introduced in a biological context. Students are trained in applying key concepts of organic, inorganic and physical/analytical chemistry, such as stability, reactivity, functional groups, reaction/mechanism types, structure, kinetics, thermodynamics, and chemometrics to understand complex biological systems as well as to design materials for biomedical applications. The newly taught concepts are integrated in multidisciplinary cases/problems, which are discussed and worked out in small groups.

General introduction

Biological materials are central to all biological processes in and outside the cells of an organism. Cells together with the extracellular matrix define tissues and organs. Together they enable normal functioning (homeostasis). The interaction and modification of biological materials will be described from a biological and a chemical perspective. The aim of this course is to provide a broad overview of molecular biology and chemistry concepts that are important for regenerative medicine and technology (RMT).
The holy trinity of RMT consists of cells, matrix and molecular signals. In the first weeks, these three individual constituents will be introduced. Next, various tissues will be dissected into their individual components using relevant molecular biology and chemistry concepts (top-down). Finally, students will be challenged to synthesize their multidisciplinary knowledge in a self-proposed case which they will present to the audience of staff and peers. Together this is expected to provide a solid basis for understanding tissues at the cellular and molecular level.

Learning Goals

What are the learning objectives of the course?

Upon completion of this course, the student is able to:

1) Elaborate how matter is built, which chemical bonds and supramolecular interactions can be present in matter as well as the molecular and physical differences between gases, liquids, solids and solutions;
2) Describe the concepts of acids and bases, nucleophiles and electrophiles, the reactivity of functional groups and their most important chemical reaction types.
3) Explain the interaction between cells and their extracellular environment (natural or synthetic) and cells.
4) Explain the key concepts of cell biology and the corresponding biochemistry that lead to cell proliferation, differentiation, homeostasis and cell death.
5) Explain the structure and functioning of proteins, nucleic acids, carbohydrates, lipids and other biologically relevant molecules.
6) Explain how tissue build-up relies on precise spatiotemporal regulation.
7) Present and discuss the components of tissues at the chemical and biological level.
8) Apply the working principles of regeneration (e.g. cells, signals and scaffolds) in various cases.
9) Explain the laws of thermodynamics, the principles of chemical kinetics and the differences between the thermodynamic and kinetic control of reactions, and understands and applies the very basics of chemo metrics in analytical and physical chemistry (errors, significant figures, signal to noise ratios, accuracy vs precision).
10) Elaborate how the learned basic concepts of general, physical, organic and inorganic chemistry can be applied to understand biological processes and to design materials for biomedical applications with specific physico-chemical properties.

How are the learning objectives achieved?

The abovementioned objectives are achieved through active participation in interactive lectures, tutorials, problem-solving sessions, group-assignments, mini-symposium, formative quizzes, formative mid-term mock exam and a summative exam as well as by implementing the feedback obtained in these activities.
The Lab Skills Line (RMT1102) and Academic Development Lines (RMT1101 run in parallel with this course (RMT1001) and as part of these lines you will be trained in how to plan, perform and report practical laboratory experiments related to the themes covered in Molecular Basis of Life (RMT1001). As part of the Orientation Design Project (RMT1103), starting in Period 2, you will familiarize yourself with various research projects in which you will be able to directly apply your knowledge from this and other courses. For more information on the learning objectives, activities and assessments of these longitudinal lines, please check the corresponding syllabi and Canvas pages.

Contact

Course-Planning Group

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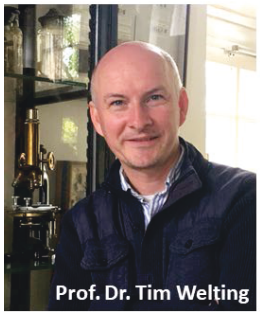

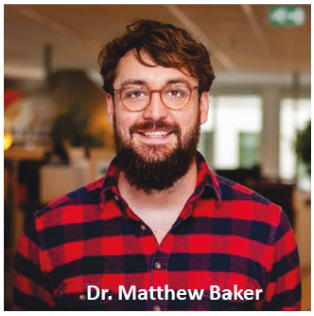

Questions
If you have questions about the timetable, registration for trainings and practicals, education and examination rules, exam dates, exam results, etc., you should contact the Institute for Education via ask FHML: www.askfhml.nl.

For questions about the content of the RMT1001 course or the exam you can contact the coordinators of this course: j.bauer@maastrichtuniversity.nl or g.vandenakker@maastrichtuniversity.nl. When writing your email, please put RMT1001 in the Subject Line of your email.

Problem-Based Learning Cases

Information about Problem-Based Learning (PBL) will be provided in the opening lecture of the program and during the first PBL session.

Weeks 1-2 Case 1: Intercellular Communication

Jeremy is a first-year Bachelor RMT student with a strong interest in biology. In his high-school biology classes, his teacher told him that the human body is designed to adapt to changing circumstances. This is something he notices himself when he encounters strong headwinds when cycling to class: his heart starts pounding and the pulsations of his arteries are clearly visible. He remembers that a substance called 'adrenalin' (US: epinephrine) plays an important role here, but he never found out how the cells in his heart become aware of the rise in adrenaline concentration in his blood. Would these cells have some kind of sensors that can detect adrenaline and respond by contracting stronger and more frequently? And how would the interaction between the adrenaline and these sensors take place?

Jeremy is also a fanatic fitness enthusiast and goes to the gym 3-4 times per week. And it shows: over the last year, his muscles have developed because of these workouts, but Jeremy is frustrated about the effort it takes to grow further. A fellow-body builder whispered to him in the dressing room that he can help his body develop muscle mass by taking substances called anabolic steroids. "Just a few shots and you will notice a difference", the guy said. This made Jeremy think: would there also be sensors in his body that can bind these anabolic substances? Would these be the same as the sensors for adrenalin or would there be multiple types? How would his muscles "know" that they need to respond by growing after taking these steroids?

A few years ago Jeremy suffered a muscle tear while pushing his limits in the gym. After a few weeks of rest the muscle completely healed. This makes Jeremy think about how the body "knows" how to heal after such an injury. Jeremy also tries to make a link with yesterday's opening lecture on tissue engineering and regenerative medicine and wonders how tissues "know" they need to grow as part of a regenerative therapy.

Jeremy also used to have chemistry in high school but was never really good at it. However, he realizes the importance of chemistry when trying to understand how his body works. What are steroids? What is adrenaline? What are these "sensors" that can detect these substances in the human body? What do these molecules look like and how are atoms connected? How do these molecules interact with one another and facilitate physiological changes?

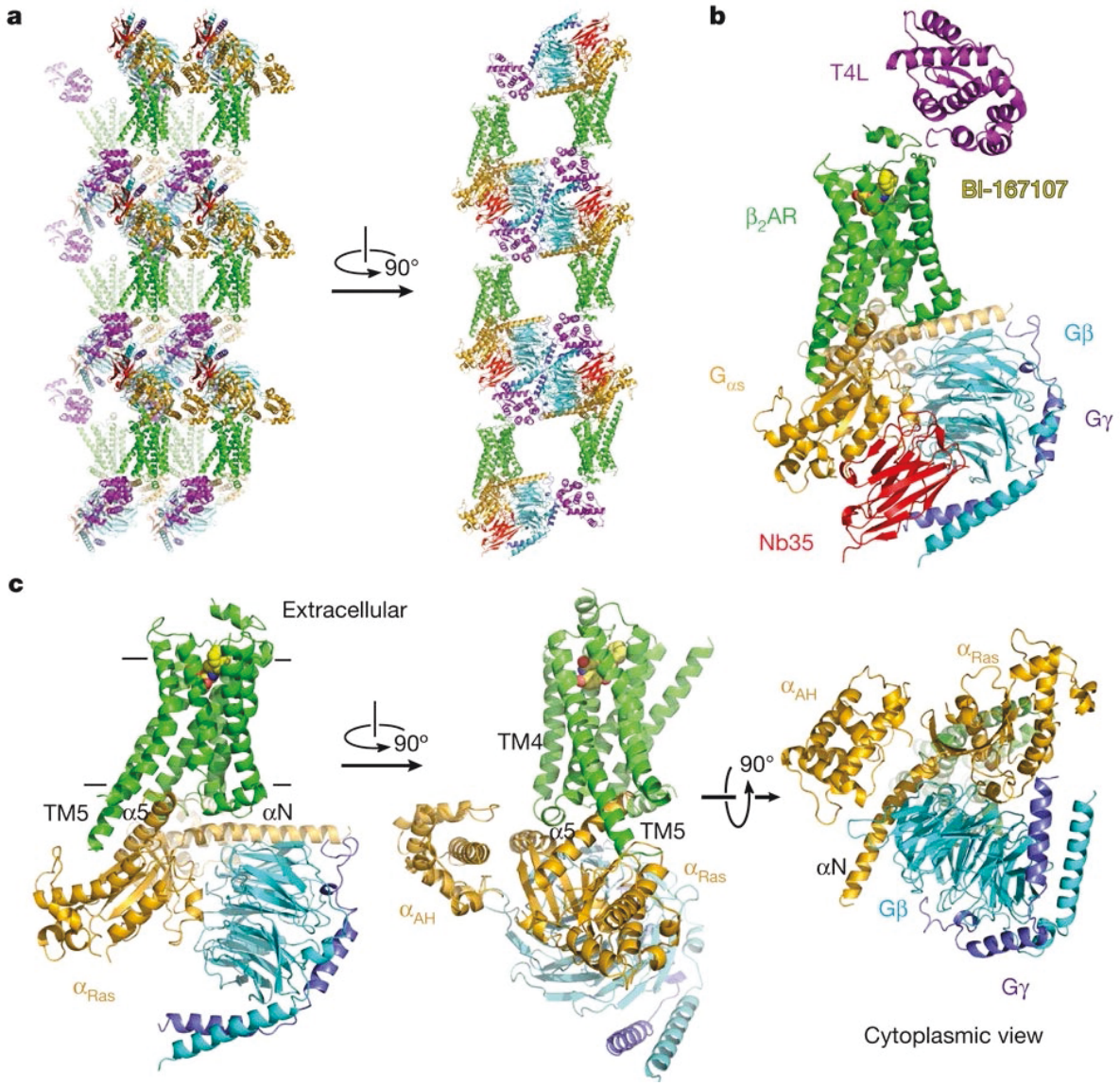

Figure 1: Crystal structure of the complex of the β₂-adrenergic receptor, its ligand and the heterotrimeric G-protein. A) Lattice packing of the complex shows alternating layers of receptor and G protein within the crystal. Abundant contacts are formed among proteins within the aqueous layers. B) The overall structure of the asymmetric unit contents shows the β2AR (green) bound to an agonist (yellow spheres) and engaged in extensive interactions with Gαs (orange). Gαs together with Gβ (cyan) and Gγ (purple) constitute the heterotrimeric G protein Gs. A Gs-binding nanobody (red) binds the G protein between the α and β subunits. The nanobody (Nb35) facilitates crystallization, as does T4 lysozyme (magenta) fused to the amino terminus of the β2AR. C) The biological complex omitting crystallization aids, showing its location and orientation within a cell membrane. Source: Crystal structure of the β2 adrenergic receptor–Gs protein complex. Rasmussen SGF et al., Nature (2011) 477, 549-555. DOI: 10.1038/nature10361.

Weeks 2-3 Case 2: Cell-Matrix Interactions - a Healthy Marriage?

The body's molecular build-up needs a number of basic elements; water, salts, amino acids, sugars, lipids, nucleic acids and other various biomolecules. Jeremy recognizes these basic elements as molecules that make-up the biochemical composition of a cell. However, looking and talking more and more about these molecules, Jeremy starts to realize that a body is not solely composed of cells. In tissues there is material between cells that is secreted and maintained by cells. This material is called extra-cellular matrix (ECM), and in many cases is the basis of connective tissue. But what is this matrix made up of? What molecules are present; what types of chemistry are active here? By weight, collagen is one of the most abundant proteins in the body. Yet, collagen comes in many forms. The ECM can be made up of different combinations of molecules working together to from various environments like strong bone, to soft and dynamic stem cell niches. Indeed, by one means or another, cells must cohere and communicate if they are to form an organized and responsive multicellular structure. What do they use to do this between cells? There is some unique chemistry/biochemistry acting in this realm.

Different tissues are made up from specialized cell types. After all, a muscle tissue contains myocytes, cartilage contains chondrocytes, bone contains osteocytes, and the basal lamina is populated by epithelium etc. Knowing this, Jeremy now starts to wonder how this would work for the composition of the ECM, is this also specific and different for each tissue? And do cells only produce this extra-cellular matrix, or is the extra-cellular-matrix also reciprocally important for the function and health of these cells?

Back in the lab, Jeremy is working on a highly innovative regenerative medicine project in which a 3D-printed scaffold for the regeneration of tissue defects is being developed. Cells should grow in these scaffolds and over-time form the desired tissue. Initially, his works started with bovine derived collagen, but there exist several problems and hurdles to clinical translation of this material. His group is moving to creating synthetic ECM mimics for his project. Suddenly he realizes that if he wants to apply cells in this synthetic scaffold, these cells need to be able to attach to the material. He read in the literature that so-called RGD-peptides can be used for such purpose. He also wonders how he can mimic the superstructure of collagen. Now he is getting really curious, would this be mimicking the real situation in a tissue?

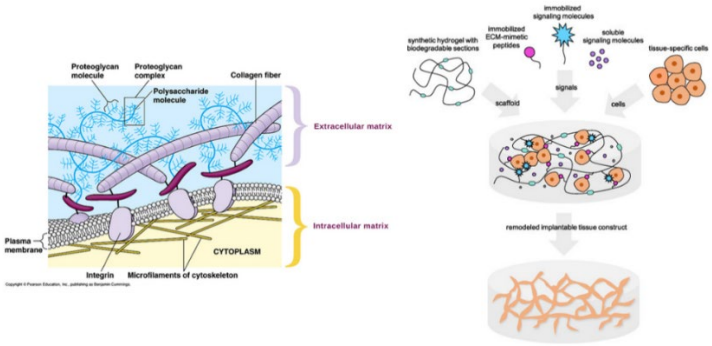

Figure 2. The native ECM (left) is quite complex, and remains a challenge to recreate synthetically (right). Source: Synthetic ECM: Bioactive Synthetic Hydrogels for 3D Tissue Engineering. Unal A.Z. & West J.L. Bioconjugate Chemistry (2020) 31, 10, 2253-2271. DOI: 10.1021/acs.bioconjchem.0c00270

Weeks 3-4 Case 3: Stem Cells and Differentiation: How Does Bone Form?

Stem cells are known to be able to form and repair tissues in the human body by differentiating into more specialized cells. Jeremy remembers from biology class that this is a one-way process; once committed, the stem cell is lost. To allow the generation of large volumes of tissue with only a few stem cells, it is important to 1) maintain a sufficient number of stem cells and 2) to generate as many differentiated cells from a single stem cell as possible.

Connective tissues like bone, tendon, cartilage and muscle derive from the embryonic mesenchyme. Together they form the musculoskeletal system, which is crucial for locomotion, internal support and protection of organs. Mesenchymal stem cells have the capacity to form bone, cartilage or adipose tissue *in vitro*. One advantage of MSCs is that they can be isolated from human adult tissues and manipulated *ex vivo*. A disadvantage is the need for the right signals and matrix to direct the MSCs in the desired direction.

While thinking about connective tissues, Jeremy cannot help but wonder what keeps bone together. Bone is an intriguing composite material, he reads in his textbook, composed of organic and inorganic matter. The collagen type I fibers are reinforced by hydroxyapatite crystals, which creates a tremendously strong material that is light and slightly flexible. At school, Jeremy always used to learn organic and inorganic chemistry separately and is now confused as to how these two separate components are built and how they are joint to form an organic-inorganic hybrid material with such remarkable physical and biological properties. Do chemical bonds form between? How are the different molecules organized? Is there something special in the chemistry or organization?

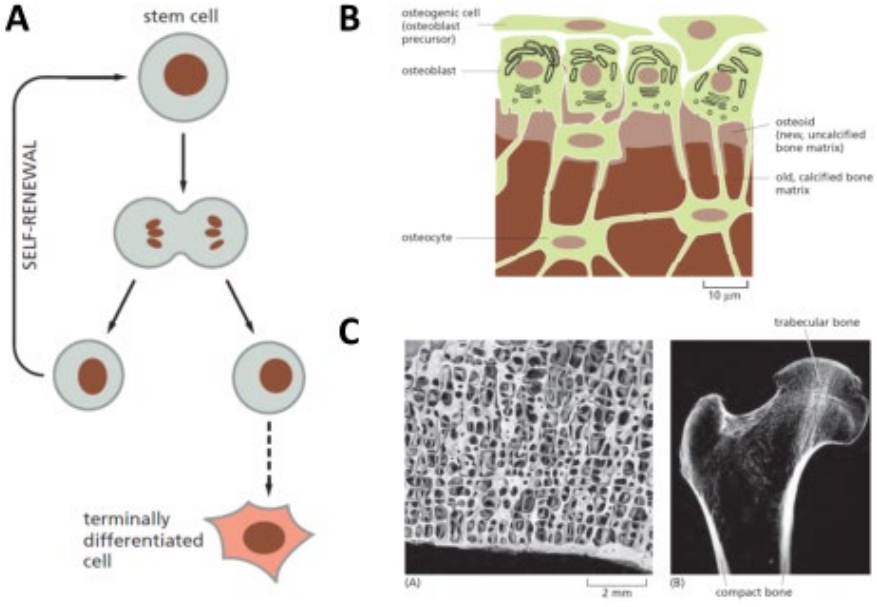

Figure 3: Stem cells and bone differentiation. A) Asymmetric division of a stem cell safe guards the stem cell population by self renewal. B) Bone cells in their tissue context: from precursor cell, to osteoblast and osteocyte. C) Left: bone matrix composed of collagen and hydroxy-apatite minerals aligned in typical honeycomb pattern (Ct image). Right: X-ray of the upper leg bone (femur). Source: Molecular Biology of the Cell 6th edition, figures 22-3, 14 & 15, pages 1120 & 1240.

Weeks 4-5 Case 4: Tissue Development: Endochondral Bone Formation

Can you remember when you were a baby? What a time it was! Babies are very flexible and can put their feet in their mouth with ease. There must be something special about your bones at that life stage. This flexibility changes when you grow up. Apparently, there is a change in the structure of your bones and its components. The skeleton needs to grow fast to keep up with development, but where does this take place? Do bone cells grow, do you add more bone cells, or is there just an increase in extracellular matrix deposition? In addition, what is the role of transient and permanent cartilage in bone growth?

The growth plate is crucial for longitudinal bone growth and forms bone through endochondral ossification. This is a complex process where progenitor cells proliferate, enlarge and ultimately die to create an extracellular matrix that serves as a scaffold. How is growth plate activity regulated? There are various systemic and local signaling molecules involved. Such as estrogen and a local gradient of Parathyroid hormone related peptide (PthRP) and Indian Hedgehog (IHH). But what do these molecules look like? How do we draw them in 2D and 3D? And what drives their proper interaction with the intended target? How do we make sure we have the correct stereoisomer? A long-time ago, someone came up with a lock-and-key mechanism for signal-receptor interactions, indicating the importance of the 3D structure in molecular recognition (compare to case 1, figure 1).

If you take a look at the molecular structures of the estrogen family, you can see subtle differences in their functional groups. But, the stereochemistry remains the same. Looking further at PthRP, and its analogs used as drugs (Teriparatide, Abaloparatide) we see portions of the molecule altered, but again few changes in stereochemistry. Digging a bit deeper, vitamin C is extremely important in collagen synthesis, a necessity for proper bone formation. Vitamin C exists as two enantiomers, where one is active in the body and the other not – but they look like the same molecule?

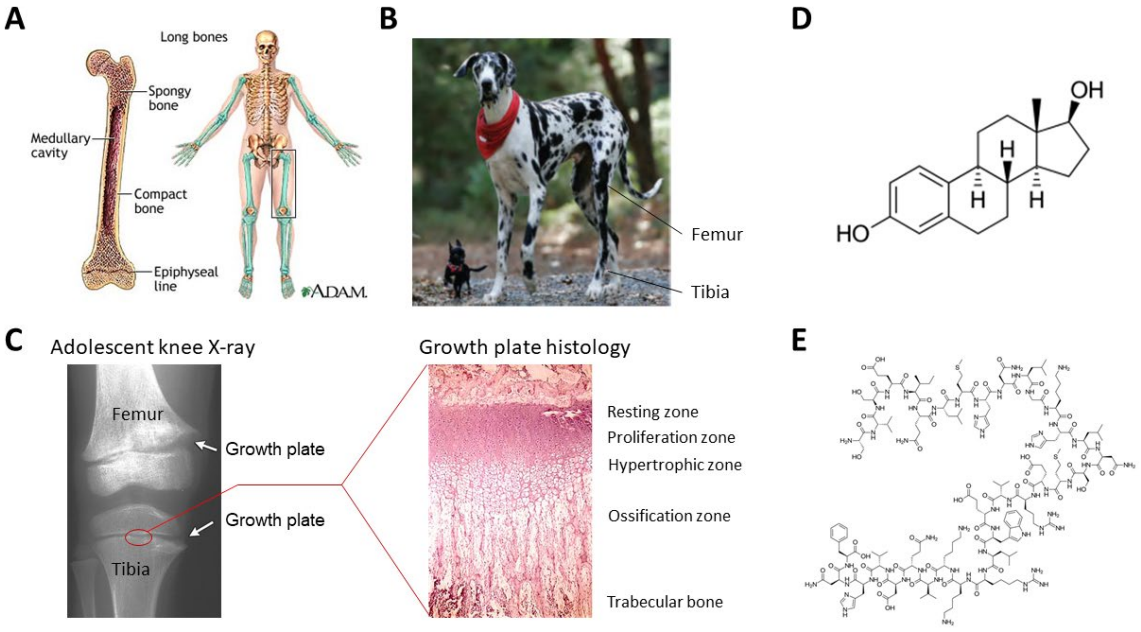

Figure 4: Growth plate regulation determines skeleton size. A) Long bones in a human skeleton. B) A chihuahua (2-5 kg) and a Great Dane (45-90 kg) use the same mechanism to grow a skeleton, yet their size is very different. C) Left: X-ray image of and adolescent lower leg (femur = upper leg bone, tibia = lower leg bone). White arrows indicate two growth plates at the end of these long bones. Right: histological slide of a human growth plate (H&E staining). A combination of chondrocyte proliferation, hypertrophy and apoptosis provides a template for bone formation. This process is highly regulated by hormones and growth factors. D) Estradiol, a building block of estrogen contains a tight carbon skeleton that give the molecule a determined 3D shape. Note the wedges and dashes in the structure, and the flat 2D style drawing. How do we translate this into 3D? E) Teriparatide, is a synthetic analog of PthRP. Note its large size and complexity. A lot of dashes and wedges and what looks like too many functional groups to count. How was this designed? Do we know anything about its 3D shape.

Weeks 5-6 Case 5: Cellular Proliferation and Degradation: Carefully Balanced Processes in Tissue Homeostasis

The cells in most of our organs appear to display remarkable plasticity. Observed at a macroscopic level, our organs grow during development and childhood, but then they reach a certain size and shape, which does not change very much during adult life. However, at a microscopic level, this apparent status quo does not hold. In fact, in most organs there is a constant proliferation and degradation of cells, which appears to be carefully balanced to maintain the constant size. This raises the question how cells actually 'know' whether they should proliferate or degrade. For cell proliferation, extracellular signal molecules called *mitogens* are identified which can activate cell division by initiating the mitotic cell cycle. Most mitogens are peptides or proteins and some of them may be classified as *lectines* or carbohydrate-binding proteins. Both proteins and carbohydrates are molecules comprised of chemically different building units but are both essential in many biological processes. Their synthesis and break-down in the body would not be possible without *enzymes*, another essential class of biologically active molecules.

On the other hand, cells that have become redundant need to be removed, either by passive or active induction of cell death. Induction of active cell death requires the activation of so-called 'death receptors' on the plasma membrane by their ligands, present in killer lymphocytes, or the activation of an intracellular pathway controlled by Bcl2. A very elegant example of active cell death, a.k.a. apoptosis, can be observed in the developing mouse paw as shown in the figure. In this process, paws are initially formed as spade-like structures. Subsequently, individual digits are formed by the controlled death of interdigital cells which eliminates the interdigital tissue. This is an example of how a carefully balanced cellular proliferation and degradation processes are both an essential part of new tissue formation.

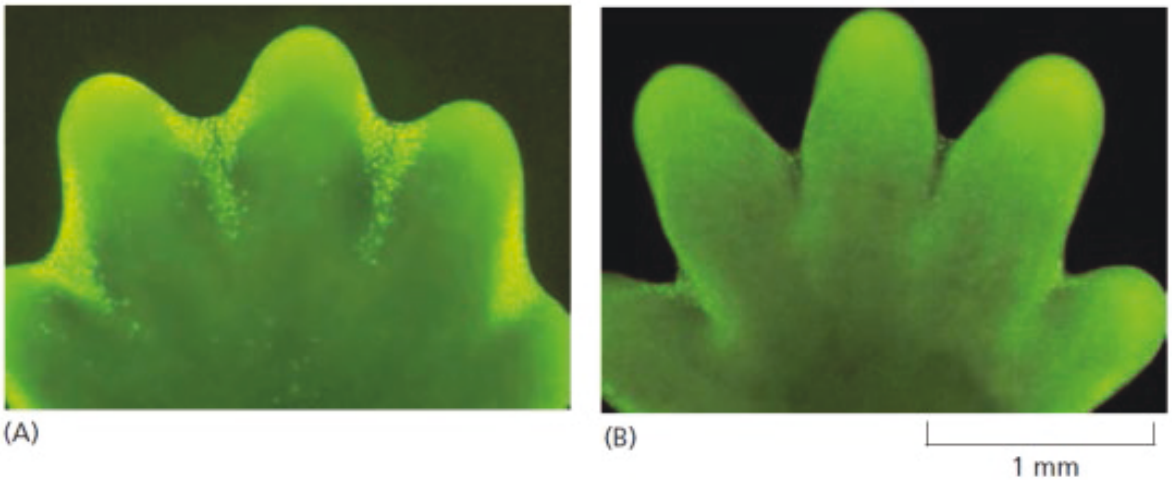

Figure 5: Sculpting the digits in the developing mouse paw by apoptosis. A) apoptotic cells labeled in bright green. B) Apoptotic cell death has removed the interdigital tissue. Source: Molecular Biology of the Cell 6th edition, figure 18.2, page 1022.

Weeks 6-7 Case 6: A Sum Greater than its Parts

The hierarchical organization of tissue, with both the cells and the extra-cellular matrix (ECM) is critical to tissue function and performance. Actually, the organization is also critical to the tissue creation. With such a multi-component system, teasing out the importance of the individual elements and their effect remains a challenge.

Human locomotion is, amongst others, made possible by articular joints, in which the articular cartilage tissue supports friction- and pain-free movement of body parts. Articular cartilage covers the epiphyses of bones and is a highly organized tissue populated by a cell type known as chondrocytes. From the articular surface down to the connection with bone, articular cartilage is organized at the molecular and supra-molecular level by collagens and glycosaminoglycans (GAGs). In the superficial layer collagen fibers are positioned in parallel to the cartilage surface to provide a smooth surface, in the transitional zone collagen fibers attain an arch-like structure to support weight, and in the deep zone collagen fibers are positioned perpendicular to the bone to support weight and connect the cartilage with the bone.

GAGs are water-retaining molecules that confer a swelling-like behavior to the cartilage collagen network. In this manner, the high water content provides unique compressive strength properties to articular cartilage, making is suitable to function as shock-absorber in the joint. GAG content in healthy articular cartilage is low in the superficial zone and increases towards the deep zone. In disease, such as osteoarthritis, collagen and GAG content and organization are jeopardized, causing a functional incompetence of the cartilage tissue to perform its anatomical task.

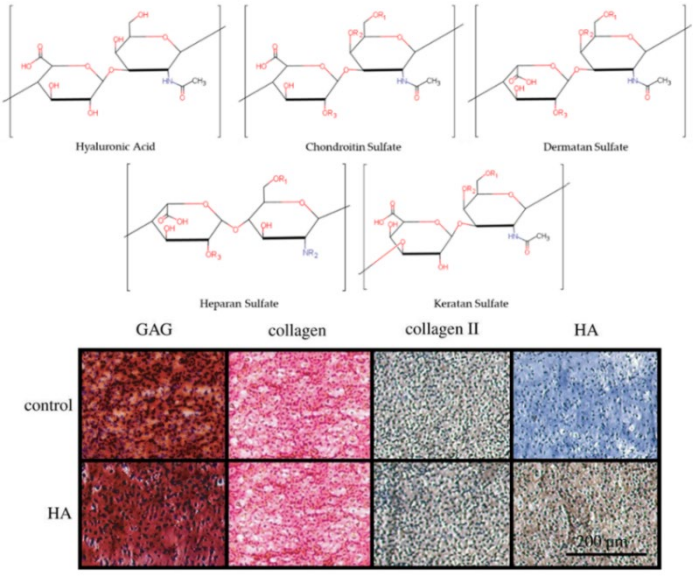

Figure 6: Glycosaminoglycans are an integral part of many tissues and extracellular spaces and their presence in cartilage is important for function and repair. Sources: top, Glycosaminoglycans in Tissue Engineering: A Review. Sodhi H & Panitch A. Biomolecules (2020)11, 1, 29. doi: 10.3390/biom11010029 and bottom, Identification of potential biophysical and molecular signaling mechanisms underlying hyaluronic acid enhancement of cartilage formation. Responte D.J., Natoli R.M., Athanasiou K.A. J. R. Soc. Interface (2012) 9, 3564–3573. doi:10.1098/rsif.2012.0399.

The amount of GAGs in a tissue can be critical to its performance. If we want to measure the amount of GAGs in a developing tissue, how do we do this? Kits are sold, but how do these work? What is the chemistry/molecular picture working within the kit, and how is this measured? And then if we wanted to know the effect of these different GAG concentrations on cell or tissue performance, how do we do this? Do we use purified GAGs and make a synthetic ECM? What would an experiment look like? Let's say we want to study tissue stiffness as an effect of GAG content; can we couple two measurements?

Now back in the lab, we want to recreate a controllable and optimized ECM to grow cartilage tissue. We know the approximate amounts of cell types and ECM components from experiments. Yet, when we mix everything together, we never seem to obtain high quality tissue. We notice that the structure and positional components are missing. What are these structural and positional components? How can we chemically introduce this into a matrix? Think of a biologically based and a synthetically based strategy!

Lectures

The slides of the lectures will be available via the course on the Canvas after the lecture.

Week 1

Opening Lecture: Bachelor RMT, PBL and RMT1001
Dr. Jurica Bauer & Dr. Guus van den Akker

The opening lecture will kick-off the Bachelor program, introduce PBL and provide an overview of the RMT1001 course content, structure, teaching and learning activities, and assessment.

Lecture 1: Cellular Signaling
Dr. Matthijs Blankesteijn

How does a cell know what is going on outside? And how can a cell let its neighbors know they should respond to changing conditions? In order to survive, cells need to be able to sense their environment and respond adequately to changes. Moreover, the evolution of multicellular life could only occur thanks to the development of communication mechanisms between cells, which is the cornerstone of homeostasis. But also processes such as development and growth of an organism require careful control and regulation. A plethora of mediators, acting either locally or systemically, can affect the behavior of cells. However, it is clear that not all cells will respond equally to the mediators they are exposed to. In this lecture, we will present the mechanisms a cell can employ to detect mediators in its environment and respond to them. We will introduce the receptor concept and discuss different signaling pathways that relay signals from the receptor at the plasma membrane towards the biochemical effectors inside the cell.

Lecture 2: Introduction to Molecular and Supramolecular Structure of Matter
Dr. Jurica Bauer

In the opening lecture we will look at how matter is built and how this is reflected in its specific physico-chemical and biological properties. What makes bone hard? How will metal implants behave in the human body? Why do some types of hair curl? What makes proteins and DNA biologically active? Why do lipids not mix with water but are still the building blocks of the cellular membrane? In order to answer these and many other questions, chemical bonds and supramolecular interactions will be introduced as well as the 2D- and 3D-structures of molecules largely determined by these bonds and interactions. We will also have a closer look at polarity of molecules and how this relates to the hydrophilic and hydrophobic properties of materials. Examples will not only concern biologically relevant molecules but also (synthetic) biomaterials applied in regenerative medicine.

Week 2

Lecture 3: Cells and the Extracellular Matrix
Prof. dr. Tim Welting

Last week we covered general cell biology from a cell signaling point-of-view. Cell signaling dictates to an important extent the behavior of cells with regard to their responses to environmental changes, cell proliferation, cell differentiation, disease processes, and more. Besides cell signaling that is initiated by soluble molecular mediators, critical cell signaling is also provoked by other mechanisms. One of such important mechanisms is interaction of the cell with the extra-cellular matrix. In this lecture we will look at the universal principles of how a mammalian cell binds or interacts with the extra-cellular matrix. We will discuss how the cell responds to interaction with the extracellular matrix, which cell signaling is regulated by this and what the consequences are for the cell. The biomolecular composition of the extra-cellular matrix depends on the tissue type. Hence, cells may interact and respond differently with and to tissue types. In this lecture we will have a look at the basic extra-cellular matrix differences between tissue types and highlight the biomolecular, chemical and biomechanical differences that characterize the extra-cellular matrix of different tissue types. Finally, cells have to be able to build, maintain, but also break-down extra-cellular matrix. The role of the cell-matrix interaction will be discussed in this respect in relation to tissue homeostasis, tissue engineering, and human disease.

Lecture 4: Molecular Structure and Solution-Phase Chemistry
Dr. Matthew Baker

In this lecture we will continue to look at how matter is built and how this is reflected in its specific physicochemical and biological properties. Why are some structures more stable than others? How do we know this? How do electrons affect the structure? How do we talk about chemicals? Do they have names? What is a buffer? How does that acidity of a solution affect the molecular structure? What does this mean for our proteins? In order to answer these and many other questions, we will take a closer look at the electronic structure of molecules. We will also start to look at acid/base chemistry and the concept of buffers. Your entire body is buffered, but what does this mean for the chemistry that happens inside? Examples will not only concern biologically relevant molecules but also (synthetic) biomaterials applied in regenerative medicine.

Lecture 5: Scientific Method
Dr. Matthew Baker

In this lecture we will learn about how to measure physiochemical properties and establish relationships we can learn from. Measuring is not easy, and is a science in of itself. How does one measure with confidence? What can we measure? And how? How do we design experiments to uncover new knowledge? And what do we already know? And how do we know it? In order to answer these and many other questions, we will take a closer look at the science of measuring and creating "good" measurements. This is often

the basis of knowledge creation for materials and is a critical step in the process. We will also look at a few classic examples of structure-property-function relationships and how this has been determined with reliability. This work often lays the foundation for understanding how cells and materials interact with one another.

Week 3

Lecture 6: Stem Cells and Connective Tissue
Dr. Guus van den Akker

Previously, we covered molecular signals that act in short or long range and the extracellular matrix. These two core components of biological matter need cells to exert an effect on a tissue or organism, such as a receptor for a suitable ligand or an integrin that allows interaction with the matrix. Cells have a certain plasticity; one copy of the DNA code per cell contains all the information for a whole organism, yet individual cells are restricted and use a limited amount of the DNA code. Moreover, there is a clear hierarchy: pluripotent stem cells can form all embryonic tissues, while a multipotent mesenchymal cell can only form connective tissue. The different types and potency of stem cells will be explained.

Connective tissue supports, protects, and gives structure to other tissues and organs in the body. The most striking connective tissue in vertebrates is perhaps the skeleton, which consists of bone and cartilage. Its structure and composition is tightly regulated at the molecular and cellular level and is surprisingly adaptable. The cells that maintain bone tissue (osteoblasts, osteoclasts, osteocytes) and their progenitor cells will be discussed. Remarkable contradictions exists in connective tissue repair: a fractured bone or damaged skin can heal easily, while damage to cartilage is often permanent. Injury can also lead to scar tissue formation, which can be a blessing or a curse for tissue repair.

Lecture 7: Inorganic Materials
Dr. Jurica Bauer

This lecture aims to introduce the most relevant and commonly used inorganic materials spanning molecular, ionic and atomic solids, as well as their applications in (regenerative) medicine. The structure of several prominent crystalline and amorphous materials is discussed in detail and related to the materials' physico-chemical and biological properties. Special attention is paid to relevant minerals, ceramics, glasses and silicones. Inorganic nanoparticles are also introduced as a means of attaining special materials properties of relevance for achieving controlled tissue growth.

Week 4

Lecture 8: Spatiotemporal Regulation of Cell Fate
Dr. Guus van den Akker

Understanding the "ingredients" of a tissue (cells, matrix, signals) gives the impression that a tissue can be grown by simply combining the right ingredients. Some successful examples of regenerative medicine exist that utilize cells or matrixes and cells. However, the recipe for a tissue is oftentimes complicated and requires the addition of each molecular signal, matrix molecule or cell type at the right moment.

This will be illustrated by bone formation, which can occur through two distinct pathways: intramembranous ossification and endochondral ossification. The former is used for the skull and clavicles (woven bone), while long bones form through the latter (lamellar bone). The growth plate is a specialized structure that regulates long bone growth. In a growth plate, chondroprogenitor cells proliferate, deposit ECM, grow in size and ultimately die, to help bone cells to produce lamellar bone. Hormones affect growth plate activity at the systemic level, while gradients of specific morphogens in the growth plate dictate cell fate. These signals are relayed by specific transcription factors in the cell, the master regulators, which can define cell identity by epigenetic remodeling. Knowledge of the different phases of development and growth of cartilage and bone has been applied to regenerate these tissues. Scientists have forced expression of master transcription factors to create cells of interest (transdifferentiation), used osteogenic proteins to cause ectopic bone formation and transplanted cells to achieve tissue repair. Examples will be provided about new developments in regenerative medicine.

Lecture 9: Functional Groups, 3 Dimensional Structure, and Stereochemistry
Dr. Matthew Baker

In this lecture we will learn about common arrangements of molecules and the 3D structure of molecules. What are some of the most common molecular motifs? Do they have unique properties? We draw molecules in 2D often, but they exist in 3D, how does this look? And are there differences in 3D space? How does the body deal with this complexity? In order to answer these and many other questions, we will take a closer look at the common functional groups and their properties. We will also start to look at the 3D shape of molecules, differences in these shapes, and what this means for the use and activity in their body. Sometimes molecules look exactly the same and have nearly identical properties, but have vastly different activity in the body leading to the success or failure of clinical strategies. How does this work?

Week 5

Lecture 10: Regulation of the Cell Cycle: the Regenerative Medicine's Perspective
Dr. Matthijs Blankesteijn

A cornerstone of regenerative medicine is the replacement of damaged cells in a tissue with new cells in order to restore its function. Many tissues contain stem cells, allowing the replenishment of lost cells by inducing their proliferation and differentiation. However, this is not the case for organs like the brain or the heart; the cells in these organs are traditionally considered to be terminally differentiated and not able to proliferate. To regenerate these organs, strategies need to be developed to re-initiate the cell cycle neurons and cardiomyocytes, respectively, in order to produce new cells that can repopulate the organ. On the other hand, uncontrolled activation of the cell cycle can be devastating since it can result in tumor formation. In this lecture, we will take a closer look at the cell cycle and its regulators in order to identify potentially promising interventions to induce tissue regeneration.

Lecture 11: Organic Molecules and Transformations
Dr. Jurica Bauer

In this lecture we introduce the concepts of nucleophilicity and electrophilicity to define the reactivity of organic molecules as well as the most common reactions they undergo. Different reaction types (addition, elimination, substitution and rearrangement) are defined and explained using the most relevant classes of organic compounds (acids, amines, alcohols, esters, amides, alkenes, etc). Relevant biological systems (lipids, carbohydrates, proteins and nucleic acids) are used to illustrate the introduced chemical reactions and their relevance for the life of a cell. Special emphasis is placed on the hydrolysis reaction and its relevance in biological systems. The application of synthetic organic reactions in the preparation of biomaterials for the purpose of tissue growth and regeneration is also discussed.

Week 6

Lecture 12: Macromolecular Structural Organization of Tissues
Prof. Dr. Tim Welting

Tissues acquire and maintain their specific characteristics from their different specialized cell types and associated cellular signaling, their specific extra-cellular matrices and the interaction between the cell and its matrix. We focused mainly at the nano-molecular level. These characteristics are, however, not only dictated at the nano-molecular level. There is also a major level of organization going on at the macro-molecular level that critically determines the biological characteristic of tissues in the human body. This lecture will elude on the different macro-molecular levels of tissue organization and how these dictate the specific characteristics of tissues. In addition, we will explore how macro-molecular structures are being built, maintained and how their failure is involved in human disease. In this manner the importance of macro-molecular structural organisation of tissue will become clear for tissue regenerative applications.

Lecture 13: Introduction to Analytics and Structure-Property Relationships
Dr. Matthew Baker

In week 2 we talked about the science of measuring. In this lecture we will go more in depth on some of the analytical methods widely used in life sciences. We will investigate the background and applicability of spectrophotometrical measurements and reflect on the use of this method during practicals.

Week 7

Lecture 14: Regenerative Medicine in Clinical Practice
Dr. Guus van den Akker

The term regenerative medicine (RM) was first coined in 1992 and described a new branch of medicine "that attempts to change the course of chronic disease and in many instances will regenerate tired and failing organ systems". The term caught on internationally from 1999 onwards and included cell and stem cell therapies, gene therapy, tissue engineering, genomic medicine, personalized medicine, biomechanical prosthetics, recombinant proteins and antibody treatments.

Based on these broad definitions, one can argue that RM has been applied in the clinic for quite some time: skin grafting, bone marrow transplantation and whole joint replacement surgery were established in the 1960/70's for humans suffering from burn wounds, leukemia or end-stage osteoarthritis. What lessons were learned from conceptualization, often already in the 19th century, to clinical application? And are these afflictions cured with these novel treatments?

New RM treatment options have emerged in the clinic by the end of the 20th century: from autologous cell transplantation for focal cartilage defects to antibody treatments for auto-immune diseases and recombinant osteogenic proteins to improve fracture healing. What is the conclusion on their success 20-25 years later? With the current progress in the biomedical and chemical knowledge, the full potential of RM should be unleashed in the 21st century. Viral gene therapy was approved for halting visual impairment and a first antibody was successful against Alzheimer's disease. Next generation DNA & RNA sequencing, CRISPR/Cas and iPSC have yet to make an impact on clinical practice, but the future looks bright for RM and technology.

Lecture 15: Controlling Chemical Reactions
Dr. Jurica Bauer

In this lecture we look at how chemical reactions can be controlled. How come some reactions are slow while others are fast? And is it possible to speed up or slow down a chemical reaction? At the same time, some reactions never proceed fully. What are the reasons behind this and how can we nonetheless get the desired product from such a reaction? These questions will be addressed using the laws of thermodynamics and concepts like enthalpy, entropy, free energy and equilibria. Examples and problems from solution chemistry, organic synthesis and biology will be used to illustrate these concepts and address the challenges. The relevance of these considerations and approaches in understanding biochemical processes as well as in preparing novel biomaterials for tissue engineering will be emphasized.

ChemOffice Workshops

ChemOffice is a suite of software tools designed for chemists and researchers in the field of chemistry. The most relevant software components for the duration of this study are ChemDraw and Chem3D. The software allows you to draw and visualize chemical structures, reactions, and diagrams. It also enables three-dimensional visualization and modelling of chemical structures as well as analysis of chemical bonds, angles and molecular properties. As such, ChemOffice is not only useful for learning purposes but also for reporting experiments and your research projects.

Week 1 – Workshop 1: Introduction to ChemOffice

In the introductory workshop we will have a look at the basic features of the software.

Week 2 – Workshop 2: Applications of ChemOffice

In this workshop we will have a look at several applications of ChemOffice in chemistry and biochemistry of relevance to your study. An example of this is looking at relevant protein receptor-substrate complexes and the non-covalent interactions holding them together.

Week 5 – Workshop 3: Working with ChemOffice

In this workshop we will continue practicing and working with ChemOffice. This workshop also offers the possibility to ask any remaining questions. Students are encouraged to already start making slides on their chemistry learning goals for their group project in this workshop and ask for feedback.

Mock Exam Assignment

A midterm mock written exam will be organized in week 4 to allow you to practice for the final exam. In this way you can evaluate your learning progress. This mock exam does not contribute to the final grade for the course.

Course Evaluation

In Week 8, during the Q&A session the students are kindly asked to fill in a course evaluation through the following link: https://iwio.fhml.maastrichtuniversity.nl/ The course planning group deems it very important to receive constructive feedback that can be used to improve this and other courses in the future. Especially considering that the programme is running for the second time this year, it is of high importance to receive as much feedback as possible.

Assignments for Problem-Solving Sessions

The textbook *Chemistry: A Molecular Approach* by Tro offers plenty of exercises and problems at the end of each chapter which can be used to assess to which extent you understand the relevant chemistry concepts and are able to apply them in different situations. Some are very basic while others are more challenging. Some also serve as a refresher of your high-school chemistry knowledge. Per week we give an overview of exercises and problems below which serve as examples of the level at which you should master the relevant concepts learned and which you may use to check your learning progress. From this list we will also select the examples to discuss in the problem-solving sessions. Please note that these are just examples and you should look for other (similar) exercises and problems in the textbook to practice the concepts which you find challenging. We advise you to work out the proposed listed assignments every week that cover most concepts discussed in the corresponding week. Bring your solutions and notes to the Problem-Solving Session on Friday. Make sure you also bring any questions that you may still have to the session.

Week 1

- CH10: Self-Assessment Quiz Q10
- CH10: Problems by Topic (43, 64, 67, 68, 74, 78, 79), Cumulative Problems (86-90, 97, 98, 102, 103, 108), Challenge Problems (119, 122, 124)
- CH11: Self-Assessment Quiz Q3, Q5, Q7
- CH11: Problems by Topic (35, 37, 41, 45, 47, 52), Cumulative Problems (88-90; 95; 96), Challenge Problems (103, 107); Questions for Group Work (115)
- CH12: Self-Assessment Quiz Q2-Q5
- CH12: Problems by Topic (35, 39, 42, 45, 48, 49, 51; 53, 55, 56, 79, 80, 82), Cumulative Problems (83), Challenge Problems (103); Questions for Group Work (113)

Week 2

- CH 16: Problems by Topic (21, 24, 26, 38, 45, 53, 63, 71), Cumulative Problems (73, 79), Challenge Problems (98), Conceptual Problems (105)
- CH 17: Self-assessment Quiz Q1, Q3, Q4, Q5, Q7, Q8, Q10, Q11, Q13
- CH 17: Problems by Topic (35, 39, 46, 49, 62, 69, 71, 75, 83, 87, 90, 102, 103, 109, 113, 119), Cumulative Problems (129, 131, 134, 136), Conceptual (157, 160)
- CH 18: Self-assessment Quiz Q3, Q5-Q8, Q11, Q15
- CH 18: Problems by Topic (27, 35, 39, 44, 53, 55, 56, 61, 99, 138, 153), Challenge Problems (138), Conceptual (149, 153, 154)

Week 3

- CH1: Problems by Topic (33, 35, 73, 78, 87, 103), Cumulative Problems (105), Challenge Problems (135), Questions for Group Work (152), Data Interpretation and Analysis (155).
- CH13: Self-Assessment Quiz Q2-Q4, Q6, Q8
- CH13: Problems by Topic (29, 30, 35, 39, 41, 45, 47, 53, 65), Cumulative Problems (77, 81, 83, 86), Challenge Problems (92)
- CH24: Self-Assessment Quiz Q1,Q2
- CH24: Problems by Topic (15, 17, 19)
- CH25: Self-Assessment Quiz Q3
- CH25: Problems by Topic (15,16, 31)

Further problems for this week will be assigned via Canvas.

Week 4

- CH22 Self-Assessment Q3, Q4, Q6, Q9
- CH22 Problems by Topic (35, 39, 43, 63, 65, 71, 75, 80), Cumulative Problems (89, 93, 100, 103), Challenge Problems (112, 113)
- CH23 Self-Assessment Q1-Q5, Q7-Q9
- CH23 Problems by Topic (33, 38, 39, 41, 49, 51, 53, 57, 57, 59, 63, 67), Cumulative Problems (71, 75, 77, 78, 81, 84), Challenge Problems (89), Conceptual Problems (91)

Week 5

- CH22: Self-Assessment Quiz Q7, Q8
- CH22: Problems by Topic (45, 47, 57, 69, 73, 77, 81, 87), Cumulative Problems (97, 98), Challenge Problems (105, 106), Conceptual Problems (114, 116)
- CH23: Self-Assessment Quiz Q1-Q5; Q7-Q9
- CH23: Problems by Topic (35, 45, 55), Conceptual Problems (90)

Week 6

- CH1: Challenge Problems (141).
- CH4: Cumulative Problems (59), Challenge Problems (72).

Additional problems for this week will be assigned via Canvas.

Week 7

- CH7: Self-Assessment Quiz Q12
- CH7: Problems by Topic (57), Conceptual Problems (138), Questions for Group Work (141)
- CH15: Self-Assessment Quiz Q1, Q4, Q8, Q12, Q13
- CH15: Problems by Topic (35, 39, 41, 59, 73, 79, 81), Cumulative Problems (95, 101), Conceptual Problems (119, 121)
- CH16: Self-Assessment Quiz Q1, Q2, Q5, Q8, Q9
- CH16: Problems by Topic (21, 23, 25, 43, 61, 65, 72), Cumulative Problems (73), Conceptual Problems (105); Questions for Group Work (110)
- CH17: Self-Assessment Quiz Q5, Q6, Q8, Q12, Q14
- CH17: Problems by Topic (33, 36, 54, 59, 62, 67, 72, 86, 88, 91, 101, 110, 120), Cumulative Problems (129, 143, 144), Challenge Problems (147, 150), Conceptual Problems (158, 159)
- CH18: Self-Assessment Quiz Q1-Q3, Q8, Q15
- CH18: Problems by Topic (32, 35, 40, 43, 44, 47, 53, 55, 61, 78), Cumulative Problems (122, 132), Challenge Problems (138), Conceptual Problems (149, 152, 154), Questions for Group Work (155)
- CH19: Self-Assessment Quiz Q1, Q2, Q16
- CH19: Problems by Topic (27, 35, 37, 45, 47, 81), Cumulative Problems (83, 91), Challenge Problems (103); Conceptual Problems (111, 114)

Group Assignment: Design Your Own Case

You have already seen several examples of PBL cases during this course. Now is the time for you to make your own!

We would like to ask you to create your own PBL case in teams of 3-4. Please form groups of 4 students (or 3 if someone is missing) within your class and notify your tutor by the end of Week 4 of your group composition.

For this assignment you will create three products:

1) 1-page PBL case text
2) 3-4 learning goals for the case text
3) 10-minute presentation presenting your case to the rest of the class and answering the learning goals

Guidelines:

0) Choose a suitable topic in consultation with your tutor by the end of week 5. Make sure your tutor approves your topic, preferably in this week's tutorial.
1) A 1-page PBL case text should be drafted, giving the students clues to the literature research you would like them to do, but without giving an answer. The text should contain at least one image. Submit the case text with your presentation in week 8.
2) Learning goals should be formulated from the exercise; For example: "How are hydrogels used in regenerative medicine." You should list these learning goals on the back side of your case description.
3) There should be a minimum of one biology and one chemistry learning goal. Each student should present one learning goal.
4) You will then briefly present your case and learning goals. The presentation should address at least these three topics:
    a. A presentation of the PBL case and the learning goals
    b. The intended discussion around the learning goals
        i. List the learning goals and describe the information that the students should get to or talk about during the post-discussion.
        ii. Think about for example: Definition of a hydrogel (list the definition), major classes of hydrogels (what are the major classes of hydrogel that the students need to know), and properties of hydrogel (what are the main properties that are important for regenerative medicine), applications of hydrogels in regenerative medicine.
        iii. Make sure to emphasize the link between the learning goals (especially between the chemistry and biology ones) and their relevance for the field of regenerative medicine.
    c. What you learned as a team during the process.

Please submit your PBL Case text (1 page + learning goals) by email to your tutor no later than Monday, the 21st of October at midnight. Submissions received after the deadline will not be considered for the first take.

Please send your tutor the slides of your presentation no later than Friday, the 25th of October at 8:00 o'clock. The group should also fill in the form "Statement of Equal and Sufficient Participation", have it signed by all group members and send it to the tutor along with the slides. If it turns out that a member of the group did not participate sufficiently in this group assignment and that the group does not want to sign the above statement for them, the tutor should be notified immediately.

NOTE: *Students are not allowed to use ChatGPT or other similar text or image-producing AI tools in assignments. AI-generated text used to answer exam questions/assignments can be seen as commissioned work that represents plagiarism and fraud and will be sanctioned by the Board of Examiners. When there is suspicion of use of an AI tool, the Board of Examiners – after having consulted the coordinator – may ask the coordinator to perform an additional inquiry.*

Resources

As part of the problem-based learning approach, students are expected to look for their own literature and consult multiple sources that will help them achieve their learning goals. However, in order to somewhat streamline the literature search, we would here like to offer the core literature (textbooks) which should definitely be consulted to acquire a good understanding of the main concepts of cell biology and chemistry relevant for the field of regenerative medicine. Students are expected to consult other sources (textbooks and scientific articles) to gain more insight into topics specific to the field of regenerative medicine. This will especially be necessary when solving multidisciplinary cases. A selection of the recommended literature is listed below but this is by no means an exhaustive list of sources to use for the duration of this course.

Core literature

- Molecular Biology of the Cell, W. W. Norton and Company, seventh edition. Alberts B. et al.
- The digital problems book in smartwork (belonging to Molecular Biology of the Cell, seventh edition, Alberts B. et al)
- Chemistry, A Molecular Approach, Pearson, fifth edition. Tro N. J.
- Solutions Manual: Chemistry, A Molecular Approach, Pearson, fifth edition. Shaginaw K. T. & Tro N. J.

Recommended literature

- Tissue Engineering, Elsevier, third edition, 2022, van Blitterswijk, C., de Boer, J.
- Human anatomy & physiology, Pearson, eleventh edition. Marieb, E. N., Hoehn, K., et al.
- Rang & Dale's Pharmacology, Elsevier, ninth Edition. Ritter J., et al.
- Organic Chemistry, Wiley, third edition. Klein D
- Crystal structure of the β2 adrenergic receptor–Gs protein complex. Rasmussen SGF et al., Nature (2011) 477, 549-555.
- Synthetic ECM: Bioactive Synthetic Hydrogels for 3D Tissue Engineering. Unal A.Z. & West J.L., Bioconjugate Chemistry (2020) 31, 10, 2253-2271.
- The skeleton: a multi-functional complex organ. Mackie et al., Journal of Endocrinology (2011) 211, 109–121.
- Developmental regulation of the growth plate. Kronenberg H.M., Nature (2003) 423, 332-336.
- Glycosaminoglycans in Tissue Engineering: A Review. Sodhi H & Panitch A. Biomolecules (2020) 11, 1, 29.
- Identification of potential biophysical and molecular signalling mechanisms underlying hyaluronic acid enhancement of cartilage formation. Responte D.J., Natoli R.M., Athanasiou K.A., J. R. Soc. Interface (2012) 9, 3564–3573.
- Silica Nanoparticles in Transmucosal Drug Delivery Ways, T. M. M. et al Pharmaceutics (2020) 12, 8, 751.
- Calcium Phosphate-Coated and Strontium-Incorporated Mesoporous Silica Nanoparticles Can Effectively Induce Osteogenic Stem Cell Differentiation, Sutthavas, P. et al Advanced Healthcare Materials (2022) 11, 4, 2101588.

- A Review on Nanoparticles: Characteristics, Synthesis, Applications, and Challenges Altammar, K. A. Frontiers in Microbiology (2023) 14, 1155622.
- Calcium Phosphates for Biomedical Applications Canillas, M. et al Boletín de la Sociedad Española de Cerámica y Vidrio (2017) 56, 3, 91.
- Calcium Phosphate Ceramics in Bone Tissue Engineering: A Review of Properties and their Influence on Cell Behavior Samavedi, S. et al Acta Biomaterialia (2013) 9, 9, 8037.
- A link to additional references is available in the course on Canvas, under 'Resources'.

Examination

All relevant information about the assessment can be found in the Assessment Plan in the course on Canvas (under 'Examination').

There is one written exam in week 8. The grade for the exam counts for 75% of the final grade for the course and must be a 5.5 or higher for a pass. A minimum of 55 % of the total number of exam points is required for a pass (grade 5.5). In addition, there is a group assignment, introduced in week 4, which will be presented and assessed in week 8. The content of the group assignment must also be assessed with a 5.5 or higher for a pass and will then contribute to the final grade for the course with 25%. The rubric to assess the content of this assignment is available on Canvas. The students' presentation skills will be formatively evaluated using the rubric available on the Canvas page of the Academic Development Line.

A resit of the written exam will be offered in the week of the 3rd of March 2025. Please refer to FHMLweb and/or the announcements on Canvas for details regarding the time and place of the exam. A retake of the group assignment needs to be scheduled with the tutor no later than two weeks after the first take; the student is expected to take this initiative.

In week 4 a (formative) midterm mock written exam will be offered to allow students to evaluate their learning progress up to that point; this mock exam does not contribute to the final grade for the course.

Maastricht University

SYLLABUS

Lab Skills Line 1

RMT1102

Academic year: 2024–2025

Faculty of Health, Medicine and Life Sciences

Regenerative Medicine and Technology

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Introduction

The practical skills longitudinal line runs through the first two years, as **Laboratory Skills I (year 1)** and Laboratory Skills II (year 2), each worth 7 ECs. Lab skills trainings are mainly concentrated in the 8-week periods, in which the experiments are aligned with the content of the courses. Every 8-week course, students need to demonstrate sufficient skills in preparing experiments (preparing the practical, performing lab-related calculations) and carrying them out, keeping a lab journal, and basic lab skills (weighing, pipetting, etc.). As the practical sessions are all part of the lab skills line, repeated practice of skills, with increasing degree of complexity throughout the bachelor is achieved, and longitudinal tracking of development of lab skills is possible. Importantly, students will also be able to practice and further develop their practical skills in a self-directed manner within the design project; this is aligned with the lab skills line.

Students receive regular formative feedback by staff and peers on these skills, which will be added to the portfolio at the end of each 8-week course. Next to this, students are assessed on their performance by means of a summative practical exam consisting of two parts (in periods 3 & 6 each year). The lab skills line formally ends at the end of year 2.

Learning Goals

Intended Learning Outcomes (ILO)	Teaching and Learning Activities (TLA)	Assessment and feedback tasks (AF-T)
RD-ILO-1: Understands and applies safety rules in the laboratory.	Lecture, online quiz, practical training, reading materials for self-study	Online quiz (formative), GLP practical exam (period 3, summative)
RD-ILO-2: Is able to apply basic practical skills (weighing, preparation of solutions, calculations etc.) to perform simple experiments following a protocol.	OLAF (online calculation tool), online quiz, practical training	Calculation exam & GLP practical exam (period 3, summative), feedback from trainer and peers (formative) to be incorporated in portfolio
RD-ILO-3: Is able to keep a lab journal.	Canvas assignment/LabBuddy	(Continuous) feedback from trainer (formative) to be incorporated in portfolio
RD-ILO-4: Describes the subsequent steps of the empirical research cycle and is able to recognize them in the preparation, execution and reporting of simple laboratory experiments*, **.	Canvas assignment/ LabBuddy, practical training	Practical skills exam (period 5/6, summative), feedback during wrap-up sessions by trainer (formative) *Incl. writing assignment which is part of the Academic Development Line.*
RD-ILO-5: Relates the results of experiments to an initially formed hypothesis and draws a conclusion based on this*.	Canvas assignment/LabBuddy, practical training	Practical skills exam (period 5/6, summative), feedback from trainer (formative) to be incorporated in portfolio
RD-ILO-6: Applies a set of pre-structured scientific methods and technologies to a specific research question*.	Canvas assignment/LabBuddy, practical training	Practical skills exam (period 5/6, summative), feedback from trainer (formative) to be incorporated in portfolio

** Specific goals related to practical activities year 1:*

- *Be able to synthesize and purify a product, follow reaction kinetics, and know how to steer a chemical reaction (RMT1001)*
- *Be able to measure receptor-ligand and cell-cell interactions in biological experiments (RMT1001)*
- *Be able to apply knowledge and understanding of mathematical and physics problems in designing, executing, and interpreting experiments (RMT1002)*
- *Be able to apply sensors, computer modelling, and 3D printing for designing and interpreting experiments (RMT1002)*
- *Be able to examine and analyse tissues based on anatomy, clinical imaging & microscopy, pathology, and measure functional parameters in these tissues (RMT1004)*
- *Be able to apply analysis and visualization of data (RMT1005)*
- *Be able to apply statistics to experimental data and report on experimental data (RMT1005)*

*** statistics and data visualization in course RMT1005; writing assignments as part of Academical Development Line (period 2-6)*

Contact

Planning Group

Block co-coordinators
Dr. Carlos Domingues Mota
Dr. Timo Rademakers

Members of the planning group
Dr. Stefan Giselbrecht
Dr. Gabriel Paiva Fonseca
Dr. Niloofar Tahmasebi Birgani

Questions
If you have questions about the timetable, registration for trainings and practicals, education and examination rules, exam dates, exam results etc. you can contact the Institute for Education via askFHML: www.askfhml.nl.
For questions about the content of the course or the exam you can contact the coordinator of this course via rmt-lsl-fhml@maastrichtuniversity.nl
For questions about a practical you can contact the coordinator of the specific practical.

Practicals & assignments

COURSE RMT1001

Course RMT1001 will start with introduction to good laboratory practice (GLP) to familiarize you with working in a laboratory environment, after which the student will apply these new lab skills in a couple of practicals related to the biochemistry taught in RMT1001.

Practicals:

- Introduction to GLP & lab journal keeping (week 1)
  During this introductory session, the student will be introduced to the concept good laboratory practice (GLP), and will receive information on how to work safely within a laboratory environment. The student will be able to quiz themselves using online tools on their safety knowledge. In addition, the student will be introduced to the online lab journal system 'LabBuddy', which will be used during all the practicals.
  Aim:
  - Follow online introductory course to GLP and lab safety
  - Get familiar with the use of LabBuddy for lab journal keeping

- GLP1 & introduction to OLAF (week 2)
  In the second week of RMT1001, the student will apply the knowledge about lab safety and GLP during their first lab visit. Safety instructions will be recapped and applied in the lab, and students will be introduced to chemical safety, pipetting, and proper weighing procedures. Also, the student will be introduced to doing lab calculations; this will be practiced both in the lab, but students will also be able to practice themselves using the online OLAF platform.
  Aim:
  - Get familiar with OLAF for doing lab calculations (e.g. molarity, dilutions)
  - Get introduced to basic lab safety and basic lab skills:
    - Safety instruction recap + providing (constructive) feedback in the lab
    - Chemical safety
    - Pipetting (large volumes and small volumes)
    - Weighing (+ calculations)

- GLP2 (week 3)
  During GLP2, the student will use the skills taught in GLP1 to not only weigh and pipette, but also to make buffers and dilutions, performing a titration, perform pH measurements (and doing calculations on these), and perform measurements using spectrophotometry.
  Aim:
  - Making buffers, & dilutions, titration (incl. pH measurements)
  - Doing molar calculations and calculations on pH
  - Making a standard curve based on dilution series

- Tissue mineralization (ALP) (week 4)
  In week 4, the student will be presented with a case with the goal is to assess cartilage quality and unwanted mineralization on human mesenchymal stromal cells that are treated with local drugstore remedies in vitro. The student will be provided with several samples of chondrocytes, treated with different local drugstore remedies, and using an ALP assay the student will determine if any mineralization will take place.
  Aim:
  - Measuring ALP activity in hMSCs
  - Use plate reader to measure absorption
  - Use Lambert-Beer Law to determine concentration

- Extracellular matrix – measuring content of glycosaminoglycans (week 6)
  In week 6, the student will be provided with cartilage samples (primary cartilage samples and cell culture samples). The student will determine the amount of glycosaminoglycans (GAGs) using a GAG assay.
  Aim:
  - Measure sGAG content in cells and primary cartilage
  - Prepare cell lysates
  - Use plate reader to measure absorption
  - Prepare a standard curve (chondroitine sulfate)
  - Use standard curve to determine unknown samples

- Synthesis of Alginate Hydrogel and Analysis of Dye Loading/Release (week 7)
  In week 7, the student will first synthesize an alginate hydrogel which they will load with a dye, In the second part of the practical, the student will assess release kinetics of this dye. This will be done by measurement of absorbance or fluorescence.
  Aim:
  - Synthesize an alginate hydrogel
  - Use plate reader to measure absorption/fluorescence

- Wrap-up RMT1001 (week 8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT1002

In course 1002, the student will be introduced to the practical use of engineering principles. A combination of computational tools and sensor-based experiments will be used to show the applications of engineering within regenerative medicine.

Practicals:

- Introduction to electronic circuits and sensors (week 1)
  Students will simulate different circuits based on some basic instructions (self-learning) and then assemble and test the parts in the laboratory (e.g. blink a LED at specific positions; operate a step motor adjusting velocity and direction)
  Aim:
  - get familiar with electronic components (e.g. resistors and capacitors)
  - assemble simple circuits to control LED lights, motors and sensors.
  - control the circuits programmatically

- Monitoring and adjusting pH and temperature (week 2)
  Students will build an electronic circuit that measures the temperature and turns a heating element on if the temperature is below a pre-defined value. Once the temperature control system is functional adjust the pH of a sample solution and monitor the pH using a pH sensor.
  Aim:
  - Use a thermistor to monitor the solution temperature and adjust it programmatically.
  - Constitutionally monitor the pH of a solution
  - Display experimental data (temperature and pH) using scripts (e.g. python or matlab)

- Mechanical experiments using a "elbow" joint and motors (week 3)
  Students will use an "knee" to study torque and other physical properties related to the physics of the human body
  Aim:
  - Simulate the movement of a "knee" joint measuring physical parameters such as force, velocity and acceleration.

- CAD modeling I - Preparation (week 4)
  Students will be introduced to CAD software and learn how to create 2D and 3D parts,
  Aim:
  - Create 2D sketches and 3D parts by means of parametric computer software (Autodesk, Solidworks or Fusion360)
    DRY LAB

- CAD modeling II (week 5)
  Students will learn how to combine parts into assemblies using joints to simulate functional parts. In addition to parametric design, medical images will be used to create patient-specific 3D models.

Aim:
- Design of (mechanical) assemblies through constraints definition
- Create 3D model from medical image dataset (e.g. Mimics, Invesalius, Slicer)

DRY LAB

- CAD design meets mechanical simulations (week 6)
  Students will use CAD software (finite element modeling) to evaluate force load distribution and use this information to optimize the design to meet certain requirements.
  Aim:
  - Use CAD software to simulate the experiments performed in the previous week with a "knee" and compare simulate results against measurements.
  - Use CAD software to further "improve" the design of the "elbow" joint (e.g. making it more robust) and compare against the current model.

  DRY LAB

- Introduction to 3D printing and scaffolds (week 7)
  Students will use FDM 3D printers to manufacture parts designed in the previous weeks. Model orientation, support structure, material properties and slicer software will be evaluated.
  Aim:
  - Use thermoplastic or hydrogel extrusion (bio)printing to produce scaffolds or constructs.
  - Use modelling of architecture with Rhinoceros and Grasshoper to design the scaffolds
  - Demonstrate the controlling options (software and hardware) for a successful print

- Wrap-up RMT1002 (week 8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT1003

In course 1003, we will test your GLP and lab calculation skills.

Exams:

- Lab calculation test (1 hr)
  Aim:
  - Show calculation skills for e.g. molarity, dilutions.
- GLP test (2hr)
  Aim:
  - Show basic lab skills for weighing, pipetting, preparing dilutions and doing basic lab measurements.

Preparation period 4:

- Introduction to anatomy (2 hr)

COURSE RMT1004

In course 1004, you will be introduced to the concept bed-to-bench, in which we will exhibit the translation of medical imaging and anatomy to microscopy and molecular techniques to study health and disease.

Practicals:

- Medical imaging demo – CT imaging (week 1)
  Students will visit a radiotherapy clinic and attend the use of a CT scanner to acquire images of anthropomorphic phantoms. This will allow students to see the connection from a clinical problem towards examining the tissue (and subsequent anatomy, microscopy, and molecular techniques). Acquisition parameters, DICOM standard and guided image analyses will be covered in this session.
  Aim:
  - Get familiar with clinical imaging (CT scan), and the link between CT and anatomy/physiology, and histology.

- Anatomy practicals (week 1-6)
  During the anatomy practicals, the student will be able to closer examine the tissue that are the focus points for course 1004 and use virtual microscope to evaluate the microscopic aspects of the hierarchical organization of the human body. This will be critical to understand the link from clinic/full tissue towards histology. Based on the anatomy practical, students will need to answer some questions regarding the tissue at hand.
  Aim:
  - Get familiar with anatomy (and its link to physiology) of:
    - Musculoskeletal system (week 1-2)
    - Heart-Lung (week 3-4)
    - Gastro-intestinal system (week 5-6)

- Introduction to microscopy & virtual microscopy (week 2-3)
  In these two practicals, students will (1) be familiarized with the workings of a light microscope by examining samples by eye, The student will understand the highly conserved concept of compartmentalization on different hierarchical levels in living organisms and their tissue (here, main focus on tissue level and how this is connected to the corresponding physiological functions of the tissue).
  Aim:
  - To understand the build-up of a of (basic) light microscope
  - To understand the value of microscopy in RMT
  - Show proper use of a basic light microscope for taking images
  - Use virtual microscopy to annotate and analyze data

- Gene expression of genes linked to mineralization (week 4-5)
  In week 4 and 5, the student will be introduced to principles of gene expression and how to measure gene expression. In two practical sessions the student will

work on (1) RNA isolation and cDNA synthesis, and (2) quantitative PCR and data analysis hereof.
Aim:

- Understand the principles of gene expression analysis
- Apply principles of quantitative PCR to extract RNA, synthesize cDNA, and determine gene expression profiles

- Western Blot analysis of protein expression upon mineralization (week 6-7)
  In week 6 and 7, the student will be introduced to principles of protein expression and how to measure protein expression using Western blot. In two practical sessions the student will on day 1 perform BCA analysis to determine protein concentration in samples, prepare samples for gel electrophoresis and blot proteins to a membrane, after which on day 2 stain the blot with antibodies, visualize/image the blot, and analyze the data. The same source samples will be used for the PCR practicals.
  Aim:
  - Understand the principles of protein expression analysis
  - Apply principles of Western blotting to determine protein expression

- Wrap-up RMT1004 (week 8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT1005 & 1006

In period 5 and 6, the student will be designing and performing their own practical on the topic of HA modification for viscosupplementation in joints. These skills (designing of experiments) align with the skills needed for the Clinical Design Project in year 2, and will be assessed for that longitudinal line. The practical skills and data analysis will be assessed as part of your final examination of the Practical Skills Line I. The report of this practical will furthermore be assessed for the 'storytelling' competency within the Academic Development Line.

Assignment:

- Guided design of a practical, execution, and reporting (week 1-7)
  You will receive a case (available on Canvas) on the basis of which you will, in a small group, design a practical to study this problem in the lab. You will design the required steps of the practical, write an SOP, and perform the practical yourself. Your results will be documented in your lab journal, and the results of the practical will be used for a written report. Furthermore, you will be assessed on your practical skills in the lab.

Resources

A link to the reference list is available in the course on the Student Portal, under 'Resources'.

Examination

ILO	Assessment and feedback tasks (AF-T)	Requirements / description	Standard setting – calculation of score/mark, if applicable	Evaluator / Assessor (e.g. tutor, practical teacher, member course planning group)
RD-ILO-1,2	RMT1102-P3 – GLP exam (formative)	Practical assignment for measuring, weighing, dilution series, and measuring of toluidine blue. Assessment based on practical skills, and outcome (graph)	Fail/pass/good (see rubric below)	Trainers or members line planning group
RD-ILO-3	RMT1102-P3 – Calculation test (summative)	Test with different lab calculations (molarity, etc).	Fail/pass/good (see rubric below)	Members line planning group
ALL ILOs	RMT1102 – Feedback (formative)	(Peer-)feedback during execution of the practical + on lab journal keeping. Reflection on this feedback is integrated in the Portfolio.	N/A	Members line planning group Peer, trainer To be discussed with mentor (ADL)
All ILOs	RMT1102 – Practical exam (summative)	Designed practical assignment for measuring, weighing, dilution series, and measuring of release of compounds. Assessment based on practical skills. Analysis and interpretation of the data is also assessed within a written report **Design process is assessed within the Design Project Line*	Fail/pass/good (see rubric below)	Assessors (re-port), trainers, or members line planning group (lab skills)

		**Writing* skills *are assessed within the Academic Development Line. If practical exam is not attended, the writing assignment will need to be done after the resit period.*		
ALL ILOs	RMT1112 – Attendance (summative)	There is a 100% attendance requirement for practical trainings. If you will be ab-sent, you must notify your peers and trainer. If you fail to give this notification, this may lead to a 'falls short of expectation' qualification in the portfolio (Academic De-velopment Line), and stu-dent will fail RMT1112. *See below for more information*.	Fail/pass	Trainers, members line planning group

Maastricht University

SYLLABUS

Track: Regenerative Medicine and Technology

Materials Science in Biological Applications

RMT2002

Academic year: 2024–2025

Faculty of Health, Medicine and Life Sciences

Regenerative Medicine and Technology

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Introduction

Course background, context

The course 'Materials Science in Biological Applications' relies on the concepts introduced in the first-year's courses The Molecular Basis of Life (RMT1001) and Foundations of Engineering (RMT1002). These concepts are now further integrated to train students in solving challenges in the application of materials in the field of regenerative medicine. The course aims to provide insight into the design, preparation and physico-chemical characterization of organic, inorganic, biological and composite materials. The focus is on (smart) biomaterials relevant to the biomedical field and especially regenerative medicine. The emphasis is on the structure/composition-property-activity relationships of materials as well as the cell-material interaction. The new chemistry and pharmacology concepts necessary for understanding the preparation, characterization, properties and the behavior of materials are also explained in the context of real-life cases. The newly taught concepts are integrated in multidisciplinary cases/problems, which are discussed and worked out in small groups. Students not only learn how to design, prepare and characterize a biomaterial but also how to select the right materials for an application within regenerative medicine.

General introduction

Biomaterials are central to the biomedical and regenerative medicine fields due to their crucial role in repairing, replacing, or regenerating damaged tissues and organs. In regenerative medicine, biomaterials function as scaffolds or matrices that provide structural support and guide cell growth, tissue regeneration, and the healing process. They can be engineered to interact with biological systems in ways that promote repair and regeneration, making them fundamental to advancing treatments that restore function and improve quality of life for patients.

In the initial weeks, we introduce the concept of materials, specifically biomaterials, examining their structures and the properties and functions that arise from them. The physical, chemical, and biological characterization of these materials is discussed in depth. We then explore examples of inorganic, organic, biological, and composite materials relevant to regenerative approaches, including their chemical reactions, preparation, and key properties (e.g., biodegradability). Cell-material interactions are a central focus in evaluating biomaterial designs for specific clinical applications. We also cover common (bio)fabrication techniques and the factors influencing their selection.

Students engage with these topics through interactive (guest) lectures and multidisciplinary, real-life cases in tutorials. In problem-solving sessions, students collaborate to solve and discuss materials science challenges and apply the underlying chemistry concepts. In ChemDraw workshops, students learn to use ChemDraw and Chem3D software to support their studies. Finally, students are challenged to propose and defend a novel biomaterial design aimed at addressing a clinical problem before an audience of staff and peers. Collectively, this course provides a strong foundation for understanding basic materials science concepts and their relevance in regenerative medicine.

Learning Goals

What are the learning objectives of the course?

Upon completion of this course, the student is able to:

ILO-1: Demonstrate knowledge and understanding of what biomaterials are, what their features are and what their relevance is in biomedical engineering and more specifically in regenerative medicine.

ILO-2: Describe the chemical identity and structure of organic, inorganic and composite biomaterials, the effect thereof on their physico-chemical properties, their preparation (synthetic vs biological) and characterization and their applicability in regenerative medicine.

ILO-3: Explain the organic reactions and reaction types most relevant for the synthesis and modification of polymer biomaterials.

ILO-4: Demonstrate and apply knowledge and understanding of polymer physics, various physico-chemical characterisation techniques in materials science, the influence of structure and composition on the physico-chemical and biological properties of a material, and degradation (mechanisms) of biomaterials in various biomedical and more specifically regenerative medicine applications.

ILO-5: Demonstrate knowledge and understanding of the application of organic, inorganic and composite biomaterials in the clinic, as well as of material-cell interactions and is able to use that to advantage when designing new biomaterials for applications in regenerative medicine.

ILO-6: Demonstrate knowledge and understanding of the design of experiments and modelling in materials science as well as of standardizing and scaling up the production of (bio)materials.

ILO-7: Use the known structure-property relationships to propose (new) organic, inorganic and composite biomaterials for various biomedical and more specifically regenerative medicine applications.

ILO-8: Elaborate what is meant by stimuli-responsive and smart biomaterials and why they are relevant in the field.

ILO-9: Compare, critically discuss and appraise the design and use of different types of biomaterials for the purpose of tissue growth.

ILO-10: Select a biomaterial with desired physico-chemical properties for a certain biomedical, clinical or regenerative medicine application, and to propose suitable preparation and characterization strategies.

How are the learning objectives achieved?

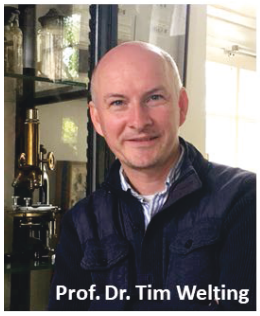
The abovementioned objectives are achieved through active participation in interactive lectures, tutorials, problem-solving sessions, group assignments, mini-symposium, formative quizzes, formative mid-term mock exam and a summative exam as well as by implementing the feedback obtained in these activities.
The Lab Skills Line (RMT2102) and Academic Development Line (RMT2101) run in parallel with this course (RMT2002) and as part of these lines you will be trained in how to plan, perform and report practical laboratory experiments related to the themes covered in this course. As part of the Design Project (RMT2103 & 2104) you will work on a research project in which you may be able to directly apply your knowledge from this and other courses. For more information on the learning objectives, activities and assessments of these longitudinal lines, please check the corresponding syllabi and Canvas pages.

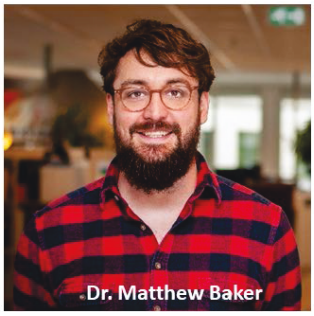
Contact

Course-Planning Group

Course coordinators
Dr. Guus van den Akker
Dr. Jurica Bauer

Members of the course-planning group
Dr. Matthew Baker
Dr. Matthijs Blankesteijn
Prof. dr. Tim Welting
Dr. Gavin Hazell
Dr. Sabine van Rijt





Questions
If you have questions about the timetable, registration for trainings and practicals, education and examination rules, exam dates, exam results, etc, you should contact the Institute for Education via ask FHML: www.askfhml.nl.

For questions about the content of the RMT1001 course or the exam you can contact the coordinators of this course: j.bauer@maastrichtuniversity.nl or g.vandenakker@maastrichtuniversity.nl. When writing your email, please put RMT2002 in the Subject Line of your email.

Problem-Based Learning Cases

Weeks 1-2 Case 1: Biomaterials

Having acquired all the credits from Year 1 of his undergraduate RMT program, Jeremy is attending an opening lecture of a Year 2 course in biomaterials. He is convinced that the course will be very interesting as the topic of materials should have something to do with chemistry and physics which he was so good at in Year 1. He does wonder, however, what makes something a biomaterial and whether biology could play a role here too.

Jeremy quickly asks ChatGPT to explain to him what biomaterials are and to provide some examples. Among many examples provided, a mention of hydrogels catches Jeremy's attention. He immediately remembers working with hydrogels in his Year 1 practical. He recalls that these jelly-like materials (Fig. 1) typically contain very long molecules. But then he reads on Wikipedia that hydrogels are mostly made of water which confuses him. Can it really be that such a mixture of large and small molecules is suitable for growing a tissue? He also recalls hydrogels releasing a dye in one of his practicals but is not sure what that has to do with culturing cells. At that moment Cindy, another RMT student, sits next to Jeremy and strikes up a conversation. "I heard that we'll need to spend days in the lab to prepare a biomaterial!", Cindy says worryingly. Jeremy thinks for a minute and remarks: "Isn't there a simpler way to obtain a biomaterial?".

The lab assignment for Jeremy and Cindy consists of preparing a biomaterial for cartilage cells (chondrocytes). They are told that chondrocytes change their phenotype on standard-culture plastics (Fig. 1). According to literature, molecules that mimic the native extracellular matrix could prevent this process.

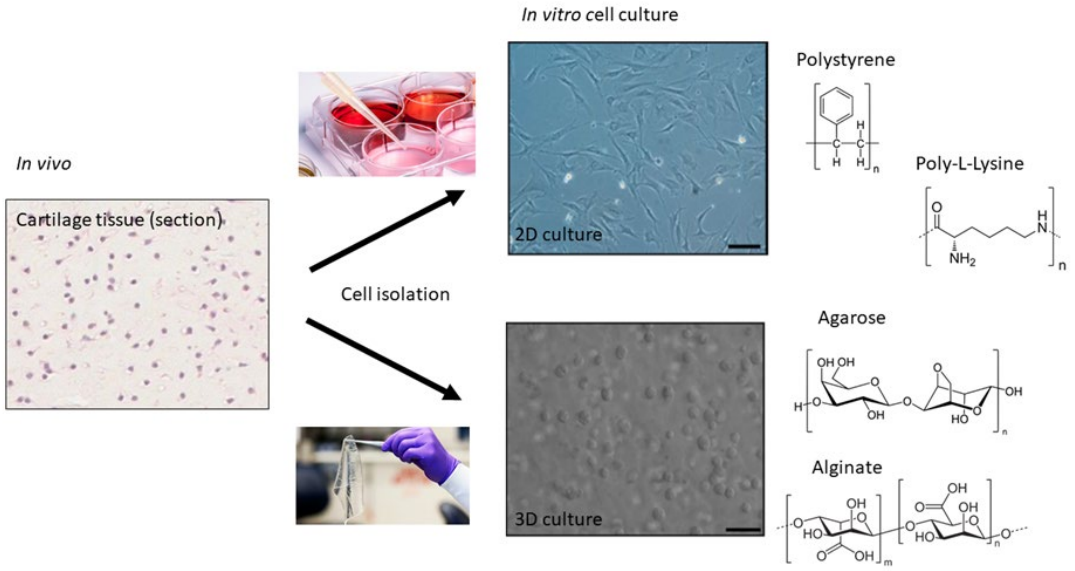


Figure 1. Use of a hydrogel maintains chondrocyte morphology *ex vivo*. Left: Cartilage tissue contains rounded chondrocytes. Top right: Chondrocytes obtain an elongated morphology upon cell isolation and culture on 2D plastic (polystyrene) or coated culture vessels (poly-L-Lysine). Lower right: Chondrocytes maintain their rounded morphology in 3D hydrogel culture (agarose or alginate).

Weeks 2-3 Case 2: Designing a Biocompatible Polymer Scaffold

You are a biomedical engineer working for a medical device company tasked with designing a biocompatible polymer scaffold for tissue engineering applications. The scaffold needs to support cell growth and integration into the surrounding tissue while possessing suitable mechanical properties for the intended application. The polymer you are considering for this scaffold is poly(lactic-*co*-glycolic) acid (PLGA), a commonly used biodegradable polymer. Fortunately, you have some knowledge of this polymer from your master's education. You recall an interesting article on the application of PLGA in tissue engineering.[1]

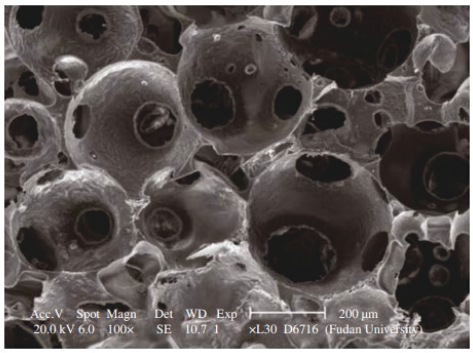


Figure 1. Scanning electron micrograph of a spherical-pore PLGA scaffold[2]

The team plans a meeting to discuss some initial ideas. The first thing you agree upon, is that you are going to focus on fabricating a PLGA scaffold for cartilage regeneration in knee injuries. You feel like this is a good direction for the company to head in as this appears to be a popular space in the market.

Your line manager begins by asking "What are the properties of PLGA that we need to focus on and how can we relate these to polymer structure?".

Some interesting ideas are suggested from different members of the team. The biologists suggest focusing on the host response to the material, ensuring that the scaffold is not toxic.

One of the biomaterials engineering team members questions this by saying: "Surely, if we are to encourage tissue integration, then the thing to focus on, is ensuring that the material we make is very similar to knee cartilage itself?". Another colleague says: "Yes, this is indeed important. We need to think about polymer morphology and how that dictates certain properties.".

A chemist chips in with: "These are all good ideas and I can support you with material characterization. What kind of techniques are you going to need?"

Literature:

1. Pan, Z.; Ding, J. Poly(lactide-*co*-glycolide) porous scaffolds for tissue engineering and regenerative medicine. *Interface Focus* **2012**, *2* (3), 366–377. https://doi.org/10.1098/rsfs.2011.0123.
2. Zhang, J.; Zhang, H.; Wu, L.; Ding, J. Fabrication of three dimensional polymeric scaffolds with spherical pores. *J. Mater. Sci.* **2006**, *41* (6), 1725–1731. https://doi.org/10.1007/s10853-006-2873-7.

Weeks 3-4 Case 3: The Quest for the Perfect Scaffold

In the bustling lab of BioGenesis Technologies, Dr. Emily Carter and her team are facing a challenge: developing a revolutionary scaffold for skin tissue regeneration. The scaffold needs to be biocompatible, biodegradable, and support cell adhesion and proliferation. This will require expertise in organic/polymer synthesis and covalent modifications. They have several decisions to make along the way, and are not sure if they have all the correct information.

Dr. Carter gathered her team, which included chemists, materials scientists, and biomedical engineers, for their first brainstorming session. They needed to decide on the backbone of their polymer scaffold.

"Should we go with a polycondensation reaction, like succinic acid and ethylene glycol?" suggested James, the organic chemist.

"Or a ring-opening polymerization of lactones, like ε-caprolactone?" countered Maria, the materials scientist.

After weighing the pros and cons, the team decided to run preliminary experiments with both approaches to compare results. They were unsure if they needed to look at other polymers as well.

With the backbone synthesis underway, the team moved on to figuring out ways to enhance the polymer's properties.

Click chemistry, like azide-alkyne cycloaddition, 'grafting to' or 'grafting from, dynamic-covalent crosslinking, like Schiff base formation, traditional methods like chemical crosslinkers or ionic crosslinking for hydrogels, even MMP sensitive chemistry came up. Far too many to test at once, they had to make some decisions.

The team experimented with different modification and crosslinking techniques. Keeping in mind that skin is the target application, which types of properties are needed?

Next, the team focused on biofunctionalization to ensure the scaffold would support cell growth.

"We need cell-adhesion peptides like RGD to promote cell attachment.", suggested Sarah, the cell biologist.

"Wait, do we need growth factors? How can we get them in the material? Or is it too complex?" wondered Susan, the molecular biologist.

The team tested several biofunctionalization strategy to determine the most effective approach. They need an approach that allows robust and scalable functionalization to treat as many patients as possible.

With the scaffold taking shape, the final step was thorough characterization. "What should we use to characterize the scaffold?", said Emily.

"Make sure we know the chemistry works first.", directed Dr. Carter.

"Don't forget about the polymer architecture!", added James.

"Oh, and physical properties!", reminded Maria.

"Don’t forget we need to know it works with cells.", insisted Sarah.

The team designed a comprehensive experimental plan, characterizing every aspect of their scaffold.

Months of intense research and countless experiments culminated in a breakthrough. The team developed a scaffold that met their criteria: biocompatible, biodegradable, and capable of supporting robust cell growth, ready for preclinical trials for skin regeneration.

Dr. Carter addressed her team, pride in her voice: "We've achieved something remarkable here! This scaffold can revolutionize skin tissue regeneration and improve countless lives. Each of you played a crucial role in this success."

As the team celebrated, they knew this was just the beginning. Their journey had equipped them with invaluable knowledge and skills, preparing them for the next challenge in regenerative medicine.

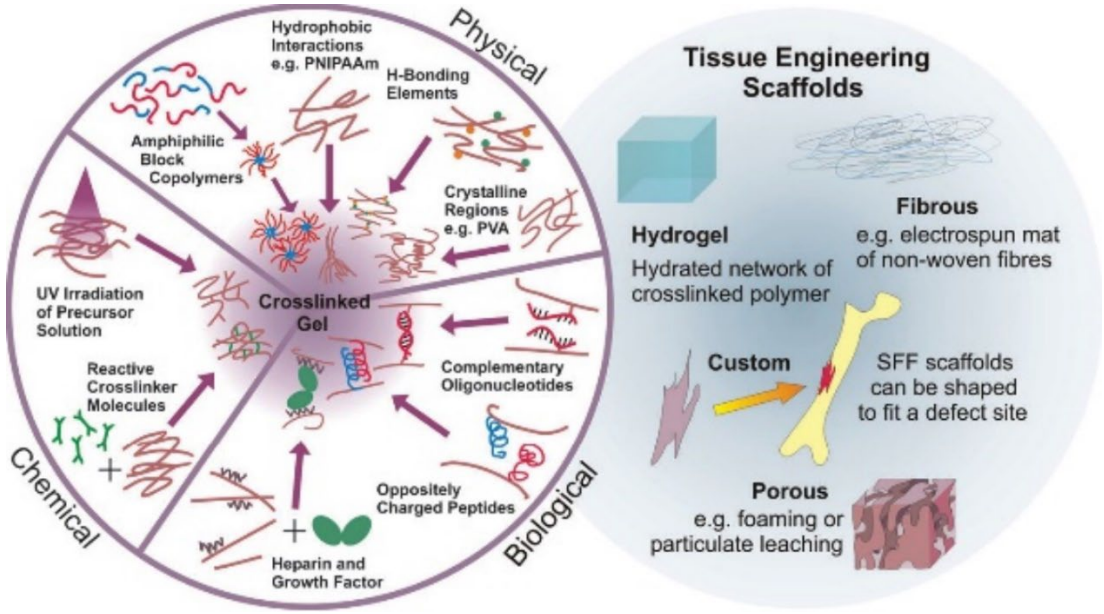


Figure 1. Designing a new polymeric material for tissue engineering. From: Place, E. S.; George, J. H.; Williams, C. K.; Stevens, M. M. Synthetic polymer scaffolds for tissue engineering. *Chem. Soc. Rev.* **2009**, *38* (4), 1139-1151. https://doi.org/10.1039/b811392k.

Weeks 4-5 Case 4: Battle of the Bone Builders - Comparing Inorganic Materials for Regeneration

You are part of a multidisciplinary research team working in a leading hospital, which is globally recognized for medical breakthroughs, especially in the development of new orthopaedic therapies. Recently, the hospital has seen an increase in patients requiring bone regeneration treatments due to various conditions such as fractures, bone defects, and joint replacements. The medical research team is considering different inorganic materials to enhance the effectiveness of these treatments and improve patient outcomes. They have been granted a large sum of money to perform clinical research on a single promising material in a specific subset of patients: older patients (60 years and over) with severe femoral fractures. The medical history of these patients includes osteoporosis which complicates the healing process.

The orthopaedic surgeon has suggested using an inorganic material to support the bone regeneration process and has shortlisted three types of inorganic materials commonly used in bone regeneration: titanium, hydroxyapatite, and bioglass.

Your research group has been tasked with evaluating these materials to determine which one is most suitable for the identified patient group. Your research group has one week to come up with advice on which material(s) to focus on in this exciting new study. After an initial brainstorm your team realizes it is not so simple and there are many aspects to consider such as biocompatibility, mechanical properties, degradation rates, and suitability for this particular application, just to name a few. You decide to divide the tasks and get to work!

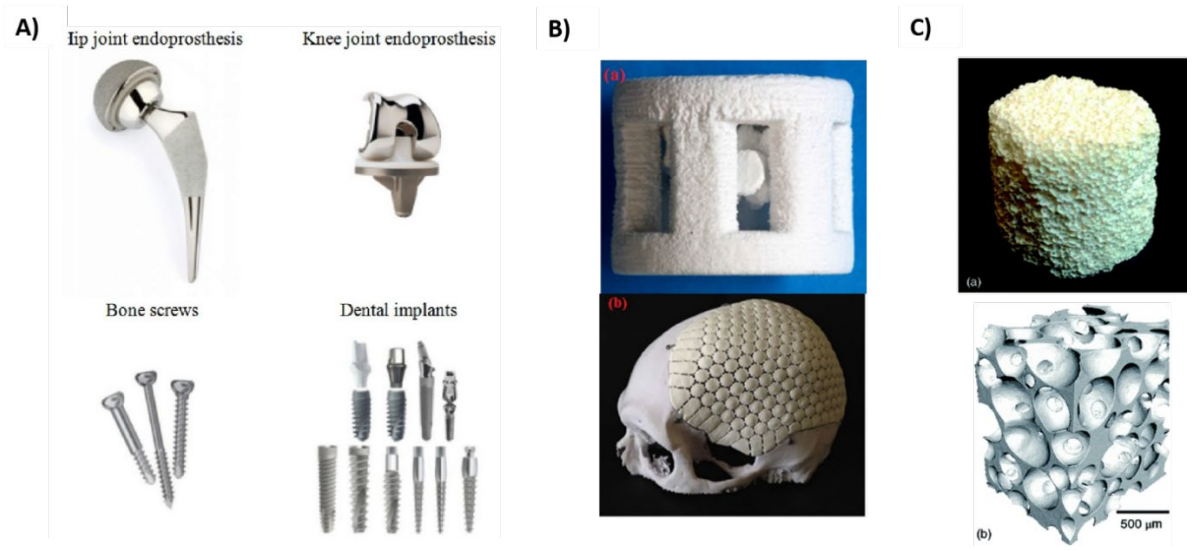


Figure 1: A) Examples of medical applications of Grade 5 Titanium ELI From: Dziubińska, A.; Majerski, K.; Winiarski, G. Investigation of the effect of forging temperature on the microstructure of Grade 5 titanium ELI *Adv. Sci. Technol. Res. J.* **2017**, *11* (4), 147–158. https://doi.org/10.12913/22998624/76488**. B)** Examples of additively manufactured implants based on calcium phosphate. From: Islam, M. T.; Felfel, R. M.; Neel, E. a A.; Grant, D. M.; Ahmed, I.; Hossain, K. M. Z. Bioactive calcium phosphate–based glasses and ceramics and their biomedical applications: A review *J. Tissue Eng.* **2017**, *8*, 204173141771917. https://doi.org/10.1177/2041731417719170. **C)** Bioactive glass foam scaffold and X-ray micro CT image. From: Deshmukh, K.; Kovářík, T.; Křenek, T.; Docheva, D.; Stich, T.; Pola, J. Recent Advances and Future Perspectives of Sol–Gel Derived Porous Bioactive Glasses: A Review *RSC Adv.* **2020**, *10* (56), 33782–33835. https://doi.org/10.1039/d0ra04287k.

Weeks 5-6 Case 5: Biological Biomaterials in Tissue Engineering

Dr. Olivia Green, a leading researcher at BioFabrication Labs, had a new mission for her team: to develop a novel biological scaffold for cardiac tissue regeneration. This scaffold needed to mimic the extracellular matrix (ECM) of the human heart, support cell growth, and integrate seamlessly with the body's tissues. It needed to be from a naturally occurring material, yet have some tailorability in properties.

Dr. Green kicked off the project with a brainstorming session. "Let's consider materials like those found in the ECM of the human body, as well as those produced by organisms such as algae and shellfish.", she suggested.

"Chitin from shellfish has great mechanical strength.", noted James, the organic chemist. "And alginate from algae is highly biocompatible.", added Maria, the materials scientist. "Don't forget the structural proteins in human ECM, like collagen and elastin, even decellularized ECM, can be used these days.", chimed in Sarah, the cell biologist.

There are a lot of pros and cons to each, ease of use, scalability, acceptability by society. The team has a tough decision to make. They choose collagen, but is this a good decision?

With collagen as their base material, the team explored decellularization processes. "Decellularized materials from animal tissues could provide a natural scaffold.", Mia, the tissue engineer, suggested. They discussed various techniques—chemical, enzymatic, and mechanical decellularization—ultimately choosing a mild chemical process to preserve the ECM's integrity while effectively removing cellular components. "I have even seen people decellularize the entire heart!", exclaimed Mia, "But we need something more scalable for production.".

Next, the team considered adding living materials to their scaffold. "Engineered bacteria or yeast could produce recombinant collagen or silk.", proposed Leo, the bioengineer. Dr. Green asked: "How can we control the properties of these living materials?". The team decided to use precision fermentation, identifying a specific microorganism to produce recombinant collagen and optimizing fermentation conditions to ensure high quality and yield.

To enhance their scaffold's properties, the team explored synthetic modifications. "Let's chemically modify our collagen to improve its mechanical strength and biocompatibility.", Ava, the materials scientist, suggested. They examined crosslinking techniques and decided to graft synthetic polymers and crosslinkable units onto the natural collagen, combining the best properties of both materials. "GelMA does this.", says Ava, "Could we use a similar strategy?". This hybrid approach aimed to create a scaffold with enhanced durability and cellular interaction.

With their hybrid scaffold ready, the team moved on to characterization and testing. "We need to assess the mechanical strength, biocompatibility, and cell-supporting capabilities.", Dr. Green instructed. They used mechanical testing, microscopy, and cell viability assays to evaluate their scaffold. After rigorous testing and iterative improvements, they noticed that there was quite some variability between samples. Checking the sourcing and process allowed them to achieve a breakthrough: a scaffold that mimicked the ECM of the human heart and supported robust cell growth and tissue integration.

In a final meeting, Dr. Green addressed her team: "We've made significant progress! This scaffold could revolutionize cardiac tissue regeneration and improve many lives. Your dedication and innovative thinking have been crucial to our success.".

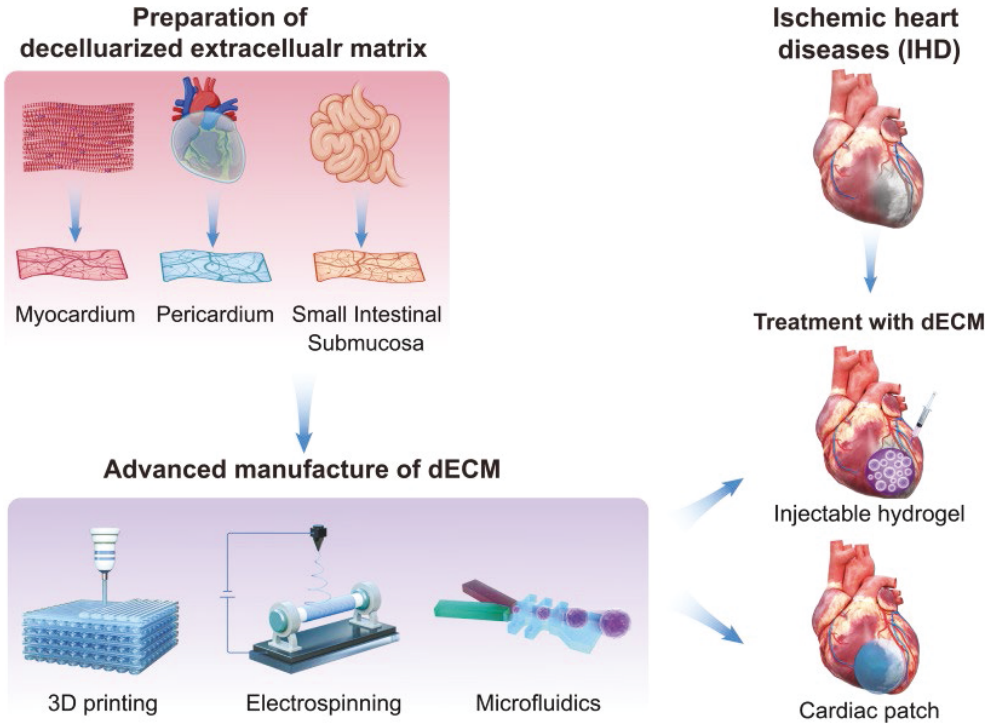


Figure 1: Using natural materials like dECM for tissue engineering enables significant advances in tissue growth but can come with many challenges for processing and reproducibility. From: Liu, W.; Zhang, X.; Jiang, X.; Dai, B.; Zhang, L.; Zhu, Y. Decellularized extracellular matrix materials for treatment of ischemic cardiomyopathy *Bioact. Mater.* **2023**, *33*, 460–482. https://doi.org/10.1016/j.bioactmat.2023.10.015.

Weeks 6-7 Case 6: Arthrosis of the Hip

Jeremy, now in his second year of the RMT program, receives a rather distressing phone call from his grandmother, a 68-year-old retired schoolteacher. She suffers from chronic hip pain that has progressively worsened over the past five years. She describes the pain as a deep ache in her right hip, exacerbated by weight-bearing activities and prolonged sitting. She has a history of osteoarthritis – a condition where the cartilage in the hip is degenerating - diagnosed a decade ago, managed initially with lifestyle modifications and conservative treatments. However, her pain has become debilitating, significantly affecting her quality of life. Therefore, she has decided that an intervention is now inevitable. Knowing of Jeremy's interest in biomaterials and regenerative medicine, she asks him for advice on which therapeutic option to consider.

Reflecting on what he has learned so far, Jeremy recalls a lecture from the RMT1001 course in which osteoarthritis was discussed. He remembers that, despite many years of intensive research, no therapy is available to repair damaged cartilage. As a result, hip replacement surgery seems to be the best option in such cases. However, instead of using conventional bare metal implants*, drug-eluting implants have now become available. The drugs included in these implants can inhibit bacterial invasion and immune responses, while also improving osteoconduction and angiogenesis. These advancements have transformed implantable medical devices into smart biomaterials. Given Jeremy's background, this piques his curiosity and he decides to make an inventory of the options available for his grandmother.

*typically made of e.g. titanium (Ti), tantalum (Ta), magnesium (Mg), zinc (Zn), stainless steels, or cobalt (Co)-based alloys

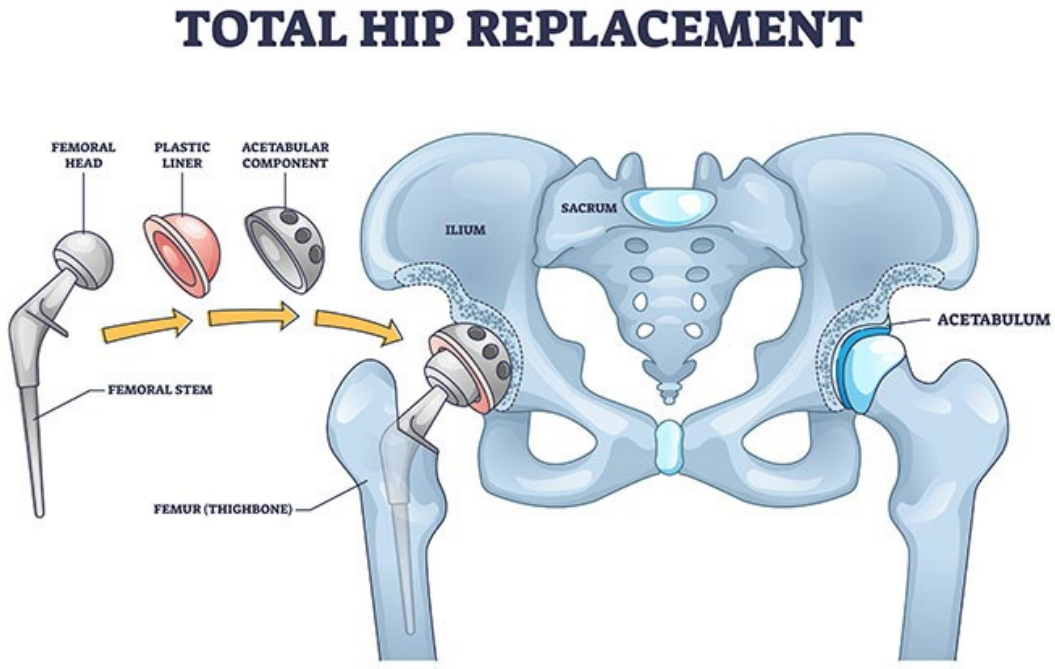


Figure 1: Total hip replacement: traditional approach. Image taken from: Flawless Physio https://flawlessphysio.co.uk/total-hip-replacement-thr (accessed on 26th September 2024)

Lectures

The slides of the lectures will be available via the course on the Canvas before the lecture.

Week 1

Opening Lecture: RMT2002
Dr. Jurica Bauer & Dr. Guus van den Akker

The opening lecture will kick-off the RMT2002 course by providing an overview of the course content, structure, teaching and learning activities, and assessment.

Lecture 1: Introduction to Biomaterials
Dr. Jurica Bauer

In the first lecture we will introduce the broad concept of materials and examples of both natural and synthetic materials attempting to mimic natural systems will be discussed. More attention will be given to macromolecular and, more concretely, polymer materials and their classifications, structure levels and nomenclature. The concepts of average molecular weights and weight distributions will be introduced and used to make a distinction between polymer and small-molecule materials. Finally, biomaterials will be defined in terms of the conditions that a material needs to meet for use in biological systems. Examples focusing on applications in regenerative medicine will be used to illustrate the concepts introduced in this week.

Week 2

Lecture 2: Characterization, Analysis and Properties of Biomaterials
Dr. Gavin Hazell and Dr. Guus van den Akker

In this lecture we turn our focus to the physico-mechanical, chemical and biological properties of materials, where they originate, how we can characterize them and how we can gain control over them. Polymer morphology will be discussed and used to introduce properties like elasticity, viscosity, glass-transition, etc. Attention will also be given to the chemical characterization of materials using a range of spectroscopic and spectrometric methods. Basic biological tests will also be introduced. Special focus will be placed on delineating structure-property relationships and how these can eventually be used in the design of biomaterials for the general biomedical and more specific tissue growth applications.

Week 3

Lecture 3: Organic Biomaterials
Dr. Gavin Hazell and Dr. Matthew Baker

This week we will cover the approach of organic and polymer based biomaterials. Topics covered will include basic organic reactions, polymerization mechanisms and classes, and strategies for covalent modifications and (dynamic)crosslinking of materials. An emphasis will be given on biofunctionalization of materials and the modification of materials using organic reactions. Furthermore, the students will be introduced to newer advances heavily seen in biological systems like supramolecular materials and dynamic covalent reactions.

Week 4

Lecture 4: Inorganic Biomaterials
Dr. Sabine van Rijt

In this lecture, we will discuss the properties of inorganic materials and highlight their use in tissue regeneration. We will begin with an overview of biocompatible metals, such as titanium, highlighting their properties and applications in medical implants, e.g. as joint replacements and dental implants. Next, we will delve into calcium phosphates, examining their role in bone and tooth mineralization and their use in bone grafts and dental restorations. The unique properties and bioactivity of bioglass will be discussed, with examples of its application in bone regeneration and wound healing. Finally, we will introduce nanomaterials, focusing on nanoparticles, their advantages in medical applications, and their use in drug delivery systems, imaging, and antimicrobial treatments. Throughout the lecture, clinical examples will be used to illustrate the practical applications and significance of these materials in facilitating tissue regeneration.

Week 5

Lecture 5: Biological Biomaterials
Dr. Gavin Hazell and Dr. Matthew Baker

In this lecture, we will cover the major classes of biological biomaterials, not only those found in the ECM of the human body, but also those produced by other organisms (algae, shellfish). We will focus on the diverse properties selected by natural evolution, for different purposes, and some of the common biosynthetic pathways for hierarchical materials. We will look at how nature produces materials as opposed to how this is done in the lab. Furthermore, an introduction to the synthetic modifications of biological materials to create hybrid systems will be given. Specific examples at the forefront of the field (e.g. the use of decellularized ECM, recombinant protein synthesis, and engineered living materials) will be discussed.

Week 6

Lecture 6: From Cell-Materials Interactions to Local Drug Delivery
Dr. Gavin Hazell and Dr. Matthijs Blankesteijn

In this lecture, we will explore the potential of (bio)materials to not only serve as a reservoir for drugs, enabling a sustained and localized release, but also to interact dynamically with cells and tissues. Local drug delivery offers the advantage of targeted therapeutic effects, minimizing systemic side effects. Clinical examples include drug-eluting stents for treating occluded blood vessels and hormone-releasing devices for contraception. We will extend this discussion to include the delivery of growth factors, which play a crucial role in modulating cell behavior and promoting tissue regeneration. The interaction between cells and biomaterials, including mechanotransduction and the role of the extracellular matrix (ECM), will be addressed to highlight how materials can influence cellular responses. We will also consider the principles of biodegradation, discussing how the controlled degradation of materials can be used to facilitate tissue integration and healing**.**

Week 7

Lecture 7: Advanced Technologies in Materials Science
Dr. Gavin Hazell

The creation and use of regenerative therapies often relies on the processability of the material. From the clinical design of injectables to advanced 3D-printing technologies how a material flows, heals, behaves over time can make or break its success. Looking forward, the processability of cell/material composites is also important for cellular manufacturing – the creation of tissue models, organoids, and cellular upscaling. We will cover the use of emerging biofabrication technologies to create 3D (living) scaffolds for tissue regeneration. We will also take a look at how emerging advances in adjacent fields like mathematical modelling, artificial intelligence, and genetic editing are influencing the research and design of biomaterials.

Guest Lecture: To be announced
To be announced

ChemOffice Workshops

ChemOffice is a suite of software tools designed for chemists and researchers in the field of chemistry. The most relevant software components for the duration of this study are ChemDraw and Chem3D. The software allows you to draw and visualize chemical structures, reactions, and diagrams. It also enables three-dimensional visualization and modelling of chemical structures as well as analysis of chemical bonds, angles and molecular properties. As such, ChemOffice is not only useful for learning purposes but also for reporting experiments and your research projects.

Week 2 – Workshop 1: ChemOffice for Macromolecules

In this workshop we will briefly recap the basic features of the software introduced in Year 1. We will also use the software to draw, visualize and analyze macromolecules of relevance to the course.

Week 5 – Workshop 2: Applications of ChemOffice

In this workshop we will use the software to present macromolecules relevant to the course and, more specifically, the group assignment. The students are encouraged to prepare their initial ideas for the group assignment and bring these to the workshop. There will also be opportunity to discuss the first ideas for the assignment and get feedback.

Midterm Mock Exam

A midterm mock written exam will be organized in week 4 to allow you to practice for the final exam. In this way you can evaluate your learning progress. This mock exam does not contribute to the final grade for the course. The exam will be taken in TestVision on the students' own laptops.

Assignments for Problem-Solving Sessions

Every week you are offered a set of exercises and problems which can be used to practice the relevant concepts for the corresponding week. Some are very basic while others are more challenging. A document with the exercises/problems per week will be published on Canvas at the beginning of the course. These also contain examples of possible exam questions and can help you assess your learning progress. We recommend that you to work out the proposed listed assignments every week. Bring your solutions and notes to the Problem-Solving Session on Thursday. Make sure you also bring any questions that you may still have to the session.

Group Assignment: Design Your Own Biomaterial

Throughout the course you have familiarized yourselves with many different biomaterials. Now it is time to design your own!

We would like to ask you to define a clinical or biomedical problem and propose a regeneration-based solution including a novel design of a biomaterial. You will work in teams of 3-4 students. Please form groups of 3 or 4 students within your tutorial group and notify your tutor by the end of Week 4 of your group composition.

For this assignment you will create three products:

1) 2-page proposal
2) 10-minute presentation presenting and defending the problem and your solution to the rest of the class

Guidelines:

0) Choose a suitable clinical or biomedical problem in consultation with your tutor by the end of week 5. Make sure your tutor approves your topic, preferably in this week's tutorial.
1) A 2-page proposal should be drafted with the following sections: title, authors, introduction (clinical or biomedical problem, justification, hypothesis), research/solution design and methods, literature. The document should contain at least one image relating to the design of a biomaterial. Submit the proposal with your presentation in week 8.
2) The proposed solution or research should include a regeneration-based approach and should focus on the design of a novel biomaterial for this approach. The focus is therefore on materials science and chemistry but well integrated in a biological, biomedical or clinical context.
3) In Week 8 you will briefly present your problem and solution/research. The presentation should address at least these three topics:
    a. A clinical or biomedical problem
    b. The proposed solution or research approach should highlight:
        i. The design of a novel biomaterial (including composition and preparation).
        ii. The expected physical, chemical and biological properties.
        iii. Proposed characterization techniques.
        iv. Explanation how the novel biomaterial will contribute to the regeneration-based solution to the problem.
        v. Merits and limitation of your approach.
    c. What you learned as a team during the process.

Please submit your 2-page proposal by email to your tutor no later than Monday, the 16th of December at 8:00 o'clock (AM). Submissions received after the deadline will not be considered for the first take.

Please send your tutor the slides of your presentation no later than Tuesday, the 17th of December, at 8:00 o'clock (AM). The group should also fill in the form "Statement of Equal and Sufficient Participation", have it signed by all group members and send it to the tutor along with the slides. If it turns out that a member of the group did not participate sufficiently in this group assignment and that the group does not want to sign the above statement for them, the tutor should be notified immediately.

NOTE: *Students are not allowed to use ChatGPT or other similar text or image-producing AI tools in assignments. AI-generated text used to answer exam questions/assignments can be seen as commissioned work that represents plagiarism and fraud and will be sanctioned by the Board of Examiners. When there is suspicion of use of an AI tool, the Board of Examiners – after having consulted the coordinator – may ask the coordinator to perform an additional inquiry.*

Resources

As part of the problem-based learning approach, students are expected to look for their own literature and consult multiple sources that will help them achieve their learning goals. However, in order to somewhat streamline the literature search, we would here like to offer the core literature (textbooks) which should definitely be consulted to acquire a good understanding of the main concepts of materials science relevant for the field of regenerative medicine. Students are expected to consult other sources (textbooks and scientific articles) to gain more insight into topics specific to the field of regenerative medicine. This will especially be necessary when solving multidisciplinary cases. A selection of the recommended literature is listed below but this is by no means an exhaustive list of sources to use for the duration of this course. Additional references may become available in the course on Canvas, under 'Resources'.

Core literature

- Polymer Chemistry: An Introduction, Oxford University Press, third international edition, 2009, Stevens, M.
- Biomaterials Science, An Introduction to Materials in Medicine, Elsevier, fourth edition, 2020, Wagner, W. R., Zhang, G., Sakiyama-Elbert, S. E., Yaszemski, M. J.
- Materials science for biomedical engineering, Eindhoven University of Technology, third edition, 2011, van Genderen, M. H. P.
- Tissue Engineering, Elsevier, third edition, 2022, van Blitterswijk, C., de Boer, J.
- Organic Chemistry, Wiley, third edition. Klein, D.

Recommended literature

- Solutions Manual for Polymer Chemistry: An Introduction, Oxford University Press, third edition, 1999, Stevens, M.
- Human anatomy & physiology, Pearson, eleventh edition, 2019, Marieb, E. N., Hoehn, K., et al.
- Rang & Dale's Pharmacology, Elsevier, ninth edition, 2018, Ritter J., et al.
- Chemistry, A Molecular Approach, Pearson, fifth edition, 2021, Tro N. J.
- Solutions Manual: Chemistry, A Molecular Approach, Pearson, fifth edition, 2019, Shaginaw K. T. & Tro N. J.
- Molecular Biology of the Cell, W. W. Norton and Company, seventh edition, 2022, Alberts B. et al.
- Synthetic ECM: Bioactive Synthetic Hydrogels for 3D Tissue Engineering. Unal A.Z. & West J.L., Bioconjugate Chemistry (2020) 31, 10, 2253-2271.
- Silica Nanoparticles in Transmucosal Drug Delivery Ways, T. M. M. et al Pharmaceutics (2020) 12, 8, 751.
- Calcium Phosphate-Coated and Strontium-Incorporated Mesoporous Silica Nanoparticles Can Effectively Induce Osteogenic Stem Cell Differentiation, Sutthavas, P. et al Advanced Healthcare Materials (2022) 11, 4, 2101588.
- A Review on Nanoparticles: Characteristics, Synthesis, Applications, and Challenges Altammar, K. A. Frontiers in Microbiology (2023) 14, 1155622.
- Calcium Phosphates for Biomedical Applications Canillas, M. et al Boletín de la Sociedad Española de Cerámica y Vidrio (2017) 56, 3, 91.

- Calcium Phosphate Ceramics in Bone Tissue Engineering: A Review of Properties and their Influence on Cell Behavior Samavedi, S. et al Acta Biomaterialia (2013) 9, 9, 8037.

Examination

All relevant information about the assessment can be found in the Assessment Plan in the course on Canvas (under 'Examination').

There is one written exam in week 8. The grade for the exam counts for 75% of the final grade for the course and must be a 5.5 or higher for a pass. A minimum of 55 % of the total number of exam points is required for a pass (grade 5.5). In addition, there is a group assignment, introduced in week 4, which will be presented and assessed in week 8. The content of the group assignment must also be assessed with a 5.5 or higher for a pass and will then contribute to the final grade for the course with 25%. The rubric to assess the content of this assignment is available on Canvas. The students' presentation skills will be formatively evaluated using the rubric available on the Canvas page of the Academic Development Line.

A resit of the written exam will be offered in the week of the 3rd of March 2025. Please refer to FHMLweb and/or the announcements on Canvas for details regarding the time and place of the exam. A retake of the group assignment needs to be scheduled with the tutor no later than two weeks after the first take; the student is expected to take this initiative.

In week 4 a (formative) midterm mock written exam will be offered to allow students to evaluate their learning progress up to that point; this mock exam does not contribute to the final grade for the course.

Course Evaluation

In Week 8, during the Q&A session the students are kindly asked to fill in a course evaluation through the following link: https://iwio.fhml.maastrichtuniversity.nl/ The course planning group deems it very important to receive constructive feedback that can be used to improve this and other courses in the future. Especially considering that the Year 2 programme is running for the first time this year, it is of high importance to receive as much feedback as possible.

Maastricht University

SYLLABUS

Lab Skills Line II

RMT2102

Academic year: 2024-2025

Faculty of Health, Medicine and Life Sciences

Bachelor Regenerative Medicine and Technology

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Introduction

The practical skills longitudinal line runs through the first two years, as Laboratory Skills I (year 1) and **Laboratory Skills II (year 2)**, each worth 7 ECs. Lab skills trainings are mainly concentrated in the 8-week periods, in which the experiments are aligned with the content of the courses. Every 8-week course, students need to demonstrate sufficient skills in preparing experiments (preparing the practical, performing lab-related calculations) and carrying them out, keeping a lab journal, and basic lab skills (weighing, pipetting, etc.). As the practical sessions are all part of the lab skills line, repeated practice of skills, with increasing degree of complexity throughout the bachelor is achieved, and longitudinal tracking of development of lab skills is possible. Importantly, students will also be able to practice and further develop their practical skills in a self-directed manner within the design project; this is aligned with the lab skills line.

Students receive regular formative feedback by staff and peers on these skills, which will be added to the portfolio at the end of each 8-week course. Next to this, students are assessed on their performance by means of a summative practical exam consisting of two parts (in periods 3 & 6 each year). The lab skills line formally ends at the end of year 2.

Learning Goals

Intended Learning Outcomes

Intended Learning Outcomes (ILO)	Teaching and Learning Activities (TLA)	Assessment and feedback tasks (AF-T)
RD-ILO-1: Understands and applies safety rules in the laboratory. (RMT2001-RMT2006)	Practical training, reading materials for self-study	Practical skills exams (period 3 & 6, summative)
RD-ILO-2: Is able to apply practical skills to perform experiments following a protocol. (RMT2001-RMT2006)	Practical training	Practical skills exams (period 3 & 6, summative), feedback from trainer and peers (formative) to be incorporated in portfolio
RD-ILO-3: Is able to keep a lab journal. (RMT2001-RMT2006)	Canvas assignment/Lab-Buddy	Feedback from trainer (formative) to be incorporated in portfolio
RD-ILO-4: Describes the subsequent steps of the empirical research cycle and is able to apply these in preparation, execution and reporting of simple laboratory experiments (RMT2001-RMT2006*)	Canvas assignment/ Lab-Buddy, practical training	Practical skills exams (period 3 & 6, summative), feedback during wrap-up sessions by trainer (formative); Incl. writing assignment which is part of the Academic Development Line (see below).
RD-ILO-5: Relates the results of experiments to an initially formed hypothesis and draws a conclusion based on this (RMT2001-RMT2006*)	Canvas assignment/Lab-Buddy, practical training	Practical skills exams (period 3 & 6, summative); feedback during wrap-up sessions by trainer (formative), to be incorporated in portfolio
RD-ILO-6: Applies a set of pre-structured scientific methods and technologies to a specific research question (RMT2001-RMT2006*)	Canvas assignment/Lab-Buddy, practical training	Practical skills exam (period 5/6, summative), feedback from trainer (formative) to be incorporated in portfolio

** Specific goals related to practical activities year 2:*

RD-ILO-6.1: Be able to work in sterile environment for culturing of cells, and perform functional assays with cultured cells. (RMT2001, RMT2002, RMT2003, RMT2005)
RD-ILO-6.2: Be able to synthesize and purify a product, follow reaction kinetics, and know how to steer a chemical reaction. (RMT2002, RMT2005, RMT2006)
RD-ILO-6.3: Be able to characterize a material using various techniques like FTIR, mechanical testing, and rheology. (RMT2002, RMT2005, RMT2006)
RD-ILO-6.4: Understand and review the link between in situ computational models (RMT2004) and applied models in the lab.
RD-ILO-6.5: Understand and apply principles of advanced regenerative medicine technology (e.g. on chip- technology, microfluidics & nanofabrication) in a lab setting. (RMT2005)
RD-ILO-6.6: Apply analysis and visualization of data (RMT2001-RMT2006)
RD-ILO-6.7: Apply statistics to experimental data and report on experimental data (RMT2001-RMT2006)

Contact

Planning Group

Block co-coordinators
Dr. Carlos Domingues Mota
Dr. Timo Rademakers

Members of the planning group
Dr. Stefan Giselbrecht
Dr. Gabriel Paiva Fonseca
Dr. Niloofar Tahmasebi Birgani

Questions
If you have questions about the timetable, registration for trainings and practicals, education and examination rules, exam dates, exam results etc. you can contact the Institute for Education via askFHML
For questions about the content of the course or the exam you can contact the coordinator of this course via rmt-lsl-fhml@maastrichtuniversity.nl
For questions about a practical you can contact the coordinator of the specific practical.

Practicals & assignments

COURSE RMT2001

Course RMT2001 will introduce students to cell culture principles, and how to properly culture cells in the lab.

Practicals:

- Introduction to cell culture (week 1)

- Cell culture maintenance (week 2-4)
  Students will learn how to start and maintain a cell culture, but also how to count cells, perform experiments for cells and do quality control (e.g. infections).

- Functional cell culture assays (week 5-7)
  During the second half of the course, maintenance of cell culture will be combined with performing functional assays on cells, e.g. metabolic assays, as well as how to do microscopic imaging on cells.

- Wrap-up RMT2001 (week 7-8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT2002

In course RMT2002, the student will get more in-depth knowledge about chemical synthesis, perform synthesis experiments, and perform materials testing afterwards.

Practicals:

- Chemical synthesis practicals (week 1-3)
  In the first weeks, student will learn how to synthesize both inorganic, organic, and composite materials.

- Materials characterization (week 4-5)
  Students will use characterization tools on the materials they made in the first weeks. For this, students will use rheology, FTIR, mechanical testing, and students will be introduced to electron microscopy.

- Materials meet cells (week 6-7)
  To finalize this course, students will culture cells on top of materials they created in the lab, and test how the materials influence the cell properties.

- Wrap-up RMT2002 (week 8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-

up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT2003

In period 3, the student will have a first exam to test their practical skills. This practical will mostly be focused on cell culture.

COURSE RMT2004

In course 2004, there will not be any practicals, as practical hours are included in coding/modelling practicals. There will be a demo which is linked to one of the modelling exercises.

COURSE RMT2005

Course RMT2005 will focus on advanced techniques in regenerative medicine, e.g. micro-/nano-fabrication.

Practicals:

- Chip fabrication and bonding (week 1-3)
  In the first practicals, students will focus on making fluidic chips, by doing the fabrication, as well as bonding of the device.

- Particle production (week 4-5)
  Secondly, students will use their chemistry skills to do some simple particle production using chemical synthesis.

- 3D printing & principles of bioprinting (week 6-7)
  Lastly, this course will cover principles of 3D printing and bioprinting for more advanced applications in regenerative medicine.

- Wrap-up RMT2005 (week 7-8)
  During the wrap-up sessions, students will in groups discuss what they learned during the practicals, but also discuss things that may be unclear. During the wrap-up session, integration with course content, as well as longitudinal integration will receive special attention.

COURSE RMT2006

In period 6, the student will have a second exam to test their practical skills. This practical will mostly be focused on chemistry and materials characterization.

Examination

ILO	Assessment and feedback tasks (AF-T)	Requirements / description	Standard setting – calculation of score/mark, if applicable	Evaluator / Assessor (e.g. tutor, practical teacher, member course planning group)
ALL ILOs	RMT2102 – Feedback (formative)	(Peer-)feedback during execution of the practical + on lab journal keeping. Reflection on this feedback is integrated in the Portfolio.	N/A	Peer, trainer *To be discussed with mentor (ADL)*
All ILOs	RMT2102 – Practical exam (summative)	Practical assignment for good cell culture practice (P3) and chemistry (P6). Assessment based on practical skills, and outcome (graph). Analysis and interpretation of the data is also assessed within a written report **Design process is assessed within the Design Project Line* **Writing skills are assessed within the Academic Development Line. If practical exam is not attended, the writing assignment will need to be done after the resit period.*	Fail/pass/good (see rubric below)	Assessors (report), trainers, or members line planning group (lab skills)
ALL ILOs	RMT2112 – Attendance (summative)	There is a 100% attendance requirement for practical trainings. If you will be absent, you must notify your peers and trainer. If you fail to give this notification, this may lead to a 'falls short of expectation' qualification in the portfolio (Academic Development Line), and student will fail RMT2112. *See below for more information.*	Fail/pass	Trainers, members line planning group

RMT1001 Molecular Basis of Life – Assessment Rubric for the Content of the Group Assignment "Design Your Own Case"

Group number:	**Students:**						
Assessment Criterion	**Insufficient (5)**	**Sufficient (6)**	**(7)**	**Good (8)**	**(9)**	**Excellent (10)**	**ILO**
Presence and quality of biological insights into regenerative medicine	A relevant biology-related learning goal is *not* presented or is presented but is explained incorrectly.	A relevant biology-related learning goal is presented, and explained with several mistakes.		A relevant biology-related learning goal is presented, and explained clearly with only minor mistakes.		A relevant biology-related learning goal is presented, and explained clearly and correctly, demonstrating in-depth understanding of the relevant topics.	SE-3-ILO-3 SE-3-ILO-4 SE-3-ILO-5 SE-3-ILO-6
Presence and quality of chemical insights into regenerative medicine	A relevant chemistry-related learning goal is *not* presented or is presented but is explained incorrectly.	A relevant chemistry-related learning goal is presented, and explained with several mistakes.		A relevant chemistry-related learning goal is presented, and explained clearly with only minor mistakes.		A relevant chemistry-related learning goal is presented, and explained clearly and correctly, demonstrating in-depth understanding of the relevant topics.	SE-3-ILO-1 SE-3-ILO-2 SE-3-ILO-5 SE-3-ILO-9
Multidisciplinary character of the case	The case is *not* relevant for the field of regenerative medicine and/or does not integrate chemical and biological learning goals.	The case is relevant for the field of regenerative medicine and integrates chemical and biological learning goals to some extent.		The case is relevant for the field of regenerative medicine and integrates chemical and biological learning goals.		The case is very relevant for the field of regenerative medicine and integrates chemical and biological learning goals in a clear and correct fashion.	SE-3-ILO-7 SE-3-ILO-8 SE-3-ILO-10
Addressing questions from the audience	The students do *not* give correct answers to the majority of questions.	The students answer at least half of the questions correctly.		The students answer the questions but the answers are not entirely clear and/or correct.		The students answer the questions clearly and correctly, demonstrating in-depth understanding of the relevant learning goals and topics.	All ILO's
Final grade							
Narrative feedback:							

Final grade = average grade over all the individual four subgrades.

Group number:	**Students:**						
Assessment Criterion	**Insufficient (5)**	**Sufficient (6)**	**(7)**	**Good (8)**	**(9)**	**Excellent (10)**	**ILO**
Presence and quality of insights into regenerative medicine	A relevant multidisciplinary solution or research approach is *not* presented or is explained incorrectly.	A relevant multidisciplinary solution or research approach is presented. There are some mistakes and inconsistencies in the presented solution or approach.		A relevant multidisciplinary solution or research approach is presented, and explained clearly and with only minor mistakes.		A relevant multidisciplinary solution or research approach is presented, and explained clearly and correctly, demonstrating in-depth understanding of regenerative medicine and the underlying disciplines.	1, 2, 4, 5, 7, 9, 10
Knowledge and understanding of materials science – Design*	The proposed biomaterial is *not* novel or it remains unclear how this design would contribute to the solution of the identified problem.	The proposed biomaterial is novel and the design is plausible. The rationale for the design is explained and substantiated by literature.		The proposed biomaterial is novel and the design is plausible. The rationale for the design is clearly explained and substantiated by relevant literature.		The proposed biomaterial is novel and the design is very plausible. The rationale for the design is clearly explained and substantiated by recent and relevant literature.	1, 2, 4, 5, 7-10
Knowledge and understanding of materials science – Methodology*	The structure/composition, preparation and characterization (physical, chemical, biological) of the proposed biomaterial are *not* presented or are explained incorrectly.	The structure/composition, preparation and characterization (physical, chemical, biological) of the proposed biomaterial are presented and explained mostly correctly, and substantiated by literature.		The structure/composition, preparation and characterization (physical, chemical, biological) of the proposed biomaterial are presented and explained correctly, and substantiated by relevant literature.		The structure/composition, preparation and characterization (physical, chemical, biological) of the proposed biomaterial are presented and explained clearly and correctly, and substantiated by recent and relevant literature, demonstrating in-depth knowledge and understanding of materials science.	2, 3, 6, 10
Presence and quality of critical analysis	The merits and limitations of the proposed approach are *not* presented (correctly) or are *not* substantiated by literature.	The merits and limitations of the proposed approach are presented and for the most part substantiated by literature.		The merits and limitations of the proposed approach are critically and clearly presented and substantiated by relevant literature.		The merits and limitations of the proposed approach are critically and clearly presented and substantiated by recent and relevant literature.	2, 9
Addressing questions from the audience	The students do *not* give correct answers to the majority of questions.	The students answer at least half of the questions correctly.		The students answer all the questions but the answers are not entirely clear and/or correct.		The students answer the questions clearly, confidently and correctly, demonstrating in-depth understanding of materials science and regenerative medicine.	All ILO’s
Final grade							
Narrative feedback:							

Final grade = average grade over all the individual five subgrades.
*These criteria need to be deemed sufficient for an overall pass.

Section 1

RMT1001 The Molecular Basis of Life (Students) **Period: 100 -2023/2024**

Number of questionnaires returned: *24* out of 24 enrolled (100%)

		Mean	Std.	N	Mean 2022
General					
	Please indicate to which extent you agree with the following statements				
1.	The objectives of this course were clear	3.9	0.7	24	-
2.	This course was well organised (e.g., clear communication, roster, information availability etc)	3.9	0.8	24	-
3.	There was a clear connection between the different teaching and learning activities within this course	3.8	1.0	24	-
4.	The teaching and learning activities aligned with the learning goals of this course	**4.0**	0.7	24	-
5.	The teachers were sufficiently proficient in the use of the English language	**4.8**	0.5	24	-
6.	The main language throughout all teaching activities in this course was English	**4.8**	0.4	24	-
7.	The assessment methods used in this course (e.g., final exam, assignments, reports etc) were aligned with the learning objectives of this course	3.5	0.8	23	-
Learning activities					
8.	Collaborating with fellow students contributed to the quality of my learning	**4.3**	0.9	24	-
9.	The course content linked well to my prior knowledge	3.7	1.0	24	-
10.	This course encouraged me to actively engage with the course content	**4.2**	0.6	24	-
11.	This course connected to future practice	**4.3**	0.7	24	-

Workload

12. The course content was ...

too easy:	0 (0.00 %)
easy:	0 (0.00 %)
just right:	12 (50.00 %)
difficult:	12 (50.00 %)
too difficult:	0 (0.00 %)

13. The workload in this course was ...

too low:	0 (0.00 %)
low:	2 (8.33 %)
just right:	12 (50.00 %)
high:	10 (41.67 %)
too high:	0 (0.00 %)

14. How many hours on average did you spend on your study in total per week, during this course? (total = sum of scheduled teaching and learning activities AND self-study)	30.5	11.5	23	-

Tutor evaluation

The tutor encouraged us ...

17. ... to summarise in our own words what we had learned	**4.1**	1.0	24	-
18. ... to make connections between the different aspects of the course content	3.9	0.8	23	-
19. ... to formulate specific learning goals ourselves	**4.6**	0.5	24	-
20. ... to provide constructive feedback during the tutorial meetings	**4.3**	0.7	23	-

21. Please indicate how many times your own tutor was absent

0:	16 (66.67 %)
1:	6 (25.00 %)
2:	1 (4.17 %)
3:	0 (0.00 %)
4:	0 (0.00 %)
5:	0 (0.00 %)
>= 6:	1 (4.17 %)

22. Please provide a grade (1-10) for the productivity of your tutorial group	**8.1**	1.0	24	-
23. Please provide a grade (1-10) for the overall performance of your tutor	**8.6**	1.1	24	-

Course-specific questions

25. The practicals are well aligned with the course content	3.8	0.7	24	-
26. The practicals are relevant for developing my laboratory skills	**4.5**	0.6	24	-
27. LabBuddy is a useful tool for preparing and executing my practicals	**4.1**	0.9	24	-

Section 2

RMT1001 The Molecular Basis of Life (Students) **Period: 100 -2023/2024**

Number of questionnaires returned: *24*

Answers to the open-ended questions:

Open-ended questions

15. What did you appreciate most about this course?
(answered by 23 persons)

- I liked the content of the course, it was very interesting.
- The bridge after we learned something new, to regenerative medicine.
- I really liked the topics of the cases during the tutorial sessions.
  Our tutorial group was also very enthousiastic about the cases.
- Things that I appreciated the most about the course were the real life topics that were used to transfer knowledge to us.
- I liked the interdisciplinarity of it, the fact that they always tried to link biology and chemistry and that i found helpful. I also liked that the main goal (regenerative medicine) was always kept in mind during lectures and PBL, with examples in the field and possible outcomes.
- The link between chemistry and biology
- The content regarding regenerative medicine in the lectures.
- I appreciate the given content and new information, which i found really interesting.
- I appreciated the most that all activities during the week were linked with each other and related to one topic.
- The active learning with fellow students was encouraging and pleasant to work in smaller groups to feel more at ease when asking questions or presenting.
- The educational system and the overall teaching and motivation of teachers.
- The relation with regenerative medicine and interesting topics.
- the practicals and the link it had with the subjects
- I appreciated that we had a lab every week, because I liked it. I also appreciate the communication between students.
- That the chemistry wasn't too new, so that the course felt like repeating the chemistry and understanding the completely new biologie.
  It was very nice to have questions about the chemistry to help practice it.
- All of the teachers tried their very best to help us during the duration of this course. I also appreciated the approach to learning here where mistakes are seen opportunities to learn and improve and not something to be ashamed of.
- Much self study.
- I liked that the topics we had were relevant for our future studies and linked to the future practice.
- I enjoyed doing the practicals, and seeing how the practicals connect to the cases we studied. The way that all the studying was cohesive in the end was nice.
- The practicals and teachers where in overall very helpful and interesting. The way the content was structures in a building manner was also very useful
- I found the course itself very interesting, and the tutor lessons were very helpful with the answering of the learning goals the correct way.
- It was a bit difficult at the beginning but I really start to appreciate the PBL session since I clearly understand , how it's work .
- The course was very broad and covered many topics. This made it interesting to learn and spend time on.

16. Which suggestions for improvement do you have for this course?
(answered by 23 persons)

- Well after the mock exam I saw a few changes in the lectures which i thought were positive, because they gave the students more structure. So my suggestion is doing this for the other lectures also and being a bit clearer about the literature, because some literature was tough to use for us.
- Line up the preknowledge and the chemistry taught at the university better. The Dutch chemistry exam syllabus of all secondary schools in the Netherlands is online available.
- I would like to receive more feedback on the practicals.
  The lectures were sometimes a little bit confusing. For me, it was really hard to understand the biology lecture and determine what was important for the final exam.
- I would suggest that that the connection between the biology parts and the chemistry parts of the course become better.
- The different PBL cases were well linked to the biology part, but not always on the chemistry one. It often happened that the tutor had to hint at the chemistry learning goals, because they were not clear with the case. I also felt like some of the lectures didn't make much sense withe the direction the course was taking.
- The chemistry learning goals could have been a bit more clearer. Sometimes they were a little vague and I did not understand what was expected.
- Maybe change the format of the Problem solving sessions because most of the time you are already done after 1 hour and then you just sit there.
- I would appreciate if the course would emphasise more which topics are more important for the study than others, because for me it's too much information and I didn't always understand how deep to go through it.
- Explain a bit more how deeply we should study in some topics. Make mock exams to understand what to expect.
- retain feedback instead of trying to form a excuse as to why that may have happened. I would also like to hear more what resources to use after the lectures.
- To make it more clear in which things exactly do we need to go in depth (where to find it) and how much, specially for the exam and our general knowledge of the course.
- Sometimes it's hard to know how much to go into detail and find information in books. I would suggest at the end of the lecture to state (as in the first weeks) the reference chapters.

  I would also like to make a note on the lab skills course. Sometimes the staff does not know exactly what needs to be done and this negatively affects the laboratory experience. Unfortunately this was my first experience in the laboratory and not knowing exactly what to do made it difficult at times.
- it would be helpfull if th answers of the chemistry book where online and not only a few copys in the library.
- I would like to see that the way feedback is handled is going to be improved. Because I have the feeling that when there is ask for feedback and we give it, it is not listened to.

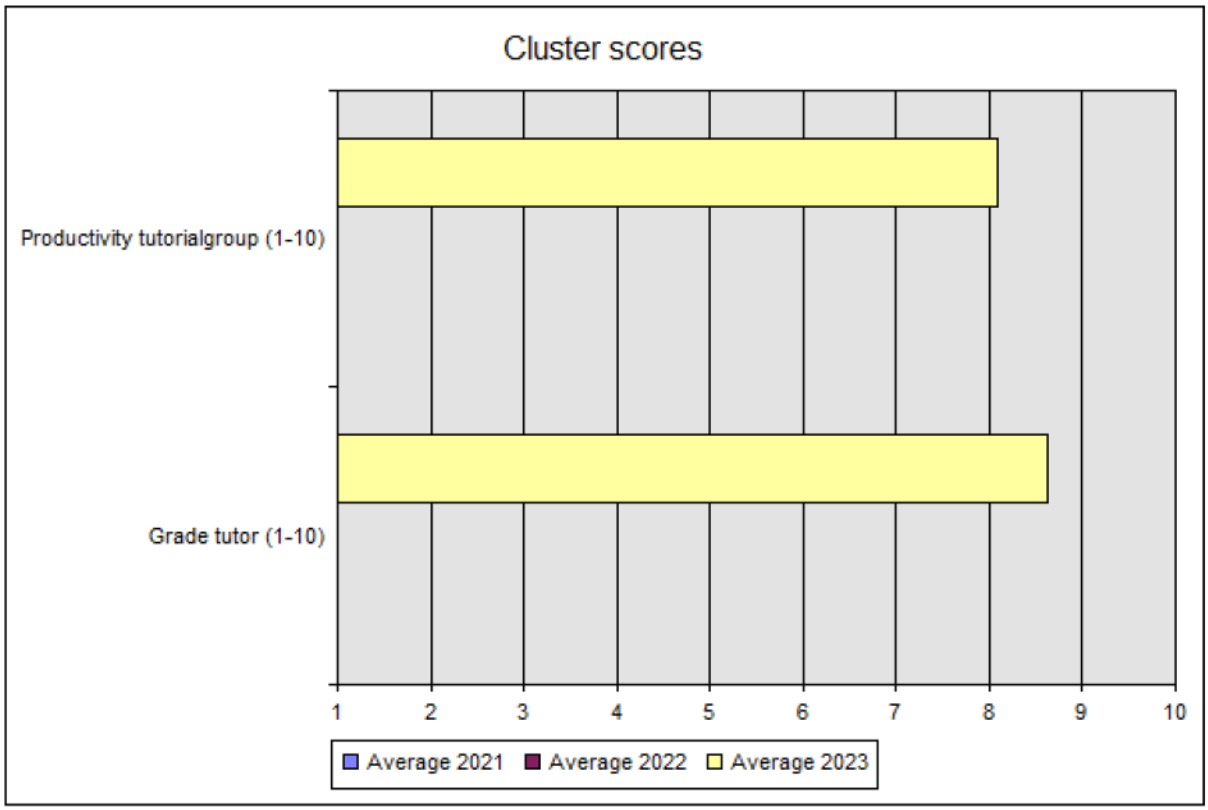
  I also sometimes did not really understand what I was doing during the practicals. Because I can follow the steps but I did not always have an overview of what is was doing.
- Have the answers for the chemistry questions online, because we are not allowed to lend these answerbooks from the library
- I believe that everything was amazingly done, I would say that Lecture 11 would have been better to have at the beginning of the course and not nearing the end. I understand that some parts of the content where already known by students but I believe an introduction with the contents of Lecture 11 during the first weeks would have improved our overall lab performance.
- The case texts could be a more about the chemistry part so it would be easier to formulate the chemistry learning goals.
- For me sometimes the chemistry learning goals where very vague and I didn't know what to do. Also sometimes the chemistry was a repetition of my prior knowledge of high school.
- To improve this course I would maybe have more assignments present. Having assignments will force you to work, if it's only self-study until the end its easy to slack off, especially in your first year of studying the Maastricht PBL method.
- Perhaps a better connection between practicals and the learning like talking about them and discussing/reviewing
- For me the scheduling of this course was very bad. Because most of the time we had a lesson in the morning till 10:30 and than we had only one other lesson from 16-18 so the scheduling could be better. Also a more repition

would be nice.

- The direction in our study , the fact that we need to our own research and our own lesson by ourself it's great but we are still student and regenerative medicine it's a new field and we need to clearly know , what we have to know and how deep .
- Creating a clearer overview of how deep the information goes, by using less examples and maybe more broad information could be an improvement.

Section 3

RMT1001 The Molecular Basis of Life (Students) **Period: 100 -2023/2024**



Section 4

RMT1001 The Molecular Basis of Life (Students) **Period: 100 -2023/2024**

	Mean	Std.	N
Grade tutor (1-10) Item 23 (?)			
Tutorial Group 1 (Akker, GGH)	**8.8**	1.0	9
Tutorial Group 2 (Blankesteijn, WM)	**9.3**	1.0	7
Tutorial Group 3 (Stassen, RHMJ)	7.9	1.0	8
Productivity tutorialgroup (1-10) Item 22 (?)			
Tutorial Group 1 (Akker, GGH)	**8.4**	1.0	9
Tutorial Group 2 (Blankesteijn, WM)	**8.4**	1.0	7
Tutorial Group 3 (Stassen, RHMJ)	7.4	0.5	8

*: grade unavailable due to low N or high tutor absence

Section 1

RMT1001-PART2The Molecular Basis of Life (Students) **Period: 100 - 2023/2024**

Number of questionnaires returned: *24* out of 24 enrolled (100%)	Mean	Std.	N	Mean 2022
Course-specific questions				
1. Biology and chemistry have been well integrated and placed into the context of Regenerative Medicine	**4.2**	0.6	24	-
2. The "Design Your Own Case" group assignment has been helpful in the learning process	**4.5**	0.7	24	-
3. The problem-solving sessions have been useful in achieving understanding of the relevant chemistry concepts in Regenerative Medicine	3.5	1.4	24	-
4. The in-lecture quizzes have been helpful in the learning process	3.8	1.1	24	-
5. The mock midterm written exam has been helpful in the learning process	**4.2**	0.8	24	-
6. The ChemOffice workshops have been helpful in the learning process	3.1	0.9	24	-
7. Please provide a grade (1-10) for the overall performance of your problem-session instructor	**4.0**	0.8	24	-
Written exam				
9. The preceding educational activities and learning materials adequately prepared me for the test	3.7	0.8	24	-
10. I feel the questions of the test were clearly formulated	3.2	1.1	24	-
11. I am satisfied with the (online) test organisation	**4.4**	0.6	24	-
12. As to the level of difficulty, I feel this test was ...				

Too easy:	0 (0.00 %)
Easy:	1 (4.17 %)
Neither easy/nor difficult:	11 (45.83 %)
Difficult:	12 (50.00 %)
Too difficult:	0 (0.00 %)

Section 2

RMT1001-PART2The Molecular Basis of Life (Students) **Period: 100 - 2023/2024**

Number of questionnaires returned: *24*

Answers to the open-ended questions:

Course-specific questions

8. What feedback do you have for your problem-solving sessions instructor?
(answered by 16 persons)

- I believe that he did an amazing job.
- He has succeeded in making the problem-solving sessions engaging and helpful.
- exercises together in order to have a guide
- Eager to help and answer any questions. I would have liked to have done more exercises together in class.
- More explanation with the whole group together on the bord.
- Good that you let us do most of the talking.
- Some problem solving session werent useful for the course learning process, because they were focusing too much on chemistry argoments that were relevant to the overall subject. Many times it happend that we were doing exercise that we were told later, weren't relevant to the goal.
- Keep acting the same way
- Too little copies of the answer book, too little staff to answer all the questions. Usually people have the same questions, discuss those ones in front of everyone instead of per group.
- In the last lecture there were some questions for us (pages 31-33) that we discussed later on the problem-solving session. It was very helpful to connect biology and chemistry topics doing these tasks.
- I think our tutor should have encouraged the participants that talked less to share their information. I felt like it was always the same people that talked during the tutorials.
- Perhaps to include everyone to talk a little bit more
- Sometimes i like to have a question preperared for the whole class
- I don't really have feedback for the instructor, but the lessons were helpfull when you had problems with the exercises, but the time when it was for me it didn't really help because I was in the weekend mode.
- In addition to just helping with the assingments, adding different explanations about difficult subjects and explaining them to the entire group would be a very nice addition.
- I personally found these sessions very helpful. However, maybe it would have been better to give a feedback about how actually deep to go with the tasks.

Section Conclusions

RMT1001 The Molecular Basis of Life (Students) **Period: 100 - 2023/2024**

Conclusions:

Students overall perceived the course content as either just right or difficult. Although 41.7% of the students perceived the workload as high, students indicated to spend an average of 30.5 hours per week.
The teaching and learning activities were well-aligned with the learning goals of this course. The alignment of the learning objectives of this course and assessment methods used could receive attention however.
Students appreciated the collaboration with fellow students, the link to future practice and the way they could actively engage with the course content. Content-wise students appreciated the link between biology and chemistry but would have welcomed a more thorough explanation during the lectures. More resources on chemistry should also be made available (e.g. answers to questions, clearer PBL cases).
Tutors overall received high grades for their performance (M=8.6), and the productivity in tutorial groups was high. Students also appreciated the problem-solving sessions and their instructor, as well as the practicals. Students described the practical as relevant for developing their laboratory skills.

Section 1

RMT2002 Materials Science in Biological Applicat (Students) **Period: 200 - 2024/2025**

Number of questionnaires returned: *19* out of 20 enrolled (95%)

	Mean	Std.	N	Mean 2023
General				
Please indicate to which extent you agree with the following statements				
1. The learning objectives of this course were clear	**4.1**	0.6	19	-
2. The communication during this course was clear (e.g., about changes, learning resources, planning and coordination)	**4.1**	0.6	18	-
3. There was a clear connection between the different teaching and learning activities within this course	**4.1**	0.7	19	-
4. The teaching and learning activities aligned with the learning objectives of this course	3.9	0.7	19	-
5. The teachers were sufficiently proficient in the use of the English language	**4.9**	0.3	19	-
6. The main language throughout all teaching activities in this course was English	**4.8**	0.4	19	-
7. I expect teaching and learning activities in the course have prepared me well for the final assessment (e.g., test, paper)	**4.2**	0.5	19	-
8. The assessment method(s) (e.g., multiple choice, open-ended questions, assignment and/or presentations) fit(s) the learning objectives of this course	3.9	0.7	19	-
Learning activities				
9. Collaborating with fellow students contributed to the quality of my learning	**4.3**	0.7	19	-
10. The course content linked well to my prior knowledge	**4.2**	0.8	19	-
11. This course encouraged me to actively engage with the course content	**4.3**	0.7	19	-
12. This course connected to future practice	**4.2**	0.8	19	-

Workload

13. The course content was ...

too easy:	0 (0.00 %)
easy:	2 (10.53 %)
just right:	9 (47.37 %)
difficult:	8 (42.11 %)
too difficult:	0 (0.00 %)

14. The workload in this course was ...

too low:	0 (0.00 %)
low:	2 (10.53 %)
just right:	11 (57.89 %)
high:	6 (31.58 %)

too high: 0 (0.00 %)

15. How many hours on average did you spend on your study in total per week, during this course? (total = sum of scheduled teaching and learning activities AND self-study)	29.2	9.4	18	-

Tutor evaluation

The tutor encouraged us ...

18. .... to summarise in our own words what we had learned	**4.2**	0.6	19	-
19. .... to make connections between the different aspects of the course content	**4.5**	0.6	19	-
20. .... to formulate specific learning goals ourselves	**4.5**	0.7	19	-
21. .... to provide constructive feedback during the tutorial meetings	**4.1**	1.0	18	-

22. Please indicate how many times your own tutor was absent

0:	12 (63.16 %)
1:	1 (5.26 %)
2:	5 (26.32 %)
3:	0 (0.00 %)
4:	0 (0.00 %)
5:	0 (0.00 %)
>= 6:	1 (5.26 %)

23. Please provide a grade (1-10) for the productivity of your tutorial group	7.7	1.4	19	-
24. Please provide a grade (1-10) for the overall performance of your tutor	**8.6**	1.4	19	-

Course-specific questions

26. Materials Science has been well integrated and placed into the context of Regenerative Medicine	**4.3**	0.8	19	-
27. The "Design Your Own Biomaterial" group assignment has been helpful in the learning process	3.9	1.1	19	-
28. The problem-solving sessions have been useful in achieving understanding of the relevant chemistry and materials science concepts	**4.6**	0.6	19	-
29. The in-lecture quizzes have been helpful in the learning process	3.4	1.0	19	-
30. The written midterm mock exam has been helpful in the learning process	**4.6**	0.6	19	-
31. The ChemOffice workshops have been useful in the learning process	**2.8**	1.2	19	-
32. Please provide a grade (1-10) for the overall performance of your problem-solving instructor	**9.4**	1.0	19	-

Practicals

34. The practicals are relevant for developing my laboratory skills	**4.3**	0.7	19	-
35. The practicals are well aligned with the course content	**4.2**	0.8	19	-
36. LabBuddy is a useful tool for preparing and executing my practicals	**4.3**	0.7	19	-

Academic development

37. The quality of the feedback received from the assessor helped me to improve my writing skills	3.6	0.8	19	-

38. There were sufficient opportunities to meaningfully interact with my mentor during meetings	3.4	1.3	19	-

Portfolio

39. The instructions for using the portfolio were clear	**2.4**	1.3	19	-
40. Using the portfolio was easy	**1.9**	1.2	19	-
41. Using the portfolio helped me to keep track of my learning experiences over time	1.5	0.7	19	-
42. Using the portfolio stimulated my reflection process	**2.4**	1.3	19	-

Section 2

RMT2002 Materials Science in Biological Applicat (Students) **Period: 200 - 2024/2025**

Number of questionnaires returned: *19*

Answers to the open-ended questions:

Open-ended questions

16. What did you appreciate most about this course?
(answered by 18 persons)

- Nice teaching
- Our tutor was willing to help and explain subjects we don't understand.
- Our tutor was very helpful and prepared us very well for the final exam.
  The problem solving sessions were in particular very useful.
- The problem solving sessions. They were very well and nicely organized.
- I appreciate the tutors and the engagement they had with us students.
- The problem solving sessions were really helpfull and nice! As well as our tutor/professor, who helped us a lot!
- Clear teaching of problem solving session.
- The way the teachers taught the content. Especially the problem solving course and midterm was very useful and explained very well.
- The guidance during the group assignment
- The teacher were super helpful for bettere understanding of the problem solving sessions.
- The problem solving were nice because you obtained gentle feedback which was useful. Also the guest lecture was also interesting.
- The group proiect wws nice to incorporate the material you learned.
- The tutor was very nice and helpful. He made me want to work more and learn more for the course without being pushed to the extent I felt last year's chemistry block.
- The lecturer's explanations and organization of this course. The Problem solving sessions were magnificent
- The problem solving session, connections between the topics discussed in different education activities, the organized non graded midterm, openness of Professors to help and answer any questions, excellent explanations during the lecture.
- the content aligned well with previous knowledge
- I liked how I got better knowledge and understanding in chemestry.
- I appreciated the problem solving sessions, well structured and exercises relevant.

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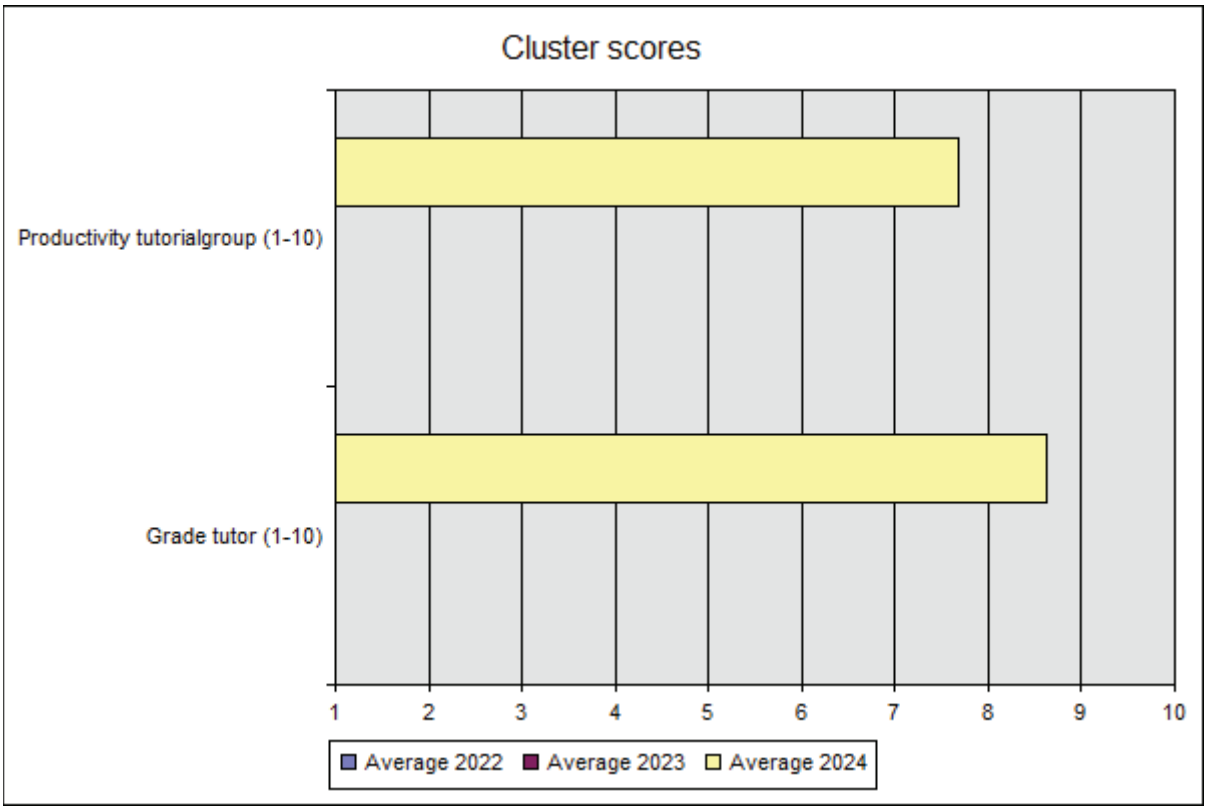
17. Which suggestions for improvement do you have for this course?
(answered by 18 persons)

- More linking of activities
- Lectures that are less repetitive.
- To align the problem solving sessions/lectures and tutorials more!
  There was a lot of repetition in some lectures, which could be improved next time!
- The connection between lectures and pbl.
- Maybe to try to make the topics in the lectures less repetitive.
- The lectures could align more with the other classes
- Better lectures, too repetitive or not relevant for course.

- Perhaps making the slides a little less long, lots of the presentations were very long and makes it more difficult to understand.
- Different lectures often covered the same information. So things were explained double
- The courses and the exercises weren't in line, the lectures were really theory based, which is not what they want in the exam.
- More guidance during the group assignment. Sometimes it was very difficult to come up with a feasible idea. The lectures also contained often duplicate information, this was annoying.
- Some lectures were repetitive. With previous lecture.
- Maybe some more excersises to practice some more but nothing too important to tell
- Check to see wether lectures are repetitive as many presentations contained the exact same slides
- Maybe try to avoid repetition of topics covered between the lectures (I think it was 1st and 3rd lectures that overlapped a lot). And maybe that would be beneficial to dive into more organic chemistry topics and discuss the rheology in lectures and/or tutorials.
  The lecture quiz in lecture 4 was helpful, so it would be nice to introduce such quizzes to other lectures as well, or just upload them on canvas like it was done in period 2 last year.
- the content of the lectures overlapped a few times, which is a bit annoying also when you want to stay focused
- during the project proposal, there was a higher expectation of the biology in the project than I anticipated. because this course was mainly focused on biomaterials did I not assume this. maybe this can be addressed more clearly for next time
- more alignment between lectures and problem solving sessions

Section 3

RMT2002 Materials Science in Biological Applicat (Students) **Period: 200 - 2024/2025**



Section 4

RMT2002 Materials Science in Biological Applicat (Students) **Period: 200 - 2024/2025**

	Mean	Std.	N
Grade tutor (1-10)			
Item 24 (?)			
Tutorial Group 1 (Hazell, GDA)	**9.3**	0.9	10
Tutorial Group 2 (Bauer, J)	7.9	1.5	9
Productivity tutorialgroup (1-10)			
Item 23 (?)			
Tutorial Group 1 (Hazell, GDA)	**8.0**	1.3	10
Tutorial Group 2 (Bauer, J)	7.3	1.5	9

*: grade unavailable due to low N or high tutor absence

Section Conclusions

RMT2002 Materials Science in Biological Applicat (Students) **Period: 200 - 2024/2025**

Conclusions:

This course is well evaluated in terms of communication and alignment between learning activities, the objectives, and the assessment of the course. Although students indicated that there was a clear connection between the topics discussed, they mentioned that the connection between the lectures and the sessions were not always clear to them. The constructivist learning principles seem well represented in this course. Students indicated that the course content aligned well with their previous knowledge. Students appreciated the problem-solving sessions and the feedback and guidance they received from their tutor.