# Degree program documentation

**Master’s Program Chemical Biotechnology**
TUM Campus Straubing for Biotechnology and Sustainability,
Technical University Munich

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<td>Additional information</td>
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1 Degree Program Objectives

1.1 Purpose

One of the key technologies to make industrial processes more cost-effective and ecological and to develop renewable raw materials for industrial use is industrial biotechnology, more appropriately called chemical biotechnology. It uses biochemical, chemical, micro- and molecular biological as well as process engineering methods to produce organic basic and fine chemicals with the help of optimized enzymes, cells or microorganisms. By replacing conventional industrial production methods with biotechnological processes, both energy requirements and raw material use can be minimized and the number of process stages reduced. In addition to lowering production costs, ecological advantages can be created by substituting processes based on fossil raw materials.

In order to enable the transformation process away from fossil raw materials and energy-intensive chemical processes and products, which are often not compatible with a closed-loop economy, towards conversion processes that comply with the principles of sustainable chemistry, modern combined methods from chemical and biotechnological processes are considered key technologies. Graduates of the chemical biotechnology course take on an important pioneering bridging function for concepts of bioeconomy and for the raw materials turnaround. As game changers, they are at home in the worlds of biology, chemistry and process engineering, which gives them a unique new perspective on existing processes and necessary procedures that need to be solved by sustainable approaches in various research fields. The graduates should be absolute specialists in the combination of these disciplines: The training should provide a deep understanding of chemistry and biotechnological processes and enable the identification of prospective process alternatives, their further development and their classification in terms of feasibility and optimization capability. Chemical biotechnologists can be employed at all points along the value-added chains of sustainable chemistry with its cyclical material flows, from raw material production or procurement, through processing, conversion and purification, to product development and end-of-life technologies (e.g. consideration of the degradability of products).
1.2 Strategic Significance

As an Integrative Research Center of the Technical University of Munich, the TUM Campus Straubing stands for biotechnology and sustainability for interdisciplinary research and teaching for the realization of a sustainable change in raw materials and energy in all areas of life. The overexploitation and heavy exploitation of fossil and natural resources, the associated release of climate-damaging gases with the consequences of global warming, the shortage of key raw materials and increasing amounts of waste are decisive arguments for a comprehensive change towards the sustainable use of biogenic raw materials. The use of renewable raw materials in chemical, mechanical and energy recovery makes a comprehensive and diverse contribution to the sustainable provision of raw materials and energy.

Central research and teaching areas are bioeconomy, recycling management, the establishment of new and innovative high-performance technologies for the material and energetic use of biogenic and other regenerative raw materials as well as their economic and business evaluation. In addition, we support innovations in the bio-economy by developing business models as well as novel products and technologies and bringing them to market maturity with the central goal of a sustainable economy.

In order for the raw material and energy change to succeed in a future-oriented and sustainable manner, both technical experts and multidisciplinary (broadly) trained specialists and managers are needed. The subject-specific courses of study serve to train specialised top managers, while the broad-based training with individually set priorities takes into account the demand for interdisciplinarity in the complex subject areas of biologisation and bioeconomy.

In line with this model, the following courses of study are currently offered:

- B.Sc. Bioeconomy
- B.Sc. Chemical biotechnology
- B.Sc. Renewable raw materials
- B.Sc. TUM-BWL with focus on renewable resources
- M.Sc. Renewable raw materials
- M.Sc. biomass technology

Further bachelor's and master's degree courses in the field of material sciences and energy technology of renewable resources as well as a master's degree course in the field of bioeconomy are being planned.

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The future even stronger interdisciplinary and international research and cooperation on renewable raw materials between the different faculties is a unique characteristic of the TUM Campus Straubing. In the field of biotechnology, this makes it possible to learn all the steps involved in establishing a biotechnological process, such as the digestion and conversion of the biomass, but also the formulation and market launch of the bio-based product as well as cost monitoring and optimization of the biotechnological process, all in one place.

Sustainability and the use of renewable resources are driving factors for the development of chemical biotechnology. The existing bachelor's degree course in chemical biotechnology covers the theoretical and practical learning of all the basic principles required in biotechnology. The planned consecutive Master's degree course in Chemical Biotechnology will now further expand and deepen the knowledge acquired in the material use of renewable resources.

In addition to the existing scientific and teaching facilities at the TUM Campus Straubing for biotechnology and sustainability, there is also physical proximity to a beneficial industrial environment, on the one hand through BioCampus Straubing GmbH with its associated Entreprenuerial Centre for Renewable Raw Materials (BioCubator) and the multipurpose demonstration plant to be built, but also with Clariant and Wacker Chemie AG in Burghausen as the largest chemical site in Bavaria ("Bavarian Chemical Triangle").

At the same time, Straubing is situated in the middle of the intensively farmed Gäubodens and close to the Bavarian Forest, making it the centre of a region of renewable raw materials. This means that the competencies for the material use of renewable raw materials are acquired where the (re)utilization of biomass is possible on a large scale.

In addition, the planned course of study will not only result in excellent networking with the existing courses in Straubing, but also with the biotechnology sector in Garching and Freising, as the course of study is designed in such a way that, depending on the desired orientation of the Master’s degree, it is possible to take or spend up to one semester in Garching (industrial biotechnology) or in Freising (molecular biotechnology/pharmaceutical bioprocess technology). In addition, an inter-location exchange or cooperation is possible via a jointly offered seminar, which includes current biotechnological research topics from all three locations.

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2 Qualification Profile

The qualification profile meets the requirements of the Qualifications Framework for German Higher Education Qualifications (Hochschulqualifikationsrahmens-HQR) in accordance with the resolution of 16 February 2017 of the German Rectors' Conference and the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany. According to the HQF, the qualification profile for the Master's program "Chemical Biotechnology" can be defined on the basis of the requirements (i) Knowledge and Understanding, (ii) Use, Application and Generation of Knowledge and (iii) Communication and Cooperation and (iv) Scientific Self-conception/Professionalism. The formal aspects according to HQF (admission requirements, duration, degree options) are described in Chapters 3 and 6 and in the corresponding subject examination and study regulations.

To (i) Knowledge and understanding:

Graduates of the planned Master's program "Chemical Biotechnology" have a basic knowledge and understanding of the field of chemical biotechnology. Along the entire process development chain, they will be able, for example, to apply biotechnological methods, test or modify isolated enzymes and entire microorganisms, participate in the development of biocatalysts and plan biotechnological apparatus and plants.

However, in addition, the students have significantly deepened and broadened their basic knowledge in the field of chemical biotechnology compared to their knowledge at the bachelor's level. In addition to the methodological skills and specialist knowledge in biology, chemistry and process engineering, they can thus become acquainted with the field of electrobiotechnology and also acquire knowledge in the field of material sciences. The current approaches dealt with in the modules can be directly methodically applied with the help of current specialist literature. For example, students are able to further optimise existing fermentation processes on the basis of current literature data.

In addition, the students have acquired a holistic problem-solving competence in order to be able, for example, to successfully work on synthesis problems under balanced consideration of technical, economic, ecological, social and ethical boundary conditions.

On (ii) The use, application and generation of knowledge:

Graduates of the planned Master's programme in "Chemical Biotechnology" will know selected fields of technology by way of example and will be able to combine their engineering and scientific fundamentals with applications related to their professional field. For example, their interdisciplinary knowledge in the field of chemical biotechnology enables them to initiate TUM Campus Straubing for Biotechnology and Sustainability

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research projects, to plan independently and, depending on their area of responsibility, to
develop new biobased products/active substances or new processes for the manufacture of
these biobased products or new processes for the recycling of waste products. At the same
time, they are able to apply their technical and methodological knowledge to new tasks. For
example, they are prepared to transfer processes developed in the laboratory to industrial
scale. Furthermore, they are able to identify problems independently and to develop suitable
ways to work on the corresponding research ideas by selecting the appropriate research
methods.

To (iii) Communication and cooperation:

Graduates of the planned Master's programme in "Chemical Biotechnology" will be able to
work successfully in a research group and, on the one hand, critically question their research
results and, on the other hand, communicate in such a way that both experts and non-
specialists are able to follow them. Students will be able to deal with the different perspectives
and interests on the topic of sustainability at an early stage and how these are to be taken into
account in the biotechnological development of products.

On (iv) Scientific self-image/professionalism:

Graduates of the planned Master's program "Chemical Biotechnology" have acquired
exemplary non-technical qualifications and are thus sensitized to the non-technical
requirements of a professional activity. Furthermore, they are equipped for the absolutely
necessary ability to socialize in a company environment through sufficient practical training
during their studies. All in all, the interdisciplinary training makes them very well equipped for
lifelong learning and for employment in various occupational fields.

3 Target Groups

3.1 Target Audience

The Master's program Chemical Biotechnology is aimed at university graduates from domestic
or foreign scientific universities with a Bachelor of Science or equivalent degree in
biotechnology, biochemistry, bioprocess engineering and chemical process engineering or
comparable courses of study. Students should have a broad and integrated knowledge and
understanding of two of the three fields of biology, chemistry and engineering.
3.2 Prerequisites

Specifically, applicants should have the following knowledge in the respective areas mentioned:

Mathematics and statistics: Applicants should have mastered the most important mathematical methods required for calculations and modelling in the natural sciences. This includes the confident application of differential and integral calculus as well as knowledge of linear algebra. In addition, candidates should know the most important probability distributions and statistical tests and be able to apply them independently.

Physics: Candidates should know the basic concepts of mechanics (statics, dynamics), thermodynamics (theorems, equations of state), electricity (direct current) and optics and understand them to the extent that they can apply them to simple physical problems in a solution-oriented manner.

Computer Science & Bioinformatics: candidates should know the general structure of computer systems and have a basic understanding of different number systems and their arithmetic. They should have a sound knowledge of basic programming and be familiar with the most important elements of programming such as variables, control structures, loops and functions. In bioinformatics, they should be familiar with the main biological databases (e.g. EBI, NCBI). In addition, a basic theoretical understanding of alignment procedures (e.g. Needleman-Wish, Smith-Waterman and BLAST) and phylogenetic analyses should be available, as well as the ability to apply these independently.

In the field of chemistry, applicants should understand the basic principles of chemical reactions and be able to formulate appropriate reaction equations and perform simple reaction-kinetic and thermodynamic analyses. They should also understand the structures and states of aggregation of chemical compounds and be familiar with practical work in chemical laboratories. In addition, they should understand the basic principles of catalysis and be able to apply physico-chemical analysis methods as required.

In the field of biology, applicants should have a basic knowledge of the structure and function of biomolecules, the components of cells and the flow of genetic information. They should be able to differentiate groups of microorganisms and know important metabolic pathways. They should be able to understand and successfully apply the most important molecular genetic methods. They should have theoretical knowledge of the purification of expressed proteins and the analysis of the kinetic parameters of enzymes. Furthermore, you should have
successfully planned, performed and evaluated biological laboratory experiments independently.

In the field of process engineering, the applicants should know the basic phenomena and modelling approaches of chemical thermodynamics and mixed-phase thermodynamics. They should be able to describe the function of the most important apparatuses of thermal process engineering, bioprocess engineering and reaction engineering as well as to balance them in terms of mass and energy.

Applicants should have acquired the ability to work independently on smaller scientific projects not only by writing a Bachelor's thesis, but ideally also by completing a research internship of about 300 hours.

Due to the fact that the programme is also aimed at international students and therefore all compulsory modules as well as some optional modules of the programme are only offered in English, good English language skills are required.

### 3.3 Target Numbers

The master's degree course in Chemical Biotechnology is planned so that the course can be taken up in both the winter and summer semesters. We assume that the Master's program will start with about 20 first-year students and grow by about 10% each year, so that after 5 years there will be about 30 first-year students and after 10 years 50 first-year students. This means about 100 students when fully enrolled and 4 semesters standard period of study.

At the moment, additional laboratories are being created in addition to the existing training laboratories, so that sufficient jobs will be available for the internship modules.

The teaching capacity for the targeted number of students is guaranteed by the (targeted) new appointments and the available resources at the participating chairs of the TUMCS. The administration of the course of studies also takes place at the TUMCS. Appropriate resources are also available here.

### 4 Analysis of Need

Upon successful completion of the Master's degree in Chemical Biotechnology, graduates are qualified to pursue a doctorate in a biotechnological research field. The goal-oriented structure of the course, the English-language training, and the high reputation of the TUM will have a

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positive effect on the acquisition of doctoral positions and coveted doctoral scholarships. It is expected that about half of the graduates will follow this career path.

Graduates are also offered a path into the biotechnologically working industry. The biotechnology sector is growing steadily, both in terms of total turnover, the number of companies and the number of employees. According to biotechnologie.de, an initiative of the German Federal Ministry of Education and Research (BMBF), the annual expenditure for research and development alone amounts to more than 1 billion euros. The strongest growth rates were recently seen in the field of industrial biotechnology (6.3% p.a.). For 2017, a total of 21,860 jobs were counted among dedicated biotech companies, which corresponds to a growth rate of 7.8%. In addition, a further 23,800 employees (+8.2%) are employed by other biotechnologically active companies in the chemical and pharmaceutical industry, so that the German biotech sector can boast a total of 45,660 jobs. At the same time, biotechnology companies are thus encountering increasing problems in recruiting technicians or scientists.

The declared political consensus to support a progressive structural change towards a bio-based economy suggests further growth in this sector and thus a shortage of skilled workers. In an international comparison, Germany is to become a dynamic research and innovation location for bio-based products, energies, processes and services (National Research Strategy Bioeconomy 2030). Biotechnology, which is essentially based on bio-based raw materials, is also seen as a key enabling technology in the European context and there are numerous initiatives in this area (e.g. Bio-based Industries Joint Undertaking). In this respect, chemical biotechnology represents a key technology for replacing conventional processes driven by fossil resources with efficient and sustainable processes.

Scientists with sound chemical and molecular biological knowledge, as well as practical experience in materials science and process engineering, are needed both for recruitment in the biotechnology sector and for achieving the research and innovation goals. Graduates of the Chemical Biotechnology Master's programme will be able to strategically develop the entire chain of chemical-biotechnological production based on molecular processes and to optimize it in practice. We therefore see very good opportunities for them on the job market. Due to the globally networked way of working, English as the language of instruction will also have a positive effect on the graduates' chances.

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5 Competition Analysis

5.1 External Competition Analysis

Universities in Germany offer a total of approximately 20 to 25 master's courses in biotechnology. The majority of these courses of study are dedicated to biotechnology in its broadest sense or focus on molecular biotechnology. A master's degree course of the same name in chemical biotechnology or chemical biotechnology is currently only offered in the German-speaking world at the TU Ilmenau (Chemical Biotechnology, Biotechnical Chemistry). Here there are significant differences to our concept. On the one hand, it is a German-language course of studies. On the other hand, the education is rather broad. In Ilmenau, for example, there is an increased emphasis on the basics in physics, chemistry, biology and various technical subjects, and there are also courses on legal issues, for example. The planned TUM Master's course in Chemical Biotechnology, which is aimed at graduates of bachelor's courses who have already been trained in two of the three fields of biology, chemistry and engineering sciences, will above all provide a subject-specific qualification.

Master's courses with elements from micro- and molecular biology, chemistry and process engineering are offered at a number of universities. In each case, however, one of these core areas is treated only marginally. Often these are courses of study in the field of biotechnology, with a focus or possibility of specialisation in the direction of process engineering. Examples are Saarland University (Master's degree in Biotechnology) or TU Berlin (Master's degree in Biotechnology, specialisation in Industrial Biotechnology). The course of studies in biotechnology and chemical process engineering at the University of Bayreuth offers the possibility of specializing in "Bioinspired Materials", "Bioprocess Engineering" or "Chemical Process Engineering". At the RWTH in Aachen, the course of studies Molecular and Applied Biotechnology is offered with compulsory modules from the fields of industrial biotechnology, molecular biology and bioanalytics as well as protein and process design. Topics such as organic chemistry and electrochemistry are only marginally dealt with.

In addition, chemical biotechnology is offered in master's degree courses with a focus on chemical process engineering or pharmaceutical technology. Examples are the study course Chemical and Biotechnology (M.Eng.) at the University of Applied Sciences Darmstadt or Biotechnology/Biopharmaceutical Technology at the Technical University of Central Hessen. In this area, however, there are mainly universities without their own doctoral rights.

A similar picture is also emerging at the international level. For example, Brock University (Canada) offers a Master of Science in Biotechnology with a focus on Chemical Biotechnology. The Warsaw University of Technology (Poland) offers an M.Sc. in Applied Biotechnology, TUM Campus Straubing for Biotechnology and Sustainability
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which is located at the Faculty of Chemistry. Within the master's programs in biotechnology, these concepts are rather an exception.

In summary, the in-depth, specialized course of study in Chemical Biotechnology is largely a unique selling point of the Chemical Biotechnology Master's program.

5.2 Internal Competition Analysis

At the TU Munich, there are already Master's programs in the field of biotechnology: Molecular Biotechnology, Pharmaceutical Bioprocess Engineering, Industrial Biotechnology and Food Technology and Biotechnology. The latter course of studies clearly distinguishes itself from chemical biotechnology and the other three courses of studies by its focus on food and is therefore not discussed further here.

The predominantly German-language Molecular Biotechnology course at the Weihenstephan Science Center for Nutrition, Land Use and Environment (WZW) is, as already implied by the name of the course, strongly characterized by molecular biological topics and methods. The various biological systems are dealt with in their full breadth, with a focus on "red" biotechnology (see, for example, the basic modules Molecular Immunology, Molecular Oncology and Animal Biotechnology). Accordingly, graduates of molecular biotechnology are in great demand directly or following a doctorate, especially from the pharmaceutical industry. In contrast, the organismic orientation of the planned Chemical Biotechnology course focuses on microorganisms, whereas animal/human systems play hardly any role. Bioprocess engineering, on the other hand, which is a main focus of the Chemical Biotechnology course, is only of minor importance in the Molecular Biotechnology course.

The German-language Master's program in Pharmaceutical Bioprocess Engineering, also located at the WZW, is also geared towards the pharmaceutical industry, but especially towards pharmaceutical applications and processes. In addition to scientific fundamentals, for example on the structure and function of proteins, aspects of bioprocess technology play an important role. Furthermore, elements of business administration are taught, for example.

Catalysis and metabolic engineering are not the focus of either course at the WZW, which clearly distinguishes it from the master's course in chemical biotechnology.

The Master's program in Industrial Biotechnology focuses on enzyme technology, metabolic engineering, bioprocess technology and the processing of bioproducts. There is a clear overlap with the Chemical Biotechnology course, but the students are also equally qualified in the fields of chemical catalysis, biobased chemical synthesis and electrochemistry. A major difference between the two courses of study is the target group of applicants and the structure.

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of the course. A considerable part of the Master's programme in Industrial Biotechnology is dedicated to bioscientific and process engineering fundamentals, which also enables bachelor students of engineering courses without previous biological knowledge to successfully complete the programme. In contrast, the Chemical Biotechnology course is particularly aimed at applicants with previous knowledge of biotechnology or bioprocess engineering. This means that a more in-depth subject-specific course of study can be taken from the 1st semester onwards.

Because of their unifying elements, an increased exchange between biotechnology-oriented courses of study is intended (see 6.2.). One of the central elements for this will be a regular joint seminar, which is a compulsory module for students of chemical biotechnology. In addition, numerous modules of the other two courses will be recognized as optional modules and the obligatory extensive research internship can be completed at one of the other locations.

6 Program Structure

Students are admitted to the full-time Master's program in Chemical Biotechnology in the winter and summer semester and are awarded 120 ECTS credits (including the Master's thesis). In total, the Master's program comprises 4 semesters (standard period of study) and the program is run across locations in Straubing, Freising and Garching (see 6.2).

Each compulsory module has a minimum of 5 ECTS, the deposited module plan gives an overview of the module structure of the Master's program Chemical Biotechnology, under 6.2 a possible study plan as well as the corresponding timetable are shown.

6.1 Module and teaching concept

The career profile of university graduates in the field of chemical biotechnology is characterised by a high degree of interdisciplinarity and requires highly qualified expertise at the intersection of biology, chemistry, process engineering and computer science in order to develop chemical processes based on and using biological principles and transfer them to industrial scale (Figure 1). Systemic considerations of process development as well as the increasing influence of the bio-economy in chemical biotechnology extend the requirement profile. These requirements define the core competencies to be acquired by students in the fields of Applied Microbiology and Metabolic Engineering, Enzymatic Biotransformations, Conceptual Design of Bioprocesses and Artificial Intelligence for Biotechnology (Figure 1).

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Figure 1: Fields of work along process development in chemical biotechnology with the respective shares of micro- and molecular biology, chemistry and process engineering. The compulsory modules and their content representation are given below.

The compulsory module Applied Microbiology and Metabolic Engineering (1st semester) deepens the students’ knowledge in the field of micro- and molecular biology. They learn how the enormous genetic resources from bacteria, fungi or plants that are available for biotechnological applications are efficiently made accessible and are able to optimise the metabolism of the corresponding production systems.

In the compulsory module Enzymatic Biotransformation (1st semester), students expand their knowledge in the field of biocatalysis, which is the basis for innovative and sustainable synthesis methods in chemistry, and can make reactions with enzymatic sub-steps more sustainable.

In process engineering, the compulsory module Conceptual Design of Bioprocesses (1st semester) is central. Building on the skills acquired in the bachelor’s programme on basic
process engineering operations (fermenters, chemical reactors, material separation, downstreaming), students learn to scale biotechnological processes developed in the laboratory to the technical scale and to equip them with a precisely fitting processing system. By bringing together different disciplines from adsorption to zeolite membranes and combining them with biological challenges, a significant increase in knowledge is achieved compared to the bachelor’s degree.

In addition to the expansion of competencies in the three subject areas of chemistry, micro- and molecular biology and process engineering, the structure and content of the course of study should also enable specialisation in innovative areas of chemical biotechnology. The compulsory module Artificial Intelligence for Biotechnology (1st semester) will take into account the increasingly new and important application possibilities of artificial intelligence, in particular machine learning, in biotechnology in order to analyse the ever larger and more complex biotechnological data using modern in silico methods. Since the existing biotechnology master’s courses at TUM described in 5.2. each have very different focuses and specialisations, the jointly offered summer school Advanced scientific planning based on current research topics at TUM (2nd semester) aims to achieve the greatest possible variety of specialisation possibilities (see 6.2.).

A further important aspect in setting up the Master’s programme is the close link between the theoretical knowledge acquired and its implementation in practice. Some of the compulsory and optional modules are directly related to laboratory practice through an internship (Applied Microbiology and Metabolic Engineering/ Enzyme Engineering/ Methods of Synthetic Biology/ Phytopharmaceuticals and natural products). In addition, students are required to complete a comprehensive research internship (15 ECTS/ 450 hours) over one or more semesters, which gives them a detailed insight into scientific practice even before writing their Master’s thesis.

Thus, in addition to the above-mentioned points (knowledge expansion in the fields of chemistry, micro- and molecular biology and process engineering/ specialization possibilities/ acquisition of laboratory practice), there are six compulsory modules of 40 ECTS in the Master’s program Chemical Biotechnology.

In addition, there is an in-depth range of elective modules from the three core subjects, from the further specialisation areas of electrobiotechnology and material sciences, and from the cross-disciplinary fundamentals (advanced topics in analytics and bioinformatics). The module sizes of the elective modules range from 3 to 5 ECTS. The modules below 5 ECTS are each special topics that relate to only one aspect of a field of knowledge. They are offered in this

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way in order to enable students to take many different elective modules and thus to achieve the greatest possible breadth and variety in the elective module area.

Specifically, the area of micro- and molecular biology is supplemented by the elective modules Enzyme Engineering, Genetic Engineering and Synthetic Biology, Methods of Synthetic Biology, Regulation of Microbial Metabolism and Plant Biotechnology.

In-depth knowledge in the field of chemistry is provided by the elective modules Chemistry of Enzymes, Glycomics, Phytopharmaceuticals and natural products, Surface Chemistry and Sustainable Chemistry.

In the field of process engineering, the knowledge acquired in the compulsory module is deepened by the elective modules Advanced Downstream Processing, Electrolyte thermodynamics, Gas-based bioprocesses and Mechanical process engineering.

In the specialisation areas of electrobiotechnology and materials science, the elective modules Electrobiotechnology, Biological materials in nature and technology as well as Materials science of renewable resources and support for basic working methods in science are offered in the elective modules Advanced Analytics for Biotechnology and Advanced Concepts of Bioinformatics.

The general education subject modules are also optional modules and supplement the timetable with soft skills; here, credits to the extent of 6 ECTS can be earned.

In the 4th semester, the Master's thesis is normally written, which includes the Master's Colloquium (30 ECTS). One sixth of the grade of the colloquium is taken into account in the evaluation of the Master's thesis. With the actual written elaboration of the Master's Thesis, which is usually based on the detailed practical work on an experimental problem, the students demonstrate that they are able to work independently and scientifically, to evaluate and document their results and to present them to an expert audience.

The planned Master's programme is specifically aimed at graduates of biotechnological and chemical/process engineering Bachelor's programmes. For this reason, the programme does not include any specific adaptation modules. Knowledge that has already been taught in the bachelor's degree course in chemical biotechnology will only be part of the course content in the form of short, summarising repetitions. This will create sufficient space for a deeper understanding of the core subjects and for learning new approaches.
6.2 Studyability and mobility within the TUM

Students should have the opportunity to complete the course within the standard period of study. The compulsory courses are therefore organized in such a way that there is no overlap in time. Attendance time is also distributed throughout the week in such a way that there is sufficient room for self-study. This is also illustrated by the following sample degree chart (Table 1), which contains only elective modules with 5 credits and an associated timetable with a specialisation in electrobiotechnology and materials science:

Table 1: Sample degree chart for the four-semester master’s program Chemical Biotechnology.

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Since all compulsory modules of the course and a sufficient number of elective modules are offered at the Straubing location, studyability in the sense that relocation is not absolutely necessary. However, students are encouraged by the following elements in the structure of the Master’s programme to get to know other locations and to spend, for example, one semester of the Master's programme in Freising or Garching:

On the one hand, the compulsory module Advanced scientific planning based on current research topics at TUM is planned as a seminar event in closed session, for example at the Akademiezentrum Raitenhaslach, in which the students should take part in the first year of study.

The course will also be open to students of the master's courses in molecular biotechnology and industrial biotechnology. Lecturers with a biotechnological research focus from all TUM locations are invited to participate and present their research topics. Thus, students will get in touch with diverse approaches in biotechnology at an early stage and can establish contacts.

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beyond the borders of the TUM Campus Straubing. The students will then be asked to develop a concept for a research project within the framework of the research internship. The students will then discuss with the corresponding professors and heads of research groups whether the concept is viable and can lead to a research internship. What has been learned on a smaller scale in preparation for the research internship should then take place in the 3rd semester in the same form for an optimal start to the Master’s thesis. The result of this second project planning will then be presented and discussed in the Master's Colloquium.

In addition, it is possible for students in the Master Chemical Biotechnology programme to take compulsory modules such as Advanced Downstream Processing or Enzyme Engineering at the Freising or Garching sites. At the same time, elective modules, in particular of the Master's courses Molecular Biotechnology and Industrial Biotechnology, are also recognized for the Master's degree in Chemical Biotechnology. Finally, the research internship can also be carried out in biotechnologically working groups at other locations that have already participated in the Advanced scientific planning module (see above). The three points mentioned above are intended to give students who wish to do so the opportunity to even study a complete semester at another TUM location. It would be desirable for the TUMCS to take on a pioneering role with this concept, which would be emulated by the existing TUM biotechnology courses in the Master's area.

6.3 Audit concept

The examination concept is adapted to the teaching methods and learning outcomes used, which is why written examinations (written exams) are mainly used to test subject-specific competences. In the written exams, students are asked to prove, by means of questions, that they have mastered the theoretical basics and that they know the relevant technical terms, designations and contents. In addition, it is checked whether the students are able to understand contexts and apply their knowledge.

In addition to written exams, laboratory performance and reports are also required as examination papers. In this way, the students document that they are able to prepare, conduct, document, evaluate and discuss their results accordingly.

Exceptions to this rule are seminars, in which a lecture by the students is usually evaluated in terms of professional competence, but also in terms of didactic structure and a convincing presentation, as well as individual elective modules (especially from the area of general education subject modules), which conclude with an oral examination to demonstrate communicative skills.

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6.4 Mobility beyond the TUM

The language of instruction and examination in all compulsory modules is English. The language of instruction and examination in the elective modules is also predominantly English, so that the course of study can be completed entirely in English. The aim is to internationalise the programme, both in terms of the applicants and the subsequent doctoral and employment opportunities.

There are no obligatory stays/internships abroad. However, the study structure offers the possibility for an industrial internship in the 2nd or 3rd semester, which can be recognised for the compulsory module "Research Internship", or for a stay abroad. For example, there are contacts to BOKU in Vienna and outside Europe within the Global Bioeconomy Alliance to partner universities in Australia and Brazil. Due to the flexible scheduling of different elective modules and the research internship, the standard period of study can be adhered to in both cases, while making optimal use of the semesters. For example, a semester can be spent at the University of Queensland (UQ) in Brisbane (Australia) in the "Master of Biotechnology" programme. Due to the good time overlap with the TUM summer semester, the second semester or, if the course of study starts in the summer semester, the third semester is the most suitable. By completing a research internship (Research Project - BIOT7010 = 15 credits) as well as three elective modules (e.g. Quality Management Systems in Biotechnology - BIOT7031 -, Research & Development Proposal - BIOL7005 - and Principles of Entrepreneurship - TIMS7301-, sum = 15 credits) (all described modules are offered at the UQ during the TUM summer semester), it is possible to continue your studies without loss of time until the TUM winter semester.
7 Organization and Coordination

7.1 Organizational connection

The Master’s program Chemical Biotechnology is part of the TUM Campus Straubing for Biotechnology and Sustainability.

Prof. Dr. Volker Sieber, Chair of Chemistry of Biogenic Raw Materials at the TUMCS, has been commissioned with the coordination.

7.2 Responsibilities

The responsibilities are defined as follows:

Course-specific consulting/ management: Dr. Margit Klier-Richter
Dr. Alexander Höldrich

Study planning, integration of stays abroad, Tel: 09421-187-148/ 153
individual career planning, general questions,
Schulgasse 22
Study regulations, advice in examination boards 94315 Straubing
Affairs, aptitude assessment procedures,
margit.klier-richter@tum.de
QM, evaluation alexander.hoeldrich@tum.de

Examination Office TUMCS
Mrs Melanie Weber
Tel: 08161-71-3721

Examination matters, examination reports, Alte Akademie 1
Performance records, final documents, 85354 Freising
Certificates Weberme@zv.tum.de

Departmental Examination Office / Study Office Study Coordination TUMCS
Student Service Campus Straubing (SSCS) Room 01.023
Booking of exams/ master theses/ Schulgasse 22
Recognitions, Progress Review 94315 Straubing

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Chemical Biotechnology

Permits (subject and supervisor of the master thesis, acknowledgements, subject and module lists)

Chair:
Prof. Dr. Cordt Zollfrank
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Secretary:
Olivia Chia-Leeson

Foreign representative

Dr. Marina Zapilko
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Information for exchange students, Help with social issues, such as visa or to open an account in Germany

Public Relations Jan Winter

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