



BIOART (Innovative Multidisciplinary Curriculum in Artificial Implants for Bio- Engineering BSc/MSc Degrees)

WP1. National report (Belgium, France)

1. Trends in biomedical engineering industry and education in Belgium.

1.1 Introduction:

The Belgian healthcare system is facing major challenges.

- There is the aging population and a growing number of chronically ill people, both significantly increasing the need for care.
- Many elder people want to stay in their home as long as possible, thus requiring more help (in people and technology) to stay independent and self-supporting.
- There are ever higher quality requirements, a growing shortage of healthcare professionals and increasingly critical and vocal healthcare consumers.
- There is the rising cost of healthcare (technology costs, pharmaceutical costs, growing quantity of participants in the system).

Thanks to advances in medical technology and digitization efficient solutions are made available to address these challenges.

This translates in new technological solutions and innovations and a boom of health-technologies over the last past years: medical implants and aids, medical tools, hearing devices, diagnostics devices and apps, pharmaceuticals...

As elder people want to stay at home longer before going to an elderly home, a number of solutions for providing comfort for them is another area of technology: surveillance, stair elevators, keeping-company solutions....

To provide all these necessary devices, more effort needs to go in this specific branch of engineering.

Buzz words and trends in the Benelux health-tech ecosystem are: medical devices, hospital networks (size up the players), in vitro diagnostics (IVD) and personalized medicine, eHealth, digitization of healthcare, Artificial intelligence in diagnostics and care.

This list clearly shows what the fields of interest for an educational curriculum leading to a specialist in



biomedical engineering.

Biomedical engineering is the multidisciplinary field concerning engineering research, developments and applications in (bio)medicine. It advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate engineering sciences with the biomedical sciences and clinical practice. Some of the well-established specialty areas within the field of biomedical engineering are: bioinstrumentation, biomechanics, biomaterials, bio-informatics, system physiology, clinical engineering, ergonomics and rehabilitation engineering.

Biomedical engineering is a young field of engineering, relatively small compared to the traditional engineering fields, like electrical or mechanical engineering. At the same time is also a more comprehensible and multi-disciplinary field than the traditional mechanical or electrical engineering field. This multi-disciplinary approach demands for newer combined curricula.

Due to these challenges in society the bio-medical engineering sector in Belgium is a growing and high tech sector which urged politicians and universities to give priority to a renewed and global approach.

1.2 Demands for bio(medical)engineering education

As research and development in biomedical engineering is complex and multi-disciplinary, it is difficult to cover all necessary knowledge and skills in one engineering study. The future challenges that biomedical engineers are expected to solve are very diverse and are expected to increase further with new, emerging and disruptive technologies and changing demands of the health sector.

From the fields of interest or priorities put forward by the experts, it is clear that that biomedical engineers is professionals with very diverse areas of expertise. Buzz words as connected care (digital, mobile, smart), big data and artificial intelligence and medtech. Thinking about connected care is all things related to tele-health and monitoring from a distance (sensors, healthcare IoT), apps and prevention systems. With big data and artificial intelligence areas of technology of image recognition, pathology recognition and expert systems are touched. Medtech covers all technology areas ranging from 3D-printing (orthoses, skeletons, phantoms) over surgical robotics and implants to CRISPR-Cas-systems and genome sequencing. The range is enormous and will not be covered in one degree of engineering.

Biomedical engineers need to have a profound knowledge of fundamental engineering and physical science. On top they must be able to apply this knowledge to solve problems of medical and biological origin (living materials), which all require a multidisciplinary approach. This is reflected in the different bio-medical engineering degrees, which consist most often in



a number of general engineering courses and next a huge part of elective courses, so that each student can more or less find an appropriate set of course that fits best the disciplinary field in biomedical engineering that is closest to his interests.

1.3 Belgium.

The growing importance and opportunities in the biomedical sector was discovered by the universities which installed new branches of engineering studies to cover the needs on the emerging industries.

In Belgium bio-medical engineering education is the exclusive field of universities, where they connect closely in multidisciplinary studies with the university hospitals. As in Belgium there is a system of comprehensive universities (covering all branches of study: humanities, medical, sciences and engineering in one university), it is obvious that the connection between engineering and medicine is easier.

Besides bio-medical, there is a huge interest in bio-technology and pharmaceuticals which both look more to the “life” side of the problem, while bio-medical looks at the technology side of the matter.

Further on we will only discuss the bio-medical field of engineering.

All major universities in Belgium (both in the Flemish and French part of the country) offer a master degree in bio-medical engineering. The overview can be found in (Chapter 2).

There is no specific training on undergraduate level or for technician in the bio-medical field. These technicians generate from the general mechanical/mechatronics/electronic undergraduate studies.

2 Brief introduction to the higher education system in Belgium, The Netherlands, France.

2.1 Belgium

The structure of Belgian higher education is structured according to Bologna (see Fig. 1).

The degrees which are interesting to BIOART are all taught at university level, in the master, or advanced masters study (ISCED 7 level). There are no specific bachelor or higher vocational training courses in biomedical engineering. There only exist courses in the biotechnology and paramedic field at undergraduate schools (University colleges).

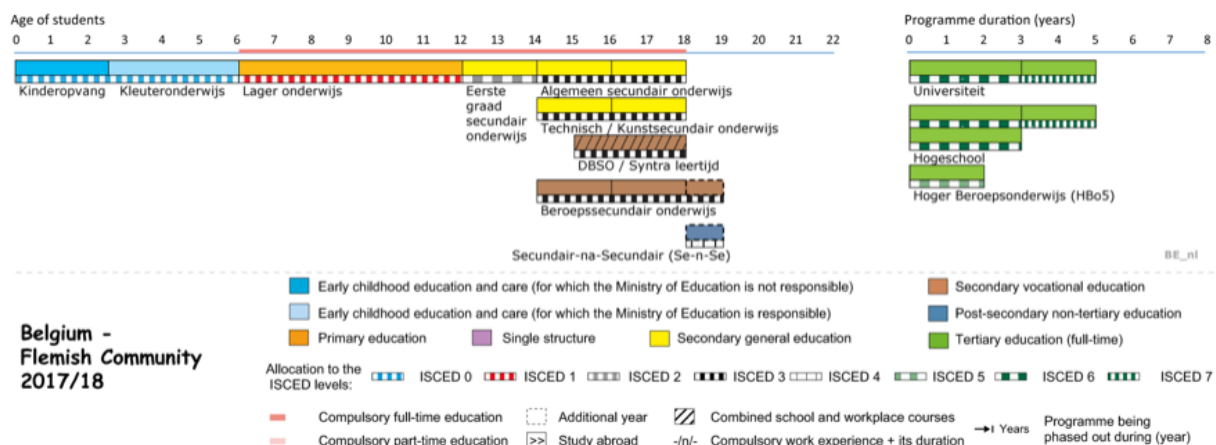
As bio-medical studies contain a high-degree of multi-disciplinarily aspects (engineering <> medical), it is of no surprise that currently universities work on multi-disciplinarily research institutes focused around life sciences and bio-medical/technology.

Higher education contains programs which result in the degree of bachelor, master and PhD (doctorate).

The study load rate according to the law is 1 ECTS = 25-30 study load hours.

Also higher vocational education is part of the level of higher education.

Access to higher education is open to all pupils from secondary general education.



source: Eurydice 2017-2018

Fig. 1 Educational structure in Belgium. (Source Eurydice)



Higher vocational education

On 1 September 2009 higher vocational education (Hoger Beroepsonderwijs - HBO5) was introduced in the Flemish educational system. HBO5 programs are professionally oriented programs situated in between secondary education and professionally oriented bachelor programs. HBO5 degrees do not offer any automatic entrance to bachelor or master degrees. Only via bridging programs access to bachelor studies is possible.

Bachelor

Bachelor programs in Flanders may be both professionally oriented and academically oriented. Professionally oriented bachelor programs are primarily aimed at practicing a profession and offer a direct access to the labor market. Professional bachelor degrees are taught in the university colleges.

Professional bachelor degrees in paramedical professions are defined: nursing, audiology, speech therapy. No specific bio-medical (in a sense of technology) degrees exist.

Academically oriented bachelor programs focus on a broad academic and researched education or an education in the arts. They aim at offering access to a master program or to the labor market. Academic bachelor degrees are offered at the universities.

Both professionally and academically oriented bachelor programs comprise at least 180 credits. In theory a student takes 60 credits a year, but variations are possible.

Master

Master programs focus on advanced scientific or artistic knowledge or competences which are needed for the independent practice of science or arts, or for practicing a profession. They are rounded off by a master thesis.

Master programs can only be offered at the universities.

A master program comprises 60 - 120 credits. An institution of higher education can, in addition to a general master, also offer a research master, which comprises 120 credits.

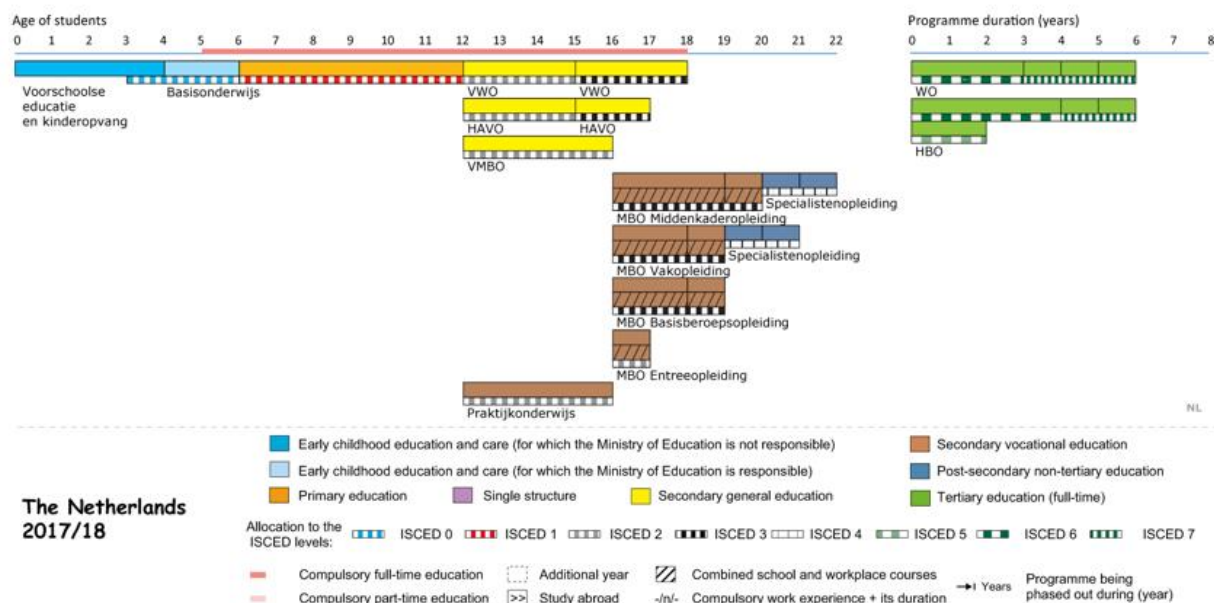
PhD (third cycle)

PhD-studies is the sole responsibility of universities.

The PhD degree in Belgium is not completely organized according to Bologna: there is not an ECTS credit system in PhD. A typical PhD will take 4 years and is solely research based. A PhD in engineering can also be done in industry, under supervision of a university professor.

2.2 The Netherlands.

Higher education in the Netherlands is offered at two types of institutions: universities of applied sciences (*hogescholen*; HBO), open to graduates of HAVO, VWO, and MBO, and research universities (*universiteiten*; WO) open only to VWO-graduates and HBO graduates (including HBO *propaedeuse*-graduates). The former comprise general institutions and institutions specializing in a particular field, such as agriculture, fine and performing arts, or educational training, while the latter comprise twelve general universities as well as three technical universities.



source: Eurydice 2017-2018

Fig. 2 Educational structure in the Netherlands (source Eurydice)

Since September 2002, the higher education system in the Netherlands has been organized around a three-cycle system consisting of bachelor's, master's and PhD degrees, to conform and standardize the teaching in both the HBO and the WO according to the Bologna process. At the same time, the ECTS credit system was adopted as a way of quantifying a student's workload (both contact hours, and hours spent studying and preparing assignments). Under Dutch law, one credit represents 28 hours of work and 60 credits represents one year of full-time study. Both systems have been adopted to improve international recognition and compliance.

Despite these changes, the binary system with a distinction between research-oriented education and professional higher education remains in use. These three types of degree programs differ in terms of the number of credits required to complete the program and the degree that is awarded. A WO bachelor's program requires the completion of 180 credits (3 years). An HBO bachelor's program requires the completion of 240 credits (4 years), and graduates obtain a degree indicating their field of study, for example Bachelor of Engineering (B. Eng.). The old title appropriate to the discipline in question (bc., ing.) may still be used.



Master's programs at the WO level mostly require the completion of 60 or 120 credits (1 or 2 years). In engineering 120 credits are always required.

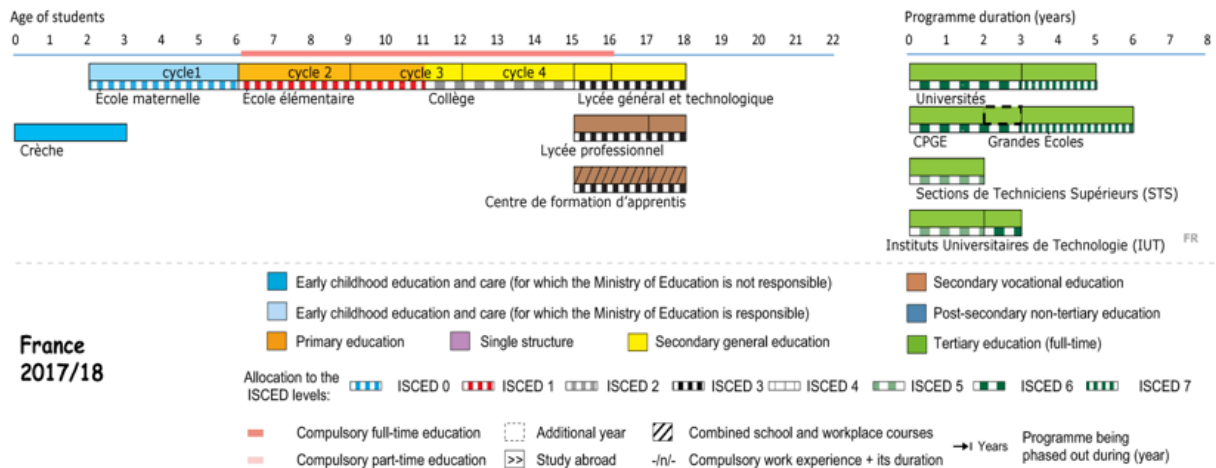
The third cycle of higher education is offered only by research universities, which are entitled to award the country's highest academic degree, the doctorate, which entitles a person to use the title Doctor (Dr.). The process by which a doctorate is obtained is referred to as "promotion" (*promotie*). The doctorate is primarily a research degree, for which a dissertation based on original research must be written and publicly defended. This research is typically conducted while working at a university as a *promovendus* (research assistant).

The degrees which are interesting to BIOART are mostly taught at university level (WO), in the master study (ISCED 7 level). There are no specific bachelor courses in biomedical engineering.

2.3 France:

Higher education in France is characterized by the coexistence of two systems: universities, – public institutions that have an open admissions policy, except for Instituts Universitaires de Technologie (IUT - University institutes of technology) – and a non-university sector, including, in particular, Grandes Écoles (Elite Schools), with a highly selective admissions policy open to baccalauréat holders having attended two years of classes préparatoires, themselves highly selective on entry and during the course. Post-secondary non-tertiary education is marginal in France: the only two diplomas of ISCED 4 that the French education system provides combined amounted to less than 10,000 graduates in 2014.

Higher education (ISCED 5 to ISCED 8), which is dispensed in higher educational institutions. These institutions have a wide variety of legal statuses that are listed in the French Code of Education. There are two types of short cycles studies (Sections de Techniciens Supérieurs and Diplôme Universitaire Technologique). Courses dispensed in French higher education institutions have different aims and conditions for admission, but most of them are structured into three study cycles (Bachelor's degree, Master's degree and Doctorate) and in ECTS credits, in compliance with the principles of the Bologna Process.



source: Eurydice 2017-2018

Fig. 3 Educational structure in France (source Eurydice)

3 List of study program in bio(medical) engineering in Belgium

Specifically on biomedical engineering there is no dedicated studies at undergraduate level.

At graduate level we find the studies in both Flemish and Wallon universities.

There is 2 kinds of engineering degrees in Belgium:

- Engineering sciences: focused at fundamental and conceptual engineering
- Engineering technology: focused at applications.

In both types of engineering we can find biomedical orientations.

Underneath is noted the different biomedical degrees offered in Belgian universities.

KU Leuven: Master of Biomedical Engineering (Ir, engineering sciences)

https://onderwijsaanbod.kuleuven.be/2018/opleidingen/e/SC_51360430.htm

The program of the master of biomedical engineering is build containing:

- a truncus communis, consisting in 3 medical courses (12ECTS)
- a compulsory part of 36ECTS engineering courses
- a 24ECTS master's thesis.
- design (6ECTS)
- 8-10ECTS soft skill courses
- electives (32-34ECTS).

Entry requirements: Bsc in engineering, field of electro-techniques or machine building.

Name of HEI and program	Degree awarded	Credits	Duration of study
KU Leuven	Master of science of biomedical engineering	120 ECTS	2 years full-time
Master of biomedical engineering			
Courses		Credits	
Truncus communis: basic medical courses		12	
Functional Anatomy of the Human Locomotor System		3	
Human cell Biology		4	
Human System Physiology		5	
Truncus communis: biomedical engineering courses		36	
Biomedical Measurements and Stimulation		6	
Biomedical Data Processing		6	
Biomaterials I		3	
Musculoskeletal Biomechanics		6	
Medical Imaging and Analysis		6	
Biofluid Mechanics		3	
Medical Equipment and Regulatory Affairs		6	
Project based learning.		30	
Design in Medical Technology		6	



Master's Thesis	24
Elective Courses:	32-34
Genetic Algorithms and Evolutionary Computing	4
Uncertainty in Artificial Intelligence	4
Structural Dynamics, Analysis and Numerical Modelling	6
Microsystems and Sensors	3
Biomedical Data Processing	6
Medical Image Analysis and Processing (Part II)	6
Host responses to implanted materials	3
Robotics	4
Mechano-biology	3
Artificial organs and tissue Engineering	3
Micro-electromechanical systems	3
Bio-informatics	4
Next generation bio-materials	3
General interest courses (selection)	8-10
Communication	3
Foundations of bioethics and principals of clinical ethics	4
Interdisciplinary perspectives on development and cultures	4
Innovation management and strategy	6
Management and policy aspects of technology in healthcare	3
Engineering&entrepreneurship	6
Intellectual property management	4,5

Table 1 Msc on biomedical engineering.

KU Leuven: Master of Electromechanical Engineering Technology (option Clinical Engineering) (ing, Engineering technology)

The degree is an option within the master of electro-mechanical engineering (general machine building).

It consists of a common backbone of courses on machine building and option courses for clinical engineering.

Name of HEI and program	Degree awarded	Credits	Duration of study
KU Leuven	Master of science of engineering technology	60 ECTS	1 years full-time
Master of Electromechanical Engineering Technology (option Clinical Engineering)			
Courses		Credits	
Common backbone		17	
Dynamics in machine building		4	
Finite Elements Analysis based design		4	
Electric drive systems		4	
Advanced automation technology		5	
Project based learning.		30	
Master's Thesis		24	
Option Courses:		16	
Dynamics and biomechanics		5	
Robotics and advanced instrumentation		5	
Medical equipment and regulatory affairs		6	
General interest courses (selection)		8	
Management and communication		4	
Pathways to sustainability		4	

Table 2 Msc in engineering sciences: in electro-mechanical engineering, option clinical engineering.

KU Leuven: Advanced Master in Healthcare.

The advanced master degree is an extra master degree. Entry requirements is a master in engineering.

Name of HEI and programme	Degree awarded	Credits	Duration of study
KU Leuven Master of Healthcare	Master of science of engineering technology	60 ECTS	1 years full-time
Courses		Credits	
Health entrepreneurship		4	
The human body		6	
Sensors&Circuits for Health Applications		5	
Information Processing in Health Applications		5	
Human Computer Interaction for Health		5	
Robotics and surgical Instrumentation		5	
Health Engineering Experience		5	
Master Thesis and internship		25	

Table 3 Msc in Healthcare engineering.

UGent (University of Ghent): Master of Science in Biomedical Engineering

<https://studiekiezer.ugent.be/master-of-science-in-biomedical-engineering-en/programma>

Entry requirements: Bsc or Msc in engineering

No.	General Courses (compulsory)	Ref	Semester	Contact	Study	ECTS
1	Quantitative Cell Biology	BLS	1	30	90	3
2	From Genome to Organism	BLS	1	60	180	6
3	Modelling of Physiological Systems	BLS	A:1 C:2	67.5	180	6
4	Biomedical Imaging	BT	1	25	90	3
5	Bioelectronics	BT	1	30	90	3
6	Biomaterials	BT	1	60	180	6
7	Biomechanics	BT	2	67.5	180	6
8	Technology in Clinical Neuroscience	BT	2	25	90	3
9	Medical Physics	BT	2	30	90	3
10	Biomedical Product Development	MDD	J	30	180	6
11	Medical Equipment	MDD	2	60	150	5
12	Human and Environment, Safety and Regulations	MDD	2	40	120	4
13	Technology and Design of Artificial Organs	MDD	1	67.5	180	6
14	Clinical Study Design and Biostatistics	HC	1	25	90	3
15	Leadership in Health Care	HC	2	22.5	90	3
16	Health Information and Decision Support Systems	HC	2	31.5	90	3
17	Hospital Project	HC	J	30	90	3

No.	Course (24 ECTS electives)	Ref	Contact	Study	ECTS
1	Modeling in Medicine and Biomedical Engineering: Case Studies		30	90	3
2	Bioelectromagnetism		22.5	90	3
3	Biomedical Acoustics		67.5	180	6
4	Internship 1 [en, nl]		7.5	90	3
5	Internship 2 [en, nl]		7.5	90	3
6	Internship 3 [en, nl]		7.5	180	6
7	International Internship 1		7.5	90	3
8	International Internship 2		7.5	90	3
9	International Internship 3		7.5	180	6
10	Manufacturing Planning and Control		60	180	6
11	Ethics, Engineering and Society [nl]		15	90	3
12	Artificial Intelligence		52.5	180	6



UGent (University of Ghent): INTERNATIONAL MASTER OF SCIENCE IN BIOMEDICAL ENGINEERING

<https://studiekiezer.ugent.be/international-master-of-science-in-biomedical-engineering-en/programma>

This is an international program run with 4 international partner universities and contains the same courses as the Master of Science in Biomedical Engineering at UGent.

General courses:

In year 1:

- Ghent University/Vrije Universiteit Brussel (Belgium): 57 credits
- Rijksuniversiteit Groningen (the Netherlands): 55 credits
- Rhenisch-Westphalian Technical University of Aachen (Germany): 60 credits
- Czech Technical University of Prague (Czech Republic): 54 credits
- Trinity College Dublin (Ireland): 44 credits

In year 2:

- Ghent University/Vrije Universiteit Brussel (Belgium): 3 credits
- all others: 30 credits from the specialisations

Elective Courses

Elective courses in accordance with the student's mobility scheme. Subject to approval by the faculty.

In year 1:

- Ghent University/Vrije Universiteit Brussel (Belgium): 3 credits
- Rijksuniversiteit Groningen (the Netherlands): 5 credits
- Rhenisch-Westphalian Technical University of Aachen (Germany): no electives
- Czech Technical University of Prague (Czech Republic): 6 credits
- Trinity College Dublin (Ireland): 16 credits

In year 2:

- Ghent University/Vrije Universiteit Brussel (Belgium): 27 credits
- All others: 30 credits from the specialisation

All courses can be seen on the weblink.



ULiege (University of Leige): Ingénieur civil biomédical, à finalité

https://www.programmes.uliege.be/cocoon/20182019/programmes/A1ICIV01_C.html

https://www.programmes.uliege.be/cocoon/20182019/programmes/A2UBIO01_C.html

At the university of Liege, there is a bachelor program in engineering with optional courses for 40ECTS in biomedical engineering. The program consists of a compulsory set of traditional engineering courses and a set of electives towards biomedical engineering.

The bachelor program is followed by a 120ECTS master in biomedical engineering.

In table (Table 4) one finds the option courses which make out the difference from the general Bsc of engineering and the Bsc of engineering in biomedical engineering.

The complete programme can be find in the annexes.

Name of HEI and programme	Degree awarded	Credits	Duration of study
Université de Liege	Bachelor of sciences, engineering sciences	180 ECTS	3 years full-time
Bachelor of engineering			
Courses		Credits	
GBIO0002-1 Genetics and bioinformatics		5	
GBIO0025-1 - Biologie générale et cellulaire		5	
GBIO0011-1 Modélisation des systèmes biologiques		5	
PHYS2021-1 - Physique 2 : Electricité et électromagnétisme		5	
MECA0003-2 - Mécanique rationnelle		4	
CHIM0286-1 - Eléments de thermodynamique		5	
GBIO0001-1 Biophysique et biochimie		5	
GBIO0021-1 Projet de laboratoire		5	
GBIO0026-1 - Physiologie des systèmes		5	
GBIO0025-1 - Biologie générale et cellulaire		5	
GBIO0013-1 Phénomènes de transport en biologie		5	
MECA0011-2 - Eléments de mécanique des fluides		4	
CHIM0286-1 - Eléments de thermodynamique		4	
GBIO0005-1 Introduction aux neurosciences cognitives		5	
CHIM9272-2 - Chimie 1		4	
CHIM9273-1 - Chimie 2		5	
Total of distinguishing courses		76	

Table 4 Bsc of Engineering: option biomedical engineering.

The master consists in a troncus communis and master thesis and a set of electives, focused to one of following specialties:

- Electronics
- Informatics
- Mechanics
- Chemistry/materials
- Basics in bioengineering

Louvain la Neuve: ingénieur civil biomédical

<https://uclouvain.be/cours-2018-lgbio2220>



4 Comparative curricula analysis - synopsis

The diversity in the courses reflects the different directions of research done at the individual universities.

However, when analyzing we see some common grounds in all programs (besides the traditional engineering subjects as mechanics, physics...):

- All degrees stress the connection to the biological side of the problem by the inclusion of courses related to the (human) body and medicine.
- A multi-disciplinary approach: in project based learning a multidisciplinary approach is strongly encouraged, needed to solve the cases. As all bio-medical cases and problems is on the interface of biology and technology it is from the nature of the problems that is can only be solved when looking at the problem from the different disciplines.
- Material sciences and the emphasis on bio- and bio-compatible materials is another omnipresent course.
- In all degrees there is attention for innovation and entrepreneurship: in a highly specialist and researched field as bio-medical engineering, chances that there will be opportunities to commercialize findings are generic. To prepare students for the entrepreneurial role, courses are included.
- Artificial intelligence/imaging technology is considered a promising field as it is present in all degrees.
- Several degrees incorporate (international) internships: specific (bio)-medical problems are in smaller niches, so international outreach is necessary to get enough interested researchers (and students) on the subjects. The bio-medical sector and research itself, from its' origin of being very capital intensive is completely globalized and all major companies are multi-nationals.

The conclusion is that there is not one path to a curriculum in biomedical engineering.

The degrees in different universities are often built in accordance to local research (in cooperation with local stakeholders). This gives a nice palette of different opportunities for students to specialize in a direction which is most appealing to them.



5 Biomedical (engineering) industry in Belgium.

Bio-medical industry is doing well in Belgium: this shows from the industry growing, for the number of startups and from predictions on the future of the industry.

The estimated turnover of the sector is roughly 3.5 billion EUR (excl VAT), offering employment to about 17000 FTE.. (“The Belgian Medical Technology Industry, Facts and Figures 2018”)

Besides bio-medical, there is a huge interest in bio-technology and pharmaceuticals which both look more to the “life” side of the problem, while bio-medical looks at the technology side of the matter.

As many countries in western Europa, bio-medical industry is also important and booming. Belgium always was a country with a strong pharmaceutical industry, of which Janssen Pharmaceutica (part of Johnson&Johnson) probably is the most well-known company.

These interests makes that there is 2 different branches in industry: the bio-technology industry is clustered under the (bio)chemical industry (www.essencia.be), while the bio-medical industry is categorized as part of the high-tech industry. The federation of bio-medical/medical industry is BeMedTech, gathering 80% of the companies in the market (www.bemedtech.be).

beMedTech is the Belgian federation of the medical technology industry and has more than 200 affiliated companies. Its members are manufacturers and/or distributors and are divided into five product segments: in-vitro diagnostics (IVD), consumables, implants, medical investment goods (MES) and Extra Muros solutions, including Digital Health. Together they represent over 500,000 technologies for an annual turnover of € 2.4 billion not including export and they account for approximately 16.820 FTEs in Belgium. beMedTech estimates that the total medical device industry has a turnover of about € 3.5 billion and employs about 20,000 people.

In October 2016 the “Pact on Medical Technologies” was signed between Maggie De Block, Minister of Public Health, and beMedTech. The pact was a result of intense and constructive discussions between the federation and the 3 main administrations (Federal Public Service Health, the reimbursement agency National Institute for Health and Disability Insurance (NIHDI), and the Federal Agency of Medicinal and Health Products (FAMHP). The pact resulted in an agreement to work around 32 topics. The objective was clear: through agreements, laws and rules provide the highest possible guarantee to safe and accessible medical devices. One of the topics is “Training and Education of healthcare professionals on medical devices”. In this project cooperation is needed between beMedTech, FAMHP and the universities.

Bio-medical and bio-technological startups make out the major part of the startups (source Sirris-data-scout), even more than Fintech. There is an important amount of organisations which promote, stimulate and support these startups (e.g. Voka Health Community, MIC Vlaanderen, Impulse Brussels innovation; Leuven Mindgate; BlueHealth Antwerp, Agoria Health, Caring



Entrepreneurship Fund, MedTech Flanders, Flanders Care, Le WeLL,...)

According to Jobat (Belgian journal which monitors the labor market) the success of the industry is visible in the present demand for labor force, but also for the future.

According to predictions, the 10 most wanted technical profiles in the future include: Technologist medical imaging and Bio-medical engineer.

As such, the strive of the universities and industry to collaborate and to provide more studies and trainings in this direction is considered positive and wanted.

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