September 30th, 2015

Syllabus MOOC IB01x

Industrial Biotechnology

Learn the basics of sustainable processing for biobased products and understand their impact on global sustainability.

A. Basic information

1. Introduction

Welcome to the MOOC Industrial Biotechnology. This syllabus describes the learning objectives for the course, the content and explains the course grading system. Our MOOC lasts six weeks plus an additional two weeks to finish previous assignments. The course provides the insights and tools for biotechnological processes design in a sustainable way. Five experienced course leaders will teach you the basics of industrial biotechnology and how to apply these to the design of fermentation processes for the production of biomaterials, chemicals and biofuels. We will also introduce best practices in process design, from Brazil and the US, from academia and industry.

This course is a re-run of the 2014 course 'Technology for Biobased Products'. Based on feedback from participants and our experiences, we have improved the assignments and the discussion options on the forum. In addition, you have the option to pursue an ID-verified certificate.

The student who performs best will win a trip to Delft in the Netherlands to participate in an advanced course on biotechnology of his/her choice. The best student is chosen based on the overall grade of the course and a motivation letter. The highest scoring students, and those that actively support other students in the discussion forum will be asked to write a motivation letter. Read more about the prize in section 7.

You will also have the opportunity to share your biobased experiences with the other students. Tell us what is going on in biotechnology in your region. Consider whether you know any inventive people in your town or region, who are using biotechnology for producing a biobased product (energy / material) from biomass or waste that is locally available. Make a two-minute movie of this activity, add the word IB01x2015 either somewhere in the title or as a tag. It will be automatically included in a playlist together with movies from other students, viewable from within the course. You can use any format you like, e.g. video, cartoon and computer graphics. At the end of the MOOC, the course team will rate all movies. The winning movie will get extra exposure on the MOOC platform and the winner will receive an international gift certificate worth USD 100,-.

2. Learning Objectives

After this course you will:

1. understand the need for sustainable innovation and how biotechnology and biobased production can contribute to this;
2. understand the global context of biobased production;
3. be acquainted with the biobased economy, from research to application and from raw materials to products;
4. have mastered the basics of industrial biotechnology;

5. be able to integrate scientific and technological knowledge on the use of bioprocesses for industrial products on the cell and process level;
6. be capable of developing and assessing the conditions for efficient and sustainable design of bioprocesses.

We know that some of you will simply audit the course because of time or other constraints. Our web lectures and readings will indeed give you the basic understandings. However, we still hope that you will join the discussions at any time. By collaborating with other students, by sharing your own reflections and by completing the assignments, you - and your fellow students! - will be able to gain the most from this course.

3. Prerequisites

The prerequisites for this course are high school understanding of mathematics and first year undergraduate knowledge of (bio)chemistry and biology. If you have a more advanced knowledge of these disciplines, we still expect that the course will challenge you.

4. Course materials & workload

Each course week contains a number of course leaders' video lectures (which have an average length of eight to ten minutes) and corresponding assignments. In addition, you will work on the 'PDO-case', in which you will design a process for sustainable production of 1,3-propanediol. And we will explore other cases, so-called best practices, presented by guest lecturers from academia and industry.
The expected workload throughout the course will be approximately eight hours per week but this will also depend on your ambitions and prior knowledge. The assignments and work on the PDO-case also function to self-monitor your progress, which is indicated at the dashboard of the course. For grading, see part C. You will have three weeks' time to finish the assignments once they are online. You can find the exact deadline dates in the navigation column under the "Courseware" tab. Do note when handing in the assignments that the deadlines are given in Coordinated Universal Time (UTC), not Dutch time or any other time zone.
Communication will occur via the announcements, e-mail, and the discussion forum. Announcements will mainly be used to address practical matters throughout the course and the discussion forum should be used to discuss the content of the course. We invite you to use the discussion forum actively!

Experience has shown us that the discussion forum can play a vital learning role in MOOCs. Students can pose their questions or topics of discussion and other students can freely respond to these topics. In this way you will also be able to help and learn from each other. The MOOC team will monitor the discussion forum and support you when needed.

For keeping track of where we are in describing and designing bioprocesses, the course provides an animated overview of the whole bioprocess under the "animation" tab. At various stages you can zoom in at will.

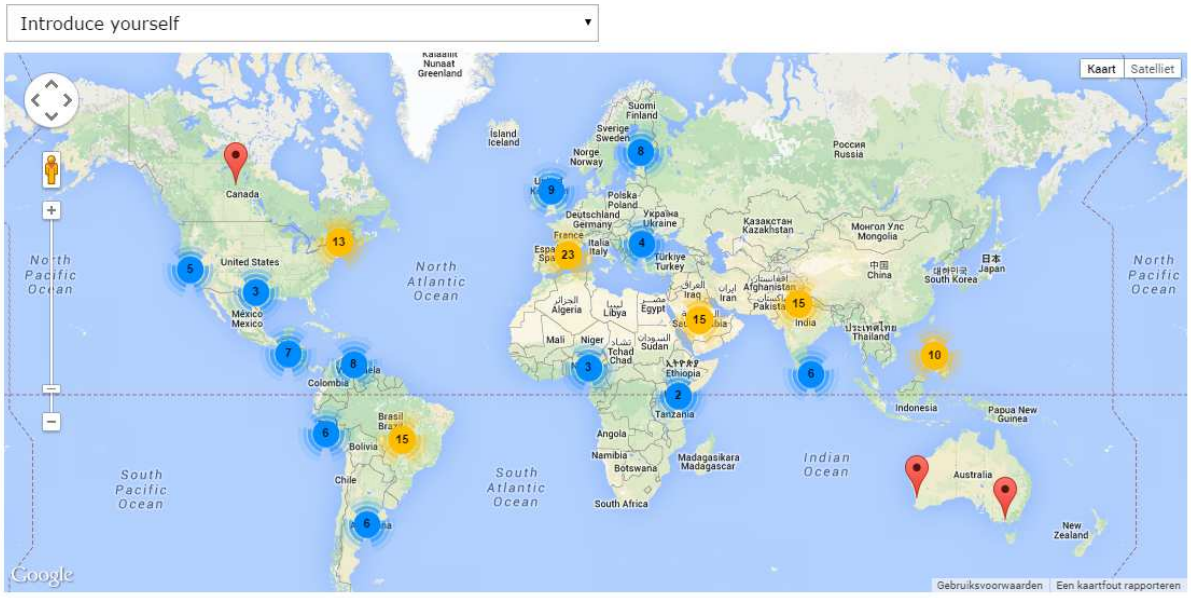
5. Networking and sharing knowledge

In this course we also count on your generosity. Become part of the network! Share your thoughts and ideas. We have a few mechanisms in place:

- A Twitter account: @IB01x
- Discussion forum. Here you can raise any questions on the content of the course and/or seek collaboration with other students.
- A world map (see picture below). You can use the world map to introduce yourself (see tab 'Map' in the navigation bar).
- In many other MOOCs, students have set-up Facebook pages, Google hang-outs or similar facilities. Please do feel encouraged to do the same.

MAP

Each marker on the map represents a participating student in this course. When clicking a marker, a text box opens containing the student's introduction. Browse through the map to explore!



6. Grading

- After each lecture there will be a number of assignments. They are meant to reflect on your new knowledge and count for 35% of your grade. You will apply this knowledge in the "PDO Case" which counts for 50%. To finish the week you will watch a "Best Practice" with additional assignments, which will count, for 15% of your grade. The lowest result of each of these three parts will automatically be dropped after six weeks. If you scored higher than 55% you will earn an IB01x certificate!

- Many lectures have extra (non-graded) questions. These non-graded questions test relevant knowledge and are a valuable addition. So try them when you have the time! Non-graded questions are marked as EXTRA QUESTION and depicted in blue font.
- The closing lecture in week 7 does not contain assignments and is therefore not graded.

7. Prize

As in last year's run, you have the chance to win a fully paid visit to the TU Delft to attend one of the advanced courses of 2016 by the Biotechnology School Delft Leiden (www.biotechnologycourses.nl). These courses offer interesting topics such as Bioprocess Design, Metabolomics and Downstream Processing. In June 2015, the winner of the 2014 MOOC, 21-year old Melissa Sanchez from Bogota, Colombia, joined the course 'Environmental Biotechnology'.

The course team will select:

1. Top 20 of students with the highest scores.
2. Top 10 of students with marks over 8.5 with the most constructive interventions at the MOOC Forum.

The selected students will be asked to send us a motivational letter and CV. From these letters, the jury will pick the winner for the Delft visit.

B. Content of the course per week

Structure per week

Each week starts with a brief overview, followed by lectures interspersed with assignments. Then, you will apply your gained knowledge in the weekly PDO case. The week is finished with a segment called “best practice”, which will give a glimpse at novel biotechnology and examples from the industry.

Terminology

In the course, you will probably encounter new words, symbols and equations. That is why we have developed a terminology list as well as lists for symbols and equations used in the course. You can find these under the heading “course handouts” in the “course info” tab.
One important word is used in two different meanings, ‘biomass’. In week 1, the term ‘biomass’ refers to feedstock, plant material used as a source for a fermentation production process. From week 2, ‘biomass’ also refers to the cells of microorganisms in the fermenter.

Handouts with the lectures

Together with the videos, there are various downloadable handouts available in each lecture.

With this link you can download the video in 360p (low) quality.

With this link you can download the video in 720p (moderate) quality.

With this link you can download the video in 1080p (high) quality.

You can also download the English subtitles in SRT format for offline viewing.

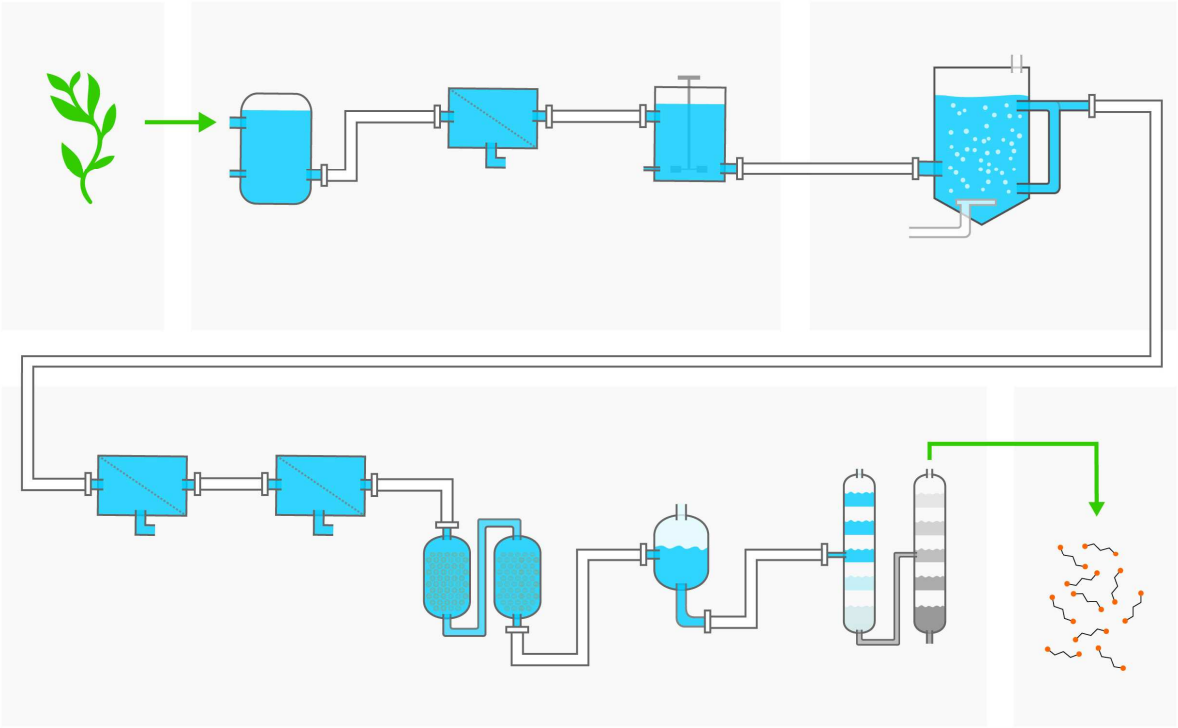
These are the slides used in the presentation in PDF format.

This is the transcript of the video in PDF format.

Week 0: Introduction to the course

This week consists of:

- An introduction to the course team;
- A survey for you to tell us more about your background and expectations of the course.



Week 1: Biotechnology for Biobased Products
30 September 2015

In this week, Isabel Arends and Patricia Osseweijer introduce you to the field of biotechnology and the biobased economy. They will show why our society should make the transition from fossil to biobased materials and explain what the role of biotechnology is. They start from sustainable feedstocks and microorganisms that can turn this biomass into valuable products. One of the products that can be made through fermentation is 1,3-propanediol (PDO). It is a liquid that can be used as building block for many different other products, such as polymers, coatings and solvents. Its production will be the central case you will work on throughout all the weeks.

Lecture units

1.1 Why develop a biobased economy
1.2 Industrial biotechnology
1.3 Feedstocks - Renewable sources of biomass for biobased products
1.4 Process to bio-PDO (1,3-Propanediol)

1.5 Benefits for society & sustainability - Evaluating the effects of biobased production

Contributing authors: Isabel Arends, professor of Biocatalysis and Organic Chemistry, and Patricia Osseweijer, professor of Biotechnology & Society, both Delft University of Technology

Best practice 'Self-Healing concrete'
Henk Jonkers, Delft University of Technology, explains how he found microorganisms that fill small cracks in concrete structures. These organisms feed on calcium lactate and CO_2 and synthesize the limestone required for 'healing' concrete.

Week 2: Balances and Microbial Rates
7 October 2015

In week 2, Sef Heijnen, will introduce the opportunities that microorganisms from nature offer for the production of compounds. He will discuss the nutrient requirements of microorganisms and teach you how to calculate rates of consumed and produced compounds using balances. Calculating these rates is crucial, as a successful new process must be designed in an economic attractive way.

Lecture units
2.1 Microorganisms and their function in nature
2.2 Functional understanding of nutrient requirements for microbial growth
2.3 Learning about the process: Broth balances
2.4 Learning about the process: Gas phase balances
2.5 Learning about the microorganism: q-rates and chemostat
2.6 Learning about the process and organism: Batch

Contributing author: Sef Heijnen, professor of Bioprocess Technology, Delft University of Technology

Best practice 'Mixed cultures for biobased products'
Mark van Loosdrecht, professor of Environmental Biotechnology at Delft University of Technology, introduces the power of nature: how to use micro-organisms in open cultures for turning waste into useful materials. Instead of engineering a single micro-organism, he introduces the engineering of a microbial community.

Best Practice 2a – Exploiting nature's biodiversity
Best practice 2b - Application of mixed cultures

Week 3: The Black Box-model and Process Reaction
14 October 2015

Sef Heijnen will follow up in week 3 with showing how to design a full scale PDO continuous fermentation. He presents the process reaction and the Black Box model of the microorganism.

Sef Heijnen will show Black Box models for energy consuming and energy producing products. At the end of the week, you can use your insights from this model as well as the process reaction to discover how to make the fermentation of PDO more sustainable.

Lecture units

3.1 The process reaction
3.2 Basics of the black box model
3.3 Energy consuming and energy producing products
3.4 A PDO black box model: experiments for parameter identification
3.5 Black box models: The PDO process reaction as function of μ
3.6 PDO continuous process design: calculation of inputs and outputs using the process reaction
3.7 Aerobic PDO process: improving sustainability

Contributing author: Sef Heijnen, professor of Bioprocess Technology, Delft University of Technology

Best practice 'Industrial Process Development for Succinic Acid'

Mickel Jansen, senior scientist Fermentation at DSM, The Netherlands, will teach about the rationale of the recently developed process for the production of succinic acid, a food ingredient.

Best Practice 3a - Introduction
Best Practice 3b - The process
Best Practice 4c - Industrial scale

Week 4: Fermentation Design
21 October 2015

In this week, Henk Noorman, will take product formation one step further. He will put you in the position of a bioprocess designer in a company. Henk Noorman will show you what a fermentation process looks like and how to design it. You will learn more about the transport of heat, nutrients, gas and product in the fermenter.

Lecture units

4.1 Introduction to fermentation technology
4.2 The large-scale fermenter
4.3 Fermenter operation
4.4 Gas transport
4.5 Heat transport
4.6 Mixing
4.7 Basic approach to design and optimize a PDO fermentation process

Contributing author: Henk Noorman, professor of Bioprocess Design and Integration, Delft University of Technology

Best practice 'Semisynthetic artemisinin production'
Chris Paddon, principal scientist at Amyris, USA, discusses how his company developed a process for producing the antimalarial drug artemisinin. He will elaborate on the decisions that were made to develop this process.

Best Practice 4a - Semisynthetic artemisinin production a
Best Practice 4b - Semisynthetic artemisinin production b

Week 5: Up- and downstream process integration
28 October 2015

Luuk van der Wielen will deal with integral bioprocess design, where feedstock preparation and product purification are necessary and important contributors to investment and operating costs. Through qualitative and quantitative examples, current and novel technologies will be discussed and placed in a complete techno-economic impact of technology for biobased products.

Lecture units

5.1 Towards an integrated bioprocess
5.2 Pre-treatment
5.3 Separation and formulation
5.4 Separation principles
5.5 Conceptual process design for 1,3 PDO production
5.6 Process integration for 1,3 PDO production

Contributing authors: Luuk van der Wielen, Distinguished professor for Biobased Economy, (course leader) and Solange Mussatto, assistant professor, both at Delft University of Technology

For this week, SuperPro Designer will be used to simulate the complete PDO process. Unfortunately SuperPro Designer is unavailable for mac operating systems. This handicap for mac users is taken into account in the grading for the course and the outcome of the process simulation is made available so a selection of questions can still be answered.

Best practice 'Bioethanol Production in Brazil'
Two experts from the University of Campinas, Brazil, introduce large-scale bioethanol production.

Best practice 5a - Luis Cortez, vice-rector, introduces the importance and history of bioethanol production in Brazil.
Best practice 5b - Joaquim Seabra, professor at the School of Mechanical Engineering explains more about the production of first generation feedstocks.

Week 6: Process Evaluation and Sustainability
4 November 2015

In week 6, Patricia Osseweijer and John Posada Duque will evaluate the overall economic, environmental and social sustainability of the production process and relate this to decision making in industry. Methods to evaluate these impacts will be presented and discussed in the context of the drivers and challenges to change fossil based production to biobased products.

Lecture units

6.1 Designing a sustainable business case
6.2 Economics of a process design
6.3 Environmental assessment of a process design
6.4 Social sustainability
6.5 Sustainability in a global context

Contributing authors: Patricia Osseweijer, professor of Biotechnology & Society, Adrie Straathof, associate professor of Biocatalysis Integration, John Posada Duque, assistant professor biotechnology and society, all Delft University of Technology,.

Best practices: 'Experiences from Brazil'

The various topics aspects of this week are illustrated in two additional lectures, one lecture on sustainability aspects of bioethanol and one on commercial production of bioplastic.

Best practice 6a - Arnaldo Walter, University of Campinas, discusses the environmental and socio-economic impact of Brazilian bioethanol production.

Best practice 6b – Roberto Werneck, chemical engineer at the company Braskem, introduces a process for producing sustainable plastics from sugar cane.

Week 7: closing lecture

11 November 2015

For your convenience, in week 7 Isabel Arends gives a closing lecture, wrapping up all six weeks. As this week does not contain assignments, no points can be gained here

GOOD LUCK AND ENJOY THE COURSE!

The IB01x team