### Summary
This course aims at a more advanced coverage of the basic aspects discussed in module ChE-311. It is however of a stand-alone nature, and even students who have little knowledge on bioprocess development shall benefit as well from this module.

### Content

**Manfred Zinn**
- Upstream processing: introduction and basics in cultivation
- Bioprocess design for batch, fed-batch and chemostat cultures
- Special bioprocesses and applications
- Paper studies including short presentations by students

**Kurt Eyer**
- Bioreactors & Fermenters: Basics
- Characterization of biological reactor systems
- Scale-up procedure: science or art?
- Applied examples and economic aspects of industrial bioprocesses

**Simon Crelier**
- Downstream processing: introduction and liquid-solid separation
- Cell lysis and precipitation
- Liquid-liquid extraction
- Adsorption and chromatography
- Membrane-based separations
- Polishing steps and latest trends

### Keywords
**Bioprocess engineering:** Basic function of a bioreactor, different types of bioreactors, agitation and oxygen transfer, upstream processing, sterilization techniques, bioprocess automation, PAT, Liebig's law, mass and energy balances, oxygen requirements, yield coefficients, growth kinetics, Monod kinetics, microbial growth on defined and complex media, substrate inhibition, feed strategies, product formation, high cell-density fed-batches, chemostat, nutrient limitation, wash-out, optimal productivity, scale-up.

**Downstream processing:** significance of DSP; chemical and biotechnological DSP; purity; yield; (bio)activity retention; physical and thermal separations; equilibrium; kinetics, sedimentation; centrifugation; filtration; cake and filter resistance; cell lysis; high pressure homogenizator; bead mill; raffinate; extract; partition coefficient; equilibrium line; operating line;
Learning Prerequisites

Required courses
Since this lecture is open to students from various backgrounds, no course is required as a mandatory prerequisite.

Recommended courses
- ChE-311 Biochemical Engineering
- Phénomènes de transfert
- Introduction au génie chimique I, II
- Techniques de séparation I, II
- Basic knowledge in microbiology, biochemistry and process engineering would constitute a helpful background (although not mandatory) for a better understanding and mastering of the material to be presented in this lecture (a short list of recommended readings can be made available if desired).

Important concepts to start the course
This course heavily relies on the basic concepts of process engineering, mass and heat transfer, equilibrium and kinetics.

Learning Outcomes

By the end of the course, the student must be able to:
- Integrate Concepts and knowledge from various domains (biology, process engineering, (bio)chemistry)
- Discuss the merits, disadvantages and characteristics of the different types of bioreactors as well as their mode of operation
- Dimension unit operations
- Interpret data or observations from case studies
- Choose an appropriate fermentation or purification strategy
- Predict the outcome or the performance of a unit operation or specific equipment
- Justify your choices and assumptions
- Solve calculation problems

Transversal skills

- Use a work methodology appropriate to the task.
- Assess one’s own level of skill acquisition, and plan their on-going learning goals.
- Manage priorities.
- Use both general and domain specific IT resources and tools

Teaching methods

The course will be held under the form of lectures also featuring the treatment of examples, the discussion of case studies and exercises.

Expected student activities

Regularly attending the course is the best way to achieve the learning goals with a minimal amount of personal work at home. The proposed exercises and case studies are integrated to the lectures. They illustrate and complete the
theoretical aspects presented during the course, and playing an active part in their resolution will make the learning process more efficient.

Assessment methods
An examination will take place at the end of the semester. The exam will be written if 9 candidates or more have signed up, and oral otherwise.

Supervision
Office hours No
Assistants No
Forum No
Others The three lecturers shall be available for enquiries or questions, be it per e-mail or telephone.

Resources
Bibliography

Ressources en bibliothèque
- Bioprocess Engineering Principles / Doran
- Bioprocess engineering basic concepts / Kargi
- Bioprozesstechnik / Chmiel

Notes/Handbook
There is no manuscript for the course. However, all the material that is presented (copies of transparencies, additional material, exercises and correction thereof) is available and can be downloaded from the Moodle platform.

Websites
- http://scgc.epfl.ch/telechargement_cours_chimie