Course Outline
ChE 3BK3: Bio-Reaction Engineering
September - December, 2022

Instructor: Dr. Kim Jones (she/her)
Contact info: JHE-371; Ext. 26333; kjones@mcmaster.ca; Bioreaction Engineering Team

Teaching Assistants: Laura Neely (she/her); Email: neelyl@mcmaster.ca
Mrunal Igawale (she/her); Email: ingawalm@mcmaster.ca

Schedule: 3 lecture-hours per week (Monday, Wednesday and Thursday: 16:30-17:20) in person in JHE 210. Because I will work on the board and have interactive components, it will not be effective to live stream. I will try to ensure that if you miss class, you will have resources to keep up. We will have a Microsoft Team and if conditions change, will switch to virtual lectures.
The land on which we learn is on the traditional territories of the Mississauga and Haudenosaunee nations, and within the lands protected by the "Dish with One Spoon" wampum agreement.

Learning Objectives: Understand the basics of -

1) Kinetics of cellular processes, microbial processes and enzyme reactions including those of immobilized cells and enzymes.
2) Cell culture. bioreactor design, operation, scale-up and control.
3) Bioprocess development including downstream processing.
4) Expression systems.

Objective: To provide students with an understanding of the fundamentals of biological processes, including biological reaction kinetics, and bioprocess design, scale-up and operation.

Course Text: M.L. Shuler, F. Kargi and M. DeLisa
Bioprocess Engineering: Basic Concepts, Third Edition, Prentice Hall, 2017

Web Page for Course: Avenue to Learn; MS Teams Bioreaction Engineering

Assessment: Problem Sets (2 oral assessments @ 9% each; 8 written @ 4% each) – 50%
Participation – 10%
Summary of Research Paper – 15%
Powerpoint presentation of research paper equations – 15%
Final exam (open book) – 10%

MSAF Policy: You will get an extension for anything you MSAF, because the assignments and projects all contribute to your learning. Grading weights will remain the same. Please contact me as soon as possible to discuss what you need to succeed. If you need accommodations (through SAS or otherwise), please let me know what your needs are so we can best work toward your success together. If you have caregiving responsibilities that may interfere with this class, please contact me and we can try to find flexible solutions.

Prerequisites: There are no prerequisites for this course. If you have previously taken courses in mass balances, reactor design or biology, some concepts will be more familiar. Don't worry if you haven't! I will cover every concept in enough detail that you will be able to succeed in this class. If you are ever feeling overwhelmed or uncertain, please reach out to me. I've had that same sense of being overwhelmed by biology: I did a master's in biology after an undergraduate degree in Chemical Engineering. I hadn't even taken biology in my last year of high school. If I can manage such a steep learning curve, you can certainly manage this. I won't lie – I thought about giving up, but I am so glad I didn't. The key was seeking help.

Course Outline
ChE 3BK3: Bio-Reaction Engineering
September - December, 2022

Office hours:

I do not set office hours, because they are restrictive. I am eager to get to know you and to help, so please reach out by email or through Teams and we'll set up a meeting time that works for both of us. My goal is to meet individually with each of you (briefly at least) at some time through the term. If you put "3BK3" in the subject line (or @ me on Teams), I will do my best to respond within 24 hours, but I do not consistently check my messages after 6 PM or on weekends because I'm spending time with my family. If I don't get back to you within that time, please send me a gentle reminder; I will appreciate it. Your teaching assistants are also available to help and will share their availability.

Assignments:

There are 11 assignments – but two (assignments 5 and 9) are more like oral midterm exams and will be worth more. These assignments will be handed in on Avenue (like all assignments), but the grading will be assigned exclusively based on oral assessment. You will arrange a Teams meeting time (ten minutes long) with a TA, who will ask you questions about your solutions that will probe your understanding and will give you immediate feedback. These two **oral assessments will each be worth 9%** of your final grade. All other assignments will be worth a total of 32% of your final grade. The bottom assignment (excluding the oral assessments) will be dropped, so **each assignment is worth 4%** of your final grade. While peer learning is valuable, it is essential that each student completes the assignments individually.

Participation:

Now that we are back in person, I want to be sure you are really engaged. We will be working on problems in class and I'll be looking for answers to questions in class. While I will not take attendance, I will have a class list with me and will be asking **questions of random students** – so I will record it if you do not answer! If your preferred name is not the same as the name that appears on the university provided roster for the course, please let me know so that I can use your preferred name. There are no participation penalties for incorrect answers (or "I don't know"): this is valuable feedback! Please let me know if you are deeply uncomfortable being asked questions (due to social anxiety or any other reason). If you cannot attend a class in person, you must submit a **three-line summary** of the previous class (based on posted Powerpoints and notes), due on Avenue before the start of the next class. In addition, you must sign up to share **written notes** at least two times during the term. These will be due within 24 hours of the class. Bonus point if you type everything (correctly and including formulas) in a Word document. I expect that there will be higher than usual absenteeism due to COVID, so this will hopefully help those who cannot attend class (and others!).

Final exam:

When we were virtual, we moved to having the final exam be worth much less. We will experiment with this again this year. In the event that we move back to virtual instruction, I will maintain an option for individual 10 minute oral exams during the exam period, in which case, you would be given the exam questions two days in advance and you would have to hand in your completed exam on Avenue. This would not be explicitly graded, but rather, you would orally answer questions about how you solved the problems. We will vote in class to see which format you prefer.

Format for the Summary of Research Paper:

The objective of this activity is for you to get into the habit of reading, understanding, evaluating and simplifying cutting-edge research publications. This is an individual project and not a group project. I feel that this is a very rich exercise in terms of being able to distill information from a high-level publication and to communicate this efficiently to others, a critical set of skills in highly dynamic industries. Imagine you are working in a biotechnology industry, you read a paper that has exciting implications for your company and you want to communicate this effectively to your management team.

While you are summarizing the paper, your focus will be on how the paper will improve a bioprocess. Describe how this advancement helps in bioreactor operation in industry. This will help you select the paper. You could look at a new bioreactor advancement (for wastewater, pharmaceuticals, waste treatment, biofuel production, enzyme production etc.), metabolic engineering, organ-on-a-chip mini-bioreactors, cell co-culture systems, gene delivery systems or more. Things like drug delivery, tissue engineering etc. are much more difficult to consider how something in the paper could improve a bioprocess - though you can be creative and consider how a bioconjugation or microencapsulation technique could be used for enzyme or cell immobilisation within a bioreactor.

The paper must be an original research paper (**not a review**) from within the last five years. I am flexible on the number of times it has been cited. I'd advise using Google Scholar to start your search (and Wikipedia to help you understand terminology). To get free access to papers, go to library.mcmaster.ca, which will give you free access to most papers. So - you might do your initial search through scholar.google.ca then type in the article title in your McMaster search. You'll have to log in (using your macid) to get access.

For the Summary, the word count (not including title or references) must be 160-240 words, and beyond that, your penalty will be based on % away from 200 (e.g. word count of 241 would be 20% off). Please include the word count in the header (or title page) of your document. The idea is that you are very briefly communicating the key idea of a paper to your boss, while explaining how it could affect your business / process. Be succinct and convincing! You should still include reference(s). I prefer 11 point Times New Roman, double spaced with standard margins.

Summary rubric:

Appropriate level of detail and explanation for a manager in the field who is not a specialist researcher	/5
- Do not just summarise the whole paper; consider what the key “improvement” is. How could the paper change your bioprocess? - Share enough detail from the paper that you are credible and convincing and you could potentially quantify improvements	
Bioprocess application and relevance to class is clearly described	/5
- The hypothetical bioprocess in your “company” is described - The paper / improvement is to improve a bioprocess, not a biomedical device (e.g. in the scope of the Bioreactors course); specifically mention the part of the course that this addresses	
Overall quality of summary	/5
- Pyramid style (e.g. first sentence has the key message, then details follow) - No grammar / spelling errors; technical terms are used properly - Demonstrates that you understood and applied the “breakthrough” in the paper	

Format for the Powerpoint Presentation of Research Paper Equations:

The objective of this activity is for you to be able to interpret and explain equations that you find in a peer-reviewed, recent bioprocessing research paper, making reference to this course. You will select a recent (2017-2022) research paper (NOT a review paper) that models cell behaviour (e.g. growth in bioreactors, synthetic biology etc.) and create a short "lesson" that is comprehensible by your classmates by the end of the term. You will record a 5-15 minute voice-over Powerpoint presentation. You must have the paper approved by me by the end of October. It can be the same paper as you summarized.

Presentation rubric:

Context of paper presented at level of our class. Significance clearly explained	/5
- include background/context of the paper - what is the purpose of the paper? - explain why the equation (in paper) is important	
Key equation presented and carefully explained	/10
- breakdown the equation into parts and explain each part, how are they used? - what parameters are used in the model (define the variables) - go into detail about the model(s): any error analysis (if applicable), comparison between models (if applicable), does it describe or predict data trends well? what does it describe? - IF THE PAPER IS LENGTHY: focus on key equations (don't cram every detail into the presentation → this presentation is not a summary of research results!) - THIS SHOULD BE THE BULK OF THE PRESENTATION	
Link to course material evident (no need to link to specific equations, but link to content from the course)	/5
- ex. system conditions assumed in class vs. those in the paper - ex. presence or absence of equation terms vs. in class - ex. are terms/equations similar or derived from equations taught in class? - ex. relate to class topics/applications/systems/reactor types/etc. - BE EXPLICIT	
Overall quality of presentation	/5
- focus on the paper's equation(s) rather than the paper outcome - easy to read text, figures/tables/other visuals not blurry - slides are uncluttered, numbered, have a good balance of text, equations, figures/tables	

Given the uncertainty associated with public health, we reserve the right to alter this outline as appropriate.

Course Outline
ChE 3BK3: Bio-Reaction Engineering
September - December, 2022

Tentative Course Outline:

LECTURE PERIODS	ACTIVITIES	CHAPTERS IN SHULER AND F. KARGI
1	Introduction	
2-3	Applied microbiology (cell growth, nutrition, the “cell factory”)	Ch. 2
4-7	Enzymes (structure/function, kinetics, industrial enzymes)	Ch. 3
8-9	Gene expression, metabolic regulation	Ch.4
10-12	Cell growth (metabolism)	Ch. 5
13-15	Growth kinetics (batch & continuous growth kinetics, structured and unstructured models)	Ch. 6
16	Stoichiometry (microbial growth and product formation)	Ch. 7
17-22	Bioreactor design and operation (suspended and immobilized cultures)	Ch. 9
23-27	Scale-up and control of bioreactors (transport phenomena, instrumentation, sterilization, examples of large-scale bioprocesses)	Ch. 10
28	Overview of downstream processes (recovery and purification)	Ch. 11
29	Choice of expression system (microbial, mammalian, transgenic)	Ch. 12
30-34	Presentations	
35	Review	

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

The following illustrates only three forms of academic dishonesty:
•plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
•improper collaboration in group work.
•copying or using unauthorized aids in tests and examinations.

AUTHENTICITY/PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

ONLINE PROCTORING

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/ software during tests or exams. This software may be required to be installed before the test/exam begins.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS)at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors. The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email

The P.R.O.C.E.S.S.

As some of you may already be aware, the department of Chemical Engineering has a storied history of education. In addition to teaching and learning, the department is proud of our graduates not only for their academic success, but their more intrinsic traits that make them respected members of the engineering community.

Recently, several high-ranking graduates from the McMaster Chemical Engineering Program employed in various industries (oil/gas, financials, *etc*.) were interviewed to ask what traits they look for when hiring for engineering positions. Using this information, the department would like to present to you the **PROCESS**: a code of conduct that we hope will guide our students throughout this program and their careers to come.

- **P**rofessionalism
- **R**esponsibility
- **O**wnership
- **C**uriosity
- **E**mpathy (and Equity)
- **S**elflessness
- **S**ervice

It is up to YOU to interpret these traits and apply them to your time at McMaster and your career as you see fit. These traits will not be assessed for grades but will be strongly encouraged throughout your time at McMaster. We hope that you identify with these character traits and what they mean to you, and that you **trust the process**.