

CHM 414H: Biosensors and Chemical Sensors

Course Syllabus: Winter 2024

I TEACHING INSTRUCTOR



INSTRUCTOR

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Online and in person student hours: available by appointment (Email)

Instructor biography

Professor Michael Thompson obtained his undergraduate degree from the University of Wales, UK and his PhD in analytical chemistry from McMaster University. Following a period as Science Research Council PDF at Swansea University he was appointed Lecturer in Instrumental Analysis at Loughborough University. He then moved to the University of Toronto where he is now Professor of Bioanalytical Chemistry. He is recognized internationally for his pioneering work over many years in the area of research into new biosensor technologies and the surface chemistry of biochemical and biological entities. He has made major contributions to the label-free detection of biological macromolecule interactions and surface behavior of cells using ultra high frequency acoustic wave physics. He has also pioneered the development of anti-fouling surface modification, in particular antithrombogenic and anti-microbial adhesion materials. Thompson has served on the Editorial Boards of a number of major international journals including *Analytical Chemistry*, *The Analyst*, *Talanta*, *Analytica Chimica Acta* and *Biosensors and Bioelectronics*. He is currently Editor-in-Chief of the monograph series "Detection Science" for the Royal Society of Chemistry, UK. He has been awarded many prestigious international prizes for his research including The Robert Boyle Gold Medal of the Royal Society of Chemistry, E.W.R. Steacie Award of the Chemical Society of Canada, the Theophilus Redwood Award of the Royal Society of Chemistry, the E.T.S. Walton Award of the Science Foundation of Ireland, Fisher Scientific Award in Analytical Chemistry of the Chemical Society of Canada and the RSC Horizons Prize. He was made a Fellow of the Royal Society of Canada in 1999.

CO-INSTRUCTOR(S) None

TA(s) None

II COURSE OVERVIEW

COURSE DESCRIPTION:

The notion of a sensor device is common knowledge to all. The range of these structures in modern times is immense, ranging from simple physical measurements such as temperature to complex devices that incorporate human cells in their design. The number of applications is also numerous including industrial processing, pharmaceutical analysis, automotive operation, military technology and environmental signaling to name just a few areas of use. In this course, we introduce the basics of a special branch of sensor technology that deals with the detection of chemicals and biological species, *the chemical and biosensor device*. The course proceeds from a description of overall sensor architecture, to devices types based on electrochemistry, piezoelectrics, acoustic wave physics and optical science. The course also covers potential applications of these devices especially in the world of medicine. The course is especially interdisciplinary in nature, allowing the student to gain a good understanding of the merging of chemistry with biology, materials science and electronic engineering.

STUDENT LEARNING OUTCOMES:

The notion of a sensor will be familiar to students in their 4th year of study. In this course class members will be able to understand how such devices can be designed for research and applications where detection of biochemical entities are involved. This aim will be achieved by first explaining how biosensors are fabricated including the various physicochemical properties required for this purpose. In particular, students will be able to appreciate the chemistry of sensor transduction processes, compare the performance of various biosensors and from the course have an excellent grounding in the potential applications of biosensors. Such knowledge will be valuable for those who intend to take up a career in bioanalytical chemistry. Finally, the course is highly disciplinary in character which lead the students to a very good understanding of links between chemistry, materials science, biology and medicine.

PREREQUISITE COURSE(S):

This course assumes you have a basic understanding of analytical and physical chemistry principles; some knowledge of biochemistry is helpful.
Prerequisite courses: CHM 217H, (CHM 220H, CHM 222H)/CHM 225Y, however course admission is at the discretion of the instructor.

READINGS:

There is no specific course text book. However, throughout the course an extensive set of review articles, papers and editorials are sent in a timely fashion to class members. In addition, following each lecture, PP slides are provided within 24 hours.

III COURSE ORGANIZATION

This course is organized by topic areas (below) in terms of specific dates during the fall semester.

COURSE SCHEDULE & RELEVANT SESSIONAL DATES:

DATES	WEEK	TOPICS
Week of Jan. 8th 2 lectures	1	<ul style="list-style-type: none">• Introduction to biosensor architecture Types of sensors; components and design; ideal requirements• Probe attachment Types of probe – antibodies, nucleic acids, enzymes, receptors; criteria for device surface attachment, introduction to the non-specific adsorption problem
Week of Jan, 15th 2 lectures	2	<ul style="list-style-type: none">• Methods for probe attachment to surfaces Adsorption; chemisorption v physisorption; polymer trapping; covalent attachment; film deposition techniques; molecular imprinted polymers and biomimicry.
Week of Jan.22nd 2 lectures	3	<ul style="list-style-type: none">• Surface characterization Probe information required; general characteristics of surface analysis, X-ray photoelectron spectroscopy; secondary ion mass spectrometry; Auger spectroscopy; probe techniques such as atomic force microscopy; scanning tunneling microscopy
Week of Jan, 29th 2 lectures	4	<ul style="list-style-type: none">• Electrochemical sensors Types of device – potentiometric, amperometric, voltammetric; ion selective electrodes; physics of field effect transistor technology - ISFETS, IMMUNOFETS; history and design of the glucose electrode; nucleic acid –based electrochemical sensing

Week Feb, 5th 2 lectures	5	<ul style="list-style-type: none"> • Applications of electrochemical devices; Detection of ions in the body, measurement of K⁺ in epilepsy; the legendary implantable glucose device for diabetic patients
Week of Feb 12th 2 lectures	6	<ul style="list-style-type: none"> • Piezoelectricity based sensors <p>The piezoelectric phenomenon; role of the Curies; basic crystal physics; the bulk acoustic wave device; gas phase sensing and analytical science; the Sauerbrey response equation</p>
Reading Week February 19-23		No lectures
Week of Feb.26th 2 lectures	7	<ul style="list-style-type: none"> • The bulk acoustic device in liquids and other devices <p>Propagation of acoustic waves in fluids; other devices – surface acoustic wave, shear horizontal wave, surface transverse wave</p>
Weeks of March 4th 2 lectures	8	<ul style="list-style-type: none"> • Applications of acoustic wave devices <p>Assay of the non-specific adsorption / fouling issue, avoidance of NSA; applications in medicine; detection of endotoxin; stage 1 ovarian cancer detection</p>
Week of March 11th 2 lectures	9	<ul style="list-style-type: none"> • Introduction to optical science based Devices <p>Basics of wave physics; Sources of radiation for sensors; laser technology; optical components; the evanescence wave effect</p>
Week of March 18th 2 lectures	10	<ul style="list-style-type: none"> • Fiber optic and surface plasmon resonance <p>Fiber optic-based systems for sensing; intrinsic versus extrinsic sensing mechanisms; evanescent wave technology; the phenomenon of surface plasmon resonance; design of the SPR experiment for bio-sensing; other types such interferometry</p>

Week of March 25rd 2 lectures	11	<ul style="list-style-type: none"> • Applications of SPR Detection of immunochemistry effects; assessment of binding properties of antibodies; assay in environmental chemistry, appraisal and comparison with acoustic devices
April 1st 1 lecture	12	<ul style="list-style-type: none"> • Review Comprehensive appraisal of biosensor technology, current problems in application, What does the future hold?
April 3rd 1 session	13	<ul style="list-style-type: none"> • Class discussion on biosensor topics and course review

TUTORIAL OBJECTIVES: No tutorials

LABORATORY OBJECTIVES: No laboratory class

IV EVALUATION/GRADING SCHEME

OVERVIEW:

Peer Assignment = 40% total grade.

Final Course Essay = 50% total grade.

Course Participation = 10% total grade (based on questions asked following lectures plus email and ZOOM discussion).

ASSESSMENT DATES & MARK BREAKDOWN:

1. Assignment handed out 2 weeks before it is due at 5:00 PM on March 4th.

Assignment is worth 40% of the total mark

2. Essays will be due on the last day of the semester (April 5th) at 11:59 PM.

Suggested essay topics will be provided to class members by March 1st. Students can choose their own topic but must be checked by MT first.

IMPORTANT: if an unexpected technical issue occurs with a university system (e.g., Quercus services, network outage) that affects availability or functionality, it may be necessary to revise the timing or weighting of the quizzes/term tests.

V COURSE POLICIES

- Each member of this course is expected to maintain a:
 - (i) professional and respectful attitude during all course activities, including classes, laboratories, tutorials, and online activity.
 - (ii) personal calendar/schedule/organizer to ensure that all course activities are completed, and due dates are met.
 - (iii) collection of notes recorded independently based on concepts covered in course activities (students registered with Accessibility Services requiring a class note-taker will have access to this accommodation)
 - (iv) familiarity with the university policy on Academic Integrity (overleaf)
- The University of Toronto is committed to equity, human rights, and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another's differences. As a Course Instructor, I will neither condone nor tolerate behaviour that undermines the dignity or self-esteem of any individual in this course and wish to be alerted to any attempt to create an intimidating or hostile environment. It is our collective responsibility to create a space that is inclusive and welcomes discussion. Discrimination, harassment and hate speech will not be tolerated. If you have any questions, comments, or concerns, we encourage you to reach out to the staff in our Equity Offices.
- Required: process for signaling course absences and requesting make-up tests or other missed pieces of work.

If you are absent from your studies due to illness or other reasons and unable to complete course work (e.g., a term test or an assignment) then a piece of written documentation is required. The following four items are the recognized forms of documentation:

1. [Absence Declaration via ACORN](#) (please note the circumstances under which an absence declaration can and cannot be submitted)
2. [U of T Verification of Illness or Injury Form](#)
3. College Registrar's letter
4. Letter of Academic Accommodation from Accessibility Services

Students who complete the ACORN Absence Declaration form must additionally contact me/the course coordinator/the course administrator to discuss their situation within five business days of the missed piece of work. This is essential action for any consideration to be granted.

For extended absences and for absences due to non-medical reasons, make sure to contact your [College Registrar's Office](#). They can help you decide between a request for an extension or other types of academic consideration.

If you suspect or know that you have a disability that is affecting your studies, [learn about the services and supports available through Accessibility Services](#). A disability can be physical disability, sensory disability, a learning disability, mental health disorder or a short-term disability like an injury. If you are not sure whether you have a disability, you can confidentially contact [Accessibility Services](#) with your questions.

- Required: information regarding used of artificial intelligence tools. Please refer to the “U of T Syllabus Language – Use of Generative AI in Assignments” document for guidance regarding this: <https://www.vicereprovostundergrad.utoronto.ca/wp-content/uploads/sites/275/2023/04/Syllabus-Language-for-Gen-AI-April-2023.pdf>. There is recommended language in terms of “can use”, “can use in certain instances” and “cannot use”. For more information, see: <https://teaching.utoronto.ca/resources/generative-artificial-intelligence-in-the-classroom/>.
- Communication with instructor (e.g., I will respond to email within 24 hrs. on weekdays).
- Privacy language and appropriate use of course materials: For additional information, see the syllabus “Copyright” section.
- Policy for late assignment submissions (e.g., x% will be deducted daily).
- Policy for reweighting due to missed pieces of academic work: For students missing one term test for a valid reason, the missed test grade will be calculated based on individual performance on the other two term tests and the class average of the other two tests. For students missing two or more tests for valid reasons the mark for the missing tests will be replaced by a cumulative, two-hour assessment to be written in-person. This assessment will cover all aspects of both the laboratory and classroom components of the course.
- Assignment/laboratory report submission methods (e.g., use Quercus only).
- Process for requesting re-grading of course work.

VI TECHNOLOGY REQUIREMENTS

- Specific guidance from the U of T Vice-Provost, Students regarding student technology requirements is available here: <https://www.vicereprovoststudents.utoronto.ca/covid-19/tech-requirements-online-learning/>

- Advice for students writing online assessments (quizzes etc.): <https://studentlife.utoronto.ca/task/online-exams-and-tests/>
- This course requires the use of computers, and technical issues are possible. When working on a piece of academic work, students are responsible for scheduling enough time to allow for reasonable delays due to technical difficulties to be overcome, so such issues will not be acceptable grounds for deadline extension. Particularly, maintaining an up-to-date independent backup copy of your work is strongly recommended to guard against hard-drive failures, corrupted files, lost computers, etc.

VII INSTITUTIONAL POLICIES & SUPPORT

AI

The use of generative artificial intelligence (AI) tools and apps is strictly prohibited in all course assignments unless explicitly stated otherwise by the instructor in this course. This includes ChatGPT and other AI writing and coding assistants. Use of generative AI in this course may be considered as use of an unauthorized aid, which is a form of cheating. This course policy is designed to promote your learning and intellectual development and to help you reach the course learning outcomes

ACADEMIC INTEGRITY

Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto's Code of Behaviour on Academic Matters (governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In laboratory reports:

1. Using someone else's ideas or words without appropriate acknowledgement.
2. Submitting your own work in more than one course without the permission of the instructor.
3. Making up sources or facts.
4. Obtaining or providing unauthorized assistance on any report. **Please note that the use of websites (such as Chegg.com or the course discussion board) to post laboratory report material/questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student**

Academic Integrity office.

On quizzes and term tests:

1. Using or possessing unauthorized aids. **Please note that the use of websites (such as Chegg.com or the course discussion board) to post quiz/term test questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student Academic Integrity office.**
2. Looking at someone else's answers or collaborating/discussing answers during a quiz or term test.
3. Misrepresenting your identity.

In general academic work:

1. Falsifying institutional documents or grades.
2. Falsifying or altering any documentation required by the University.

All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see www.academicintegrity.utoronto.ca/).

Plagiarism Detection

Required: note for instructor: *Ouriginal (<https://teaching.utoronto.ca/tool-guides/plagiarism-review-ouriginal/>) is a very highly recommended tool directly integrated into Quercus that will assist in detecting textual similarities between compared works. **Students must be informed at the start of the course if an instructor will be using Ouriginal.** If you plan to use this tool, the course syllabus must include the following statement (as is):*

"Normally, students will be required to submit their course essays to the University's plagiarism detection tool for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their essays to be included as source documents in the tool's reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of this tool are described on the Centre for Teaching Support & Innovation web site (<https://uoft.me/pdt-faq>)".

COPYRIGHT

Required: note for instructor: *sample statements for policies regarding class recordings are available here: <https://teaching.utoronto.ca/ed-tech/audio-video/sample-statements/>*

If a student wishes to copy or reproduce class presentations, course notes or other similar materials provided by instructors, he or she must obtain the instructor's written consent beforehand. Otherwise, all such reproduction is an infringement of copyright and is absolutely prohibited.

ACCESSIBILITY NEEDS

Students with diverse learning styles and needs are extremely welcome in this course. The University of Toronto is committed to accessibility: if you require accommodations for a disability, or have any other accessibility concerns about the course, please contact [Accessibility Services](#) as soon as possible.

ACCOMMODATIONS FOR RELIGIOUS OBSERVANCES

Following the University's policies, reasonable accommodations will be made for students who observe religious holy days that coincide with the due date/time of an assignment, tutorial, class or laboratory session. Students must inform the instructor **before** the session/assignment date to arrange accommodations.

ADDITIONAL SERVICES & SUPPORT

The following are some important links to help you with academic and/or technical service and support:

- General student services and resources at [Student Life](#)
- Full library service through [University of Toronto Libraries](#)
- Resources on conducting online research through [University Libraries Research](#)
- Resources on academic support from the [Academic Success Centre](#)
- Learner support at the [Writing Centre](#)
- Information for [Quercus Support](#)

ACKNOWLEDGEMENT OF TRADITIONAL LANDS

: <https://indigenous.utoronto.ca/about/land-acknowledgement/>): We wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and, most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.³