CHBE 472/572: Technologies for Human and Environmental Health

This course provides an introduction to the fundamental underpinnings and applications of modern technologies used to analyze human and environmental samples to facilitate clinical or ecological decisions. Application areas emphasize health diagnostics and environmental health monitoring. The course is highly interactive and will include invited academic and industrial speakers. In this course, you will be asked, frequently, to practice thinking about hypotheses, the science underlying the methods, and interpretation of data in a deep way. Assessment of learning and performance in the undergraduate course will be based on presentations, assignments, and a final project. Students enrolled in the graduate course will be assessed based on presentations and assignments, but will be required to complete a more extensive term project that may be linked to their broader research goals.

Prerequisites: 4th year BASc or BSc standing.

Course Overview

Instructor: Jane E. Hill
jane.hill@ubc.ca
https://hilllab.chbe.ubc.ca/index.html
https://humanbreathatlas.com/
Short bio: Born and raised in Australia, spent 25 years in the USA (East Coast), and moved to BC at the start of the SARS pandemic. Canada Research Chair in Breath Science and Technologies. Leading the Human Breath Atlas. Enjoys: tennis, science, business, gardening, music, and science fiction.

TA: Antao Gao
agao3@mail.ubc.ca
Short bio: From Shandong Province, China, and started his Ph.D. at CHBE (Hill Lab) in 2020. His research focused on volatile biomarkers in human breath and body fluids associated with lung diseases. Enjoys: piano, documentaries, and tennis.

Lectures: Tuesdays 4-7 pm

Assessments:

CHBE 472
Weekly assignments (25 %)
Weekly presentations (20 %)
Mid-term assignment (25 %)
Term project + project presentation/Q&A (30 %)

CHBE 572
Weekly assignments (25 %)
Weekly presentations (20 %)
Mid-term assignment (15 %)
Large term project + project presentation/Q&A (40 %)

Course Location - CHBE

During your time at UBC's Point Grey campus, you will often hear or read that UBC or a department, unit, or faculty is situated on the traditional, ancestral and unceded territory of the Musqueam people. This may seem like virtue signaling … and maybe it is. However, as an indigenous person from another place, this is still a step forward, so, there is that … Perhaps take a moment to appreciate the meaning behind the words we use:

- **Traditional**: recognizes lands traditionally used and/or occupied by the Musqueam people or other First Nations in other parts of the country.
- **Ancestral**: recognizes land that is handed down from generation to generation.
- **Unceded**: refers to land that was not turned over to the Crown by a treaty or other agreement.

- Adapted from https://students.ubc.ca/ubclife/what-land-acknowledgement

In addition, we recognize our class diversity as well as the diverse populations encompassed by the studies we will review as part of the course material. One key takeaway from this course is that human physiology differs between people in all sorts of ways (age, sex, ethnicity mix, diet, et cetera) i.e., taking into account diversity is good science, too.

Course – Basic Details

Course Structure

This course is divided into modules. They are:

Module 1: Health technology; guide to evaluating papers
Module 2: Genomes, proteomes, metabolomes
Module 3: Human health applications – case studies on sepsis
Module 4: Health and environmental applications - biological aerosol case studies on tuberculosis
Module 5: Environmental health applications – case studies on toxic exposures
Module 6: Term project presentations plus Q and A

The classes typically include a mix of lectures, in-class group activities, vigorous discussions, and occasional guest speakers. Student may be assigned pre-readings or other material to prepare for classes. Canvas will be used to provide students with all materials relating to the course.

Course Website: canvas.ubc.ca

Course notes

Lecture notes and additional materials will be provided through Canvas. There is no textbook for the course.

Academic integrity

TL:DR → the work you are assessed on should be your own. Cheating will have serious consequences.

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others, as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences. (*Adapted from the APSSC 366 syllabus*)

Course - Assessment Details

UBC's grading policies are outlined here: http://www.calendar.ubc.ca/vancouver/?tree=3,42,96,0

Evaluation

Weekly assignments	25 %
Weekly presentations	20 %
Mid-term presentation	25 %
Term project	30 %

Weekly assignments

These are 1-2 page technical notes that you will write focusing on an emerging or an established method or diagnostic. When we have guest speakers present, this assignment will be focused on their areas of expertise. These will be individual assignments.

Weekly presentations

Depending on the number of students in the course, you will do weekly or biweekly presentation/discussion session on an established or emerging technology. These assignments will be done in pairs.

Mid-term presentation

This is an in-depth bioanalytic-focused description of an 'omic technology platform from a recent paper from Science, Nature, or PNAS. The emphasis of this assignment is on the system processes, for example, fluid transport, chemistries, etc, i.e., the fundamental principles behind the advance. The deliverable is a 10 minute presentation and 5 page appendix.

Term project

The culminating project focuses on your hypothetical diagnosis of a specific disease using one of the tools (in a novel way) discussed in the course or a completely new system you have thought of yourself. Depending on the number of students in the course, this may be an individual or paired assignment. The deliverables are a 10 minute presentation and an (up to) 5 page response to questions raised during the presentation Q and A session. Graduate students will have an additional assignment deliverable at the end of term, which will be determined after consultation with the instructor.

Extensions/Late Policy

- Weekly assignments are due at 4 pm the day of class. Submit to Canvas.
- Assignments submitted within 24 h of deadline will have 10% (of the total grade potentially earned) deducted.
- Assignments submitted within 48 h of deadline will have a 25% (of the total grade potentially earned) deducted.
- No grade will be assigned for assignments handed in after the 48 h grace period.

Academic concession

Academic concession may be requested for a variety of reasons, such as illness, injury, or family tragedy, which prevent you from completing graded work. Within APSC, all requests for academic concession go through a webform. Please complete the "Academic Concession: In-Term Work" form here:

https://academicservices.engineering.ubc.ca/exams-grades/academic-concession/

Course - Big Picture Learning Goals

Upon successful completion of this course, it is expected that students will be able to:

- Speak the language of bioanalytics and diagnostics
- Develop a fundamental understanding of and appreciation for (bio)technology, specifically through the lens of bioanalytics and diagnostics for health and environmental applications.
- Recognize and be able to evaluate diagnostic data in the context of disease
- Become familiar with current technologies as well as emerging approaches
- Demonstrate a fundamental understanding of the primary 'omic approaches (genomics, transcriptomics, proteomics, and metabolomics)

In each class you will be practicing how to think and evaluate health and environmental tools, including integration of systems level components as well as the fundamental physics and/or chemistry being utilized.

Course – Learning Outcomes

More specifically, at the end of this course, you should be able to:

Module 1: Introduction to health technologies; guide to evaluating papers (week 1)

- Explain the role of chemical and biological engineering in the biotechnology field, particularly as it pertains to diagnostics and monitoring.
- Coherently share the following for any published scientific manuscript:
    - Paper hypotheses and aims,
    - Diagram of the project study design,
    - Listing the key chemical and physical concepts employed,
    - Interpretation of the results, and
    - Context of the advance in terms of clinical and/or environmental utility.

Module 2: Genomes, proteomes, metabolomes (week 2)

- Define what is meant by the following terms: genomics, transcriptomics, proteomics, metabolomics, and any other 'omic approaches discussed in the course.
- Explain why the sequencing of the human genome did not lead to the resolution of all diseases in human beings.
- Explain the most common technologies for sequencing genomes as well as measure a transcripts, proteomes, and metabolomes. And, be familiar with emerging technologies and how they compare to current systems.
- List applications of 'omics science in environmental monitoring and preservation
- Describe (including formulae): diffusion, capillary action, buffers, reagents, reaction kinetics.

Module 3: Human health applications – case studies on sepsis (weeks 3-6)

For sepsis pathophysiology:

- Articulate and list the clinical features of disease onset, treatment, and progression of sepsis.
- List the treatment options and their effectiveness.
- Give morbidity, mortality, and prognosis for those with sepsis and septic shock.

- For sepsis diagnostics:
    - Explain how sepsis is currently diagnosed for neonates, pediatric, and adult populations.
    - Diagram the diagnostic approval pathway for a new diagnostic (by the FDA/EMA/etc).
    - Define the physical, chemical, and fluid-based methodologies employed in diagnosing sepsis used by:
        - Blood tests,
        - Blood culture and susceptibility tests, and
        - Procalcitonin.

- Explain and evaluate new technologies and their ability to diagnosis sepsis in a way that leads to clinical action for:
    - Bugs in blood and
    - Host 'omic profiling approaches.
- Describe and calculate, in the context of sepsis: electrophoresis, gel filtration, ion exchange chromatography, fluorescent signal chemistry, nanopore electrochemistry, and electrospray ionization.
- Describe and provide formula for the following processes: chemistries for the preservation and processing of blood, the pressures needed and the flow rates induced for vacutainer blood collection, CO_2 sensing technologies for blood culture, the unique biochemistry of *Staphylococcus aureus*, *Escherichia coli*, and coagulase-negative *Staphylococcus spp*.

Module 4: **Health and environmental applications - biological aerosol case studies on tuberculosis (weeks 6-7)**

- For MTB complex pathophysiology,
    - Articulate and list the clinical features of disease onset, treatment, and progression of TB for:
        - Regular adults
        - Children
        - Cattle
    - List the treatment options and their effectiveness.
    - Give morbidity, mortality, and prognosis for those with drug-susceptible TB, MDR TB and XDR TB.
- For TB diagnostics:
    - Explain how TB is currently diagnosed for humans (pediatric and adult) as well as in cattle
    - Define the physical, chemical, and fluid-based methodologies employed in diagnosing TB used by:
        - GeneXpert
        - MGIT culture
    - Calculate broadly around the concepts of extraction, batch reactors, capillary-based transport of sample and reagents, as well as RT-PCR.
- Diagram aerosol transmission concepts and calculate airborne residence time
- Explain and evaluate new technologies and their ability to diagnosis TB in a way that leads to clinical action for:
        - Breath
        - Mask aerosol collection
        - Impact samplers
    - Describe and calculate principles associated with gas chromatography for the separation of molecules found in exhaled breath
    - Describe and calculate the extraction of TB from filters for the ultimate purpose of conducting NAATs

Module 5: Environmental health applications – case studies on toxic exposures (weeks 8-10)

- Describe the routes of inhalation exposure in the workplace and environment
- Diagram the fate and transport of inhalation exposures
    - Describe the broad classes of chemical transformations during compound fate and transport
    - Describe sample collection, sample preservation, and sample analysis tools employed to measure chemical fate, chemical transformation, and chemical transport
- In the context of climate change creating increasing forest fires (including loss of property)
    - Diagram the factors causing an increase in the frequency of forest fires in the Pacific Northwest
    - Interpret and map particulate and volatile molecule transport for fires in BC
    - Describe the acute and chronic impacts of these exposures?
        - What populations are most at-risk?
        - What are the treatment options?
        - What is the associated
        - morbidity and mortality
- Describe and calculate the principles of gas and liquid chromatography as well as their use in combination with mass spectrometry, to measure particulate and volatile molecules in:
    - The air
    - The lung

- In fatty tissues

Module 6: Term project presentations plus Q and A (weeks 11-12)

- Integrate what you have learned in this course and show in your term project presentation.
- Generate a sufficiently detailed technical response to any (and all) questions asked during your final project presentation and share those answers with the class in the second sequenced lecture.

And generally,

- Describe the function of the clinical and analytical laboratories as a service to hospitals and clinics or government agencies and companies. Give examples of the types of tests run in each as well as their level of automation today as well as the automation expected in the next 5-10 years.
- Given a disease or environmental exposure, give it's pathophysiology. Using a given dataset, set up a framework to not only calculate the sensitivity, specificity, accuracy, and limits of detection for a target as well as show how you would evaluate if the tool is specifically and where it is not useful via SN, SP, AC, and LOD, etc. Where possible, include actionable context, too.