Faculté de pharmacie

Université de Montréal | Plan de cours

Register

General Information

Course	
Title	**Quantitative Systems Pharmacology**
Number of credits	2 credits
Course code	PHM 6062
StudiUM Site	
Faculty / School/ Department	Faculté de pharmacie
Term	Automn
year	2026

Teacher	
Name and Title	Fahima Nekka, professeure titulaire
Contact Information	Fahima.nekka@umontreal.ca
Availability	On demand

Contact Person	
Name and rRle	Mikelsie Féquière, technicienne en gestion de dossiers étudiants
Coordonnées	vice-decanat-recherche-sc-pharm@pharm.umontreal.ca
Availability	Sur demande, veuillez prévoir un délai dans les réponses

Course description

In this interactive course, the students will be introduced to Quantitative Systems Pharmacology (QSP), including its applications and computational aspects. The course includes interactive exercises designed to facilitate knowledge integration. Several case studies will be discussed to illustrate the progressive increase in complexity of the models and methodologies employed, and to highlight the role of QSP in drug development.

This course is intended for Master's and PhD students, as well as researchers working in clinical, regulatory, and industrial settings. Its objective is to introduce the foundations of QSP and its application across various therapeutic areas. The instructors are experts in classical pharmacokinetics (PK), population pharmacokinetics (PopPK), and Quantitative Systems Pharmacology (QSP), with complementary expertise in research and data analysis within academic, regulatory, and industrial environments.

The lessons will address :

- Introduction to the fundamental principles of Pharmacokinetics (PK), Population Pharmacokinetics (PopPK), and Quantitative Systems Pharmacology (QSP), with a particular emphasis on QSP.
- Introduction to scientific programming, data analysis, visualization, and simulation tools, including Monolix and MATLAB.
- Interactive illustration through educational examples (toy models) designed to demonstrate key concepts in pharmacometric modeling.
- Interactive discussion of scientific literature, including articles inspired by the speakers' own research, to highlight practical applications of PK, PopPK, and QSP.

Learning objectives

General Objectives

The objective of this course is to present the evolution of quantitative pharmacology and its growing role in supporting drug development. This graduate-level course aims to provide advanced scientific content at the forefront of QSP, illustrated through recent therapeutic applications. The course is complemented by discussions and practical examples designed to facilitate knowledge integration and deepen students' understanding of the concepts presented.

Learning Objectives

These new insights will help students acquiring the following skills:

- Integrate and compare different pharmacological modeling approaches more effectively.
- Understand the varying levels of complexity among these approaches and their contextual relevance.
- Learn how to conceptualize and develop a model based on available information, and make informed decisions regarding the most appropriate methodologies to adopt.
- Develop a broader perspective on pharmacometric research and stay at the forefront of emerging developments and evolving needs in the therapeutic sciences.

Calendar

- **When : September/October 2026**
- **Where : Faculté de pharmacie, Université de Montréal (Pavillon Jean-Coutu)**

	DATE	TITle	Teacher
Semaine 1			
1	21 September 2026 LOCAL	*Pharmacometrics: historical facts*	Fahima Nekka 3h
2		*Foundations of pharmacokinetics (PK)*	
3		*Parameter estimation*	
4	22 September 2026 LOCAL	*Introduction to MATLAB*	Dider Zugaj 2h
5	23 September 2026 LOCAL	*Target mediated drug disposition (TMDD) : theory and applications*	Fahima Nekka, Didier Zugaj 2h
6		*Why QSP : a necessicity complexity or an unnecessary burden?*	
7	24 September 2026 Online	*Suggested reading based on QSP papers for the course and students' presentations. Instructions for oral presentations. Q&R*	Fahima Nekka 1h
8	25 September 2026	*Free reading period*	
Semaine 2			
9	28 September 2026 LOCAL	*PopPK 1*	Guillaume Bonnefois & Olivier Barrière 2h
10	29 September 2026 LOCAL	*PopPK 2*	Guillaume Bonnefois & Olivier Barrière 3h
11	30 September 2026 LOCAL	A methodological framework for QSP model development and analysis	Fahima Nekka & Didier Zugaj 3h
12		Introduction to sensitivity analysis	
13		Introduction to identifiability analysis	
14	1er October 2026 LOCAL	*Introduction to immuno-oncology (IO)*	Didier Zugaj 2h
15		*Application. Immunogenomic DATA extraction from CRI-iAtlas*	
16		*Introduction to cancer growth models*	Fahima Nekka 1h

17	2 October 2026	*Free reading period*	
Semaine 3			
18	5 October 2026 LOCAL	Application: Dynamical systems analysis applied to QSP models: a case study of fibrosis	Fahima Nekka & Didier Zugaj 4h
19		Application: Coarse-grained non-small cell lung cancer (NSCLC) tumor-immune interaction model	
20	6 October 2026 LOCAL	Application: A physiologically based in silico kinetic model predicting plasma cholesterol concentrations in humans	Didier Zugaj 2h
21		*QSP modeling standardization using modular platforms*	Miriam Schirru 1h
22	7 October 2026 LOCAL	*Modeling in neurology/psichiatry : physiology, pharmacology and behaviour*	Philippe Robaey & Miriam Schirru 3h
23	8 October 2026 LOCAL	*Free reading period*	
24	9 October 2026 LOCAL	*Oral presentations by students*	Fahima Nekka and collaborators3h

Please note! In exceptional cases, the instructor may change the dates of assessments. If so, the instructor must obtain the support of a majority of the students in the class. Please refer to: l'article 4.8 du Règlement des études de premier cycle et à l'article 28 du Règlement pédagogique de la Faculté des études supérieures et postdoctorales.

Assessment

1. Group Work : adaptation to students' research projects; critique of models and assessment of learning outcomes : 50%
2. Oral presentation : 50%

Artificial Intelligence Tools

Unless explicitly authorized by the course instructor, the use of artificial intelligence tools is not permitted and is considered a case of plagiarism, as described in Article 1.2 o) du Règlement disciplinaire sur le plagiat ou la fraude concernant les étudiants du premier cycle and Règlement disciplinaire sur le plagiat et la fraude concernant les étudiants des cycles supérieurs.

Use of technology in class	
Courses recording	Recording classes is generally not permitted. If, for valid reasons, you wish to record a class session, you must first obtain written permission from your instructor using the form provided for this purpose. Please note that permission to record does NOT grant permission to distribute the recording.

Course content

Pharmacometrics. Historical facts
Evolution of pharmacometrics: necessity and feasibility. Application of pharmacometrics to drug development and therapeutics. Achievements and future potential.

Foundations of pharmacokinetics (PK)
LADMER framework. Drug adherence. Pharmacokinetic modeling. Different approaches to PK modeling. Compartmental models. Single-dose and multiple-dose regimens.

Parameter estimation
Regression algorithms. Linear and nonlinear regression methods. Best-fit criteria. Least-squares method. Selection of weighting schemes. Constraints on the parameter space. Residual method (stripping/peeling).

Introduction to MATLAB
Why MATLAB in Quantitative Systems Pharmacology (QSP)? Use of MATLAB and its toolboxes for QSP model development. Overview of applications in immuno-oncology (QSP-IO), virtual population generation, and evaluation of combination therapies using dynamical systems. Conceptual and mathematical framework: from dynamic systems to virtual populations. Case studies and MATLAB implementations.

Target-Mediated Drug Disposition (TMDD) Models: Theory and Applications
TMDD concepts with or without endogenous ligand production. Case study of a QSP-TMDD model in rheumatoid arthritis. Interindividual variability in pharmacokinetics and target engagement. Generation of virtual populations and TMDD-associated nonlinear PK behavior. Analysis of PK profiles, receptor occupancy, and the impact of target saturation at therapeutic doses.

Why Quantitative Systems Pharmacology (QSP): Necessary Complexity or Unnecessary Burden?
The role of QSP in drug development and its contribution to precision medicine. QSP models as mechanistic, data-driven, and purpose-oriented representations integrating biological processes across multiple scales.

Population Pharmacokinetcis (PopPK) I
Introduction to population PK/PD approaches. Historical perspective, fundamental concepts of population PK, interindividual and intraindividual variability, and Nonlinear Mixed-Effects Models (NLME).

Population Pharmacokinetcis (PopPK) II
Population PK/PD approaches. Applications. Different model specification strategies, estimation methods, and inference techniques.

Methodological Framework for QSP Model Development and Analysis
Key challenges in QSP model development and validation. Methodological framework, predictive reliability, limited data availability, interindividual variability, high parameter uncertainty, non-identifiability, model validation, and translation of results.

Introduction to Sensitivity Analysis
Local and global sensitivity analysis methods. Morris method, Partial Rank Correlation Coefficients (PRCC), and variance-based methods. Time-dependent sensitivity analysis in dynamical QSP models.

Introduction to Identifiability Analysis
Structural and practical identifiability: a problem or an opportunity? How to detect it, resolve it, and exploit it. Profile likelihood analysis.

Introduction to immuno-oncology (IO)
Major molecular, cellular, and pathophysiological mechanisms in immuno-oncology: protein function, immune cell differentiation, dynamics of the tumor microenvironment (TME), and therapeutic modulation. Understanding the structure and components of a QSP model.

Application: Extraction of Immunogenomic Data from the CRI-iAtlas Portal
Use of the iAtlas portal for immunogenomic data exploration and analysis. Reproduction in MATLAB of cellular profiles (M1, M2, CD8, CD4, etc.) using published data (Wang H. et al., 2023, *NPJ Precision Oncology*). Generation of data-driven virtual patients using a QSP model to predict response to PD-L1 inhibition in advanced non-small cell lung cancer (NSCLC).

Introduction to Tumor Growth Models: Fundamental Concepts
Tumor growth models. Linear growth. Exponential growth with or without decay. Model nondimensionalization. Modeling treatment-sensitive and treatment-resistant cell populations. Tumor volume dynamics and the concept of carrying capacity. Interactive MATLAB demonstrations (Live Scripts, *.mlx*).

Application: Dynamic Systems Applied to QSP Models – A Fibrosis Case Study
Use of dynamic systems theory to analyze equilibrium states, their stability, and transitions between dynamic behaviors. Interactive demonstrations using MATLAB (Live Scripts (*.mlx*) and graphical user interfaces (GUI)).

Application: Coarse-grained non-small cell lung cancer (NSCLC) tumor-immune interaction model
Analysis of a reduced QSP model of NSCLC. Generation of virtual populations, investigation of the impact of parameter variability on tumor growth and treatment response, and analysis of equilibrium states and their stability using MATLAB simulations.

Application: A physiologically based in silico kinetic model predicting plasma cholesterol concentrations in humans
Analysis of the influence of parameter variability on plasma cholesterol concentrations. Steady-state calibration through mass balance under physiological conditions and MATLAB-based demonstrations. Comparison of local sensitivity analysis and Partial Rank Correlation Coefficients (PRCC).

Standardization of QSP Modeling Using Modular Platforms
Predictive assessment of the efficacy of combined radiotherapy and nivolumab treatment in NSCLC. Enhancement of a modular QSP-IO platform through integration of radiotherapy. Linear-quadratic radiotherapy model. Simulation of virtual clinical trials and prediction of therapeutic response.

Modeling in Neurology and Psychiatry: Physiology, Pharmacology, and Behavior
Pharmacometrics-based dose adaptation modeling in attention-deficit/hyperactivity disorder (ADHD). Development of mobile health tools. QSP approaches to modeling ADHD and Parkinson's disease. Behavioral modeling using the Reinforcement Learning Drift Diffusion Model (RLDDM). Applications to clinical data.