

Frédéric Paquin-Lefebvre

Position

- NSERC Postdoctoral Fellow at École normale supérieure and Université Paris Sciences & Lettres (ENS-PSL)
 - Group of Applied Mathematics and Computational Biology lead by David Holcman (DR CNRS)
 - **Personal webpage:** <https://www.bio.ens.psl.eu/~paquin/>
 - **Email:** paquin (at) bio (dot) ens (dot) psl (dot) eu

Education

- Ph. D. in Applied Mathematics, The University of British Columbia, 2015-2020
 - Thesis: *On the Weakly Nonlinear Analysis of Coupled Bulk-Surface Reaction-Diffusion Systems: Theory, Numerics and Applications.*
 - Advisors: Michael J. Ward and Wayne Nagata
- M. Sc. in Applied Mathematics, Université de Montréal, 2012-2014
 - Thesis: *Sur un Modèle d'Érythroïèse Comportant un Taux de Mortalité Dynamique.*
 - Advisor: Jacques Bélair
- B. Sc. in Mathematics, Université de Montréal, 2009-2012

Publications

Book chapters:

2. **Paquin-Lefebvre F**, Holcman D. *Modeling Ionic Flow Between Small Targets: Insights from Diffusion and Electro-Diffusion Theory.* In: Grebenkov, D., Metzler, R., Oshanin, G. (eds) *Target Search Problems.* Springer, Cham (2024).
1. Dora M, **Paquin-Lefebvre F**, Holcman D. *Analyzing Photoactivation with Diffusion Models to Study Transport in the Endoplasmic Reticulum Network.* In: Kriechbaumer, V. (eds) *The Plant Endoplasmic Reticulum. Methods in Molecular Biology*, vol 2772. Springer US (2024).

Journal articles:

13. **Paquin-Lefebvre F**, Barea Moreno A, Holcman D. *Voltage Laws in Nanodomains Revealed by Asymptotics and Simulations of Electro-Diffusion Equations.* Preprint: arXiv:2412.20570 [cond-mat.soft] (2024).
12. **Paquin-Lefebvre F**, Holcman D. *Voltage Mapping in Subcellular Nanodomains Using Electro-Diffusion Modeling.* J. Chem. Phys. 161(3), 034108 (2024).
11. **Paquin-Lefebvre F**, Basnayake K, Holcman D. *Narrow Escape in Composite Domains Forming Heterogeneous Networks.* Physica D: Nonlinear Phenomena. 454, 133837 (2023).
10. **Paquin-Lefebvre F**, Toste S, Holcman D. *How Large the Number of Redundant Copies Should Be to Make a Rare Event Probable.* Phys. Rev. E 106, 064402 (2022).
9. **Paquin-Lefebvre F**, Holcman D. *Modeling and Asymptotic Analysis of the Concentration Difference in a Nanoregion Between an Influx and Outflux Diffusion Across Narrow Windows.* Proc. R. Soc. A. **477**: 20210501, (2021).
8. **Paquin-Lefebvre F**, Iyaniwura S, Ward MJ. *Asymptotics of the Principal Eigenvalue of the Laplacian in 2-D Periodic Domains with Small Traps.* Europ. J. Appl. Math. 1-28 (2021).
7. Gomez D, Iyaniwura S, **Paquin-Lefebvre F**, Ward MJ. *Pattern Forming Systems Coupling Linear Bulk Diffusion to Dynamically Active Membranes or Cells.* Phil. Trans. R. Soc. A. **379**: 20200276, (2021).
6. Kolokolnikov T, **Paquin-Lefebvre F**, Ward MJ. *Competition Instabilities of Pulse Patterns for the 1-D Gierer-Meinhardt and Schnakenberg Models are Subcritical.* Nonlinearity. 34(1), 273-312 (2021).

5. Kolokolnikov T, **Paquin-Lefebvre F**, Ward MJ. *Stable Asymmetric Spike Equilibria for the Gierer-Meinhardt Model with a Precursor Field*. IMA J. Appl. Math. 85(4), 605–634 (2020).
4. **Paquin-Lefebvre F**, Nagata W, Ward MJ. *Weakly Nonlinear Theory for Oscillatory Dynamics in a 1-D PDE-ODE Model of Membrane Dynamics Coupled by a Bulk Diffusion Field*. SIAM J. Appl. Math. 80(3), 1520–1545 (2020).
3. **Paquin-Lefebvre F**, Xu B, DiPietro KL, Lindsay AE, Jilkin A. *Pattern Formation in a Coupled Membrane-Bulk Reaction-Diffusion Model for Intracellular Polarization and Oscillations*. J. Theor. Biol. 497, 110242 (2020).
2. **Paquin-Lefebvre F**, Bélair J. *On the Effect of Age-Dependent Mortality on the Stability of a System of Delay-Differential Equations Modeling Erythropoiesis*, Acta Biotheor. 68, 5–19 (2020).
1. **Paquin-Lefebvre F**, Nagata W, Ward MJ. *Pattern Formation and Oscillatory Dynamics in a Two-Dimensional Coupled Bulk-Surface Reaction-Diffusion System*. SIAM J. Appl. Dyn. Syst. 18(3), 1334–1390 (2019).

Peer-review activities:

- Journal of Mathematical Biology (2)
- Journal of Physics A: Mathematical and Theoretical (1)
- SIAM Journal on Applied Dynamical Systems (1)
- Proceedings of the Royal Society A (1)
- Discrete and Continuous Dynamical Systems Series B (1)
- Nonlinear Dynamics (1)
- International Journal of Bifurcation and Chaos (1)
- International Journal of Systems Science (1)

Students Supervision

Supervision of Alejandro Barea Moreno, M2 student at Sorbonne Université, Master Mathématiques de la Modélisation, March-August 2024.

- Topic: Simulations and analysis of an electro-diffusion model based on the Poisson-Nernst-Planck equations.

Teaching

The University of British Columbia:

- Lecturer for the course *Integral Calculus with Applications to Physical Sciences and Engineering* (MATH 101), Winter 2020.
- Teaching assistant for a number of upper-level courses, including *Engineering Analysis* (MATH 358), *Vector Calculus for Electrical Engineering* (MATH 264), *Complex Analysis* (MATH 301 and 305), *Variational and Approximate Methods in Applied Mathematics* (MATH 406) and *Multivariable Calculus* (MATH 253).

Université de Montréal:

- Teaching assistant for the course *Introduction à l'Analyse Numérique* (MAT 2412), Falls 2012 and 2013.

Research Interests

My research focuses on the analysis of PDE models in cellular biology using a variety of numerical (time-dependent simulations, continuation methods, etc) and analytical (bifurcation theory, asymptotic analysis, etc) tools. Most recently I studied the dynamics of ions in neuronal nano-compartments using electro-diffusion theory, where I show how the geometry of neuronal structures can modulate voltage dynamics. During my PhD I analyzed the stability of spatio-temporal patterns in certain coupled bulk-surface reaction-diffusion systems, a class of models motivated by the compartmentalization of intracellular proteins between membrane-bound and cytosolic species.

Keywords: Cellular Biology Modeling, Computational Neuroscience, Electro-Diffusion Theory, Poisson-Nernst-Planck Equations, Reaction-Diffusion Theory, Dynamical Systems and Bifurcation Theory, Asymptotic Analysis, Numerical Simulations, Path-Following Continuation Methods.

Seminars and Conferences

Invited seminar presentations:

10. *How geometry affects ionic flow and voltage response in cellular nanodomains*, Seminar at the Institute of Ecology and Evolution, University of Bern, host: Dr. Xiang-Yi Li Richter, July 9th 2024, Bern, Switzerland.
9. *Problèmes d'échappée belle dans les microdomaines organisés en réseaux*, Séminaire A3 du LAMFA, Université de Picardie Jules-Vernes, host: Prof. Paul Vigneaux, October 2nd 2023, Amiens, France.
8. *Problèmes d'échappée belle dans les microdomaines organisés en réseaux*, Séminaire du LJAD, Université Côte d'Azur, host: Claire Guerrier (CR CNRS), June 16th 2023, Nice, France.
7. *The narrow escape problem for diffusion*. Séminaire de l'Institut de Biologie de l'Université de Neuchâtel, host: Dr. Xiang-Yi Li Richter, February 22nd 2023, Neuchâtel, Suisse.
6. *Asymptotic Analysis of the Concentration Difference Due to Diffusive Fluxes Across Narrow Windows*. UBC Math Biology Virtual Seminar (Zoom), host: Prof. Leah-Edelstein Keshet, February 9th 2022, Vancouver, Canada.
5. *Bulk-Surface Coupled Models: Coupling Passive Diffusion in Bounded Domains to Dynamically Active Boundaries*. Virtual Zoom Talk at the Interdisciplinary Center for Quantitative Modeling in Biology (ICQMB), University of California Riverside, host: Prof. Jia Gou, Jan. 26th 2021, Riverside, USA.
4. *Bulk-Surface Coupled Models: Coupling Passive Diffusion in Bounded Domains to Dynamically Active Boundaries*. UBC Department of Mathematics Colloquium (Virtual) in recognition of a Graduate Research Award, host: Prof. Lior Silberman, November 27th 2020, Vancouver, Canada.
3. *Pattern Formation in a Coupled Membrane-Bulk Reaction-Diffusion Model for Intracellular Polarization and Oscillations*. CRM (Centre de Recherche Mathématiques) Applied Maths Seminar, McGill University, host: Prof. Jean-Philippe Lessard, September 30th 2019, Montréal, Canada.
2. *Pattern Formation and Oscillatory Dynamics in a 2-D Coupled Bulk-Surface Reaction-Diffusion System*. Applied Maths Seminar, University of Notre-Dame, hosts: Prof. Alan Lindsay and Alexandra Jilkine, August 28th 2018, South Bend, USA.
1. *Bifurcations dans les Systèmes Couplés EDOs-EDPs*. Séminaire du Groupe Interdisciplinaire de Recherche en Éléments Finis (GIREF) de l'Université Laval, host: Prof. Jean-Philippe Lessard, December 16th 2016, Québec, Canada.

Conference talks:

9. *Bulk-Surface Coupled Models: Coupling Passive Diffusion in Bounded Domains to Dynamically Active Boundaries*, SIAM Conference on Nonlinear Waves and Coherent Structures, NWCS22, Aug. 30th 2022, University of Bremen, Allemagne.
8. *Bulk-Surface Coupled Models: Coupling Passive Diffusion in Bounded Domains to Dynamically Active Boundaries*, SIAM Conference on Applications of Dynamical Systems, DS21, May 23rd 2021, (virtual).
7. *A Study of Two-Spike Equilibria in the 1-D Gierer-Meinhardt Model*, Annual Meeting of the Canadian Applied and Industrial Mathematics Society, CAIMS2020, July 10th 2020, (virtual).
6. *Spatio-temporal Pattern Formation in 2-D Coupled Bulk-Surface Reaction-Diffusion Systems*, PIMS - Germany Workshop on Modeling and Analysis of PDEs for Biological Applications, June 25th 2019, Heidelberg, Germany.
5. *Spatio-temporal Pattern Formation in 2-D Coupled Bulk-Surface Reaction-Diffusion Systems*, SIAM Conference on Applications of Dynamical Systems, DS2019, May 10th 2019, Snowbirds, Utah, USA.
4. *Pattern Formation and Oscillatory Dynamics in a 2-D Coupled Bulk-Surface Reaction-Diffusion System*, Advanced Summer School on Continuation Methods for Nonlinear Problems, August 13th 2018, University of Illinois at Urbana-Champaign, USA.

3. *Pattern Formation and Oscillatory Dynamics in a 2-D Coupled Bulk-Surface Reaction-Diffusion System*, Annual Meeting of the Canadian Applied and Industrial Mathematics Society, CAIMS2018, June 6th 2018, Ryerson University, Toronto, Canada.
2. *Interactions of 1-D Bulk Diffusion with Localized Reactions*, Annual Meeting of the Canadian Applied and Industrial Mathematics Society, CAIMS2017, July 20th 2017, Dalhousie University, Halifax, Canada.
1. *Complex Dynamics and Patterns in a 2-D Coupled Model of Bulk Diffusion and Surface Reaction*, Annual Meeting of the Canadian Applied and Industrial Mathematics Society, CAIMS2016, June 29th 2016, University of Alberta, Edmonton, Canada.

Poster presentations:

3. *Voltage mapping in subcellular nanodomains using electro-diffusion modeling*. Poster presentation at the 8th Edwards Symposium – Statistical Physics of Soft and Multicomponent Systems, Sept. 11-13rd 2024, University of Cambridge, Cambridge, UK.
2. *Complex Dynamics and Patterns in a Coupled Model of Bulk Diffusion and Surface Reaction*, Séminaire de Mathématiques Supérieures on Dynamics of Biological Systems, SMS2016, June 1st 2016, University of Alberta, Edmonton, Canada.
1. *Mathematical Modeling of Erythropoiesis*, Frontiers in Biophysics Conference, FIB2015, March 14th 2015, The University of British Columbia, Vancouver, Canada.

Grants and Awards

- NSERC Postdoctoral fellowship, Jan 2024 - Dec 2025.
- Postdoctoral fellowship from the Fondation ARC pour la Recherche sur le Cancer, Jan 2021 - Dec 2023.
- Graduate Research Award, Department of Mathematics, UBC, 2020.
- AARMS Postdoctoral Fellowship, Dalhousie University, 2020 (**declined**).
- Stanley M Grant Scholarship, Department of Mathematics, UBC, 2018.
- NSERC Doctoral Award, UBC, 2015-2017.
- Four Year Doctoral Fellowship (FYF), UBC, 2015-2018.
- Admission Fellowship, Institute of Applied Mathematics, UBC, 2015.
- FRQNT Doctoral Award, UdeM, 2014 (**declined**).
- FRQNT Master Research Scholarship, UdeM, 2013-2014.
- B. Sc. admission scholarship from the Faculté des Arts et des Sciences, UdeM, 2009-2010.

Relevant Skills

- French: native level. English: advanced level. Spanish: basic level.
- Advanced programming skills with MATLAB, Maple and Mathematica.
- Commercial PDE software: COMSOL Multiphysics and FlexPDE.
- Numerical bifurcation and continuation software: AUTO, COCO and *pde2path*.
- Knowledge of Java, python, C/C++ and R.