

# Antoine Allard

## Curriculum Vitæ

Associate Professor  
Département de physique, de génie physique et d'optique  
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Université Laval  
Québec (Québec)  
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## ACADEMIC POSITIONS

### Université Laval

Québec, Canada

Associate Professor

2023–present

- ★ Sentinelle Nord Research Chair on Applications and Theory of Network Analysis
- Codirector of the [Dynamica Research Lab](#) on the structure and the dynamics of complex systems
- Board member of the [Centre Interdisciplinaire en Modélisation Mathématique de l'Université Laval \(CIMMUL\)](#)

### Université Laval

Québec, Canada

Assistant Professor

2018–2023

- ★ Sentinelle Nord Research Chair on Applications and Theory of Network Analysis
- Codirector of the [Dynamica Research Lab](#) on the structure and the dynamics of complex systems
- Board member of the [Centre Interdisciplinaire en Modélisation Mathématique de l'Université Laval \(CIMMUL\)](#)

### Universidad de Zaragoza

Zaragoza, Spain

External member of the [Institute for Biocomputation and Physics of Complex Systems](#)

2023–present

### University of Vermont

Burlington, USA

External faculty at the [Vermont Complex Systems Center](#)

2021–present

*"Created with the intention of honoring scholars in our external network who make complex systems a welcoming intellectual community and keep meaningful collaborations with the Center."*

### Universitat de Barcelona

Barcelona, Spain

Postdoctoral Fellow

2018

- ★ Awarded the Juan de la Cierva – Incorporación postdoctoral fellowship

### Centre de Recerca Matemàtica

Bellaterra, Spain

Senior Research Fellow

2017

### Universitat de Barcelona

Barcelona, Spain

Postdoctoral Fellow

2014–2016

- ★ Awarded the Fonds de recherche du Québec – Nature et Technologies postdoctoral fellowship

## EDUCATION

### Université Laval

Québec, Canada

Ph.D. in Physics

2009–2014

- Thesis Title: [Percolation sur graphes aléatoires: Modélisation et description analytique](#)<sup>1</sup>
- ★ Awarded the CIHR Frederick Banting and Charles Best Canada Graduate Scholarship
- ★ Thesis added to the Board of Honor for receiving the highest overall mark

**Santa Fe Institute**  
Complex Systems Summer School

Santa Fe, NM, USA  
2011

**Université Laval**  
M.Sc. in Physics

Québec, Canada  
2006–2008

- Thesis Title: *Modélisation Mathématique en Épidémiologie par Réseaux de Contacts: Introduction de l'Hétérogénéité dans la Transmissibilité*<sup>2</sup>
- ★ Thesis added to the Board of Honor for receiving the highest overall mark

**Université Laval**  
B.Sc. in Physics (Theoretical Physics option)

Québec, Canada  
2003–2006

- ★ Rouge et Or Distinction for excellence in academic undergraduate results
- ★ Nominated 2003 AESGUL Prize for “Student of the year” (chosen by the peers)

## FUNDING AND AWARDS

### Team funding

- Fonds d'accélération des collaborations en santé, *Consortium québécois sur la découverte du médicament*, 2021–2024 (15.32M CAD)
- Alliance Grant, *Natural Sciences and Engineering Research Council of Canada*, 2021–2026 (481k CAD)
- Sentinelle Nord Research Project, *Canada First Research Excellence Fund*, 2020–2023 (750k CAD)

### Individual funding

- Discovery Grant, *Natural Sciences and Engineering Research Council of Canada*, 2019–2025 (157k CAD)
- Sentinelle Nord Research Chair, *Canada First Research Excellence Fund*, 2018–2024 (500k CAD)

### Individual funding as postdoctoral fellow, graduate student or undergraduate student

- Juan de la Cierva – Incorporación (postdoctoral fellowship), *Ministerio de Economía, Industria y Competitividad de España*, 2017–2019 (50k EUR)
- Postdoctoral Fellowship, *Fonds de recherche du Québec – Nature et Technologies*, 2014–2016 (65k CAD)
- Frederick Banting and Charles Best Canada Graduate Scholarships - Doctoral Awards, *Canadian Institutes of Health Research*, 2009–2012 (105k CAD)
- Doctoral Research Scholarship, *Fonds de recherche du Québec – Nature et Technologies*, 2008 (63k CAD; declined)
- Doctoral Research Scholarship, *Fondation de l'Université Laval*, 2008 (36k CAD; declined)
- Undergraduate Student Research Award, *Natural Sciences and Engineering Research Council of Canada*, 2006 (4.5k CAD)
- Undergraduate Student Research Award, *Natural Sciences and Engineering Research Council of Canada*, 2005 (4.5k CAD)

### Funding through scholarships awarded to mentees

- *Natural Sciences and Engineering Research Council of Canada*, Charles Murphy (42k CAD), Guillaume St-Onge (35k CAD), Olivier Ribordy (22k CAD), Béatrice Désy (17.5k CAD), Jérémie Lesage (17.5k CAD)
- *Fonds de recherche du Québec – Nature et Technologies*, Vincent Thibeault (84k CAD), Olivier Ribordy (19.5k CAD), Béatrice Désy (24k CAD), Jérémie Lesage (17.5k CAD), Simon Lizotte (100k CAD)
- *Sentinelle Nord (Canada First Research Excellence Fund)*, Simon Lizotte (63k CAD), Charles Murphy (54k CAD), Béatrice Désy (32.5k CAD)

### Awards

- 2022 Star Teacher Prize (based on students evaluation)
- Nominated 2022 AESGUL Prize for “Teacher of the year” (elected by the undergraduate students)
- 2021 ADEPUL Prize for “Teacher of the year” (elected by the undergraduate students)

- 2020 ADEPUL Prize for “Teacher of the year” (elected by the undergraduate students)
- Nominated 2020 AESGUL Prize for “Teacher of the year” (elected by the undergraduate students)
- 2019 Star Teacher Prize (based on students evaluation)
- 2019 ADEPUL Prize for “Teacher of the year” (elected by the undergraduate students)
- 2019 AESGUL Prize for “Teacher of the year” (elected by the undergraduate students)
- Board of Honor for a Ph.D.’s Thesis (highest distinction), Faculty of Graduate Studies, Université Laval, 2014
- Nominated 2013 AESGUL Prize for “Staff member of the year” as the Teaching Assistant of PHY-3000 Statistical Physics (elected by the undergraduate students), 2014
- Board of Honor for a Master’s Thesis (highest distinction), Faculty of Graduate Studies, Université Laval, 2009
- Third Place at the Student Competition (Poster Presentation), Congress of the Canadian Association of Physicists, Quebec City, 2008
- 2006 AESGUL Prize for “Staff member of the year” as the Teaching Assistant of PHY-1002 Mathematical Physics II (elected by the undergraduate students), 2007
- Rouge et Or Distinction for excellence in academic undergraduate results, 2006
- Nominated 2003 AESGUL Prize for “Student of the year” (chosen by the peers), 2004

## TEACHING

### Université Laval

Québec, Canada

#### Teacher

- PHY-7053 Theory of Complex Systems and Networks 2020–2022
- PHY-3500 Computational Physics 2020, 2023, 2024
- PHY-2502 Nonlinear Dynamics, Chaos and Complexity 2019, 2022, 2024
- PHY-7008 Deep Learning: Theory and applications 2019
- PHY-3000 Statistical Physics 2018–2023
- ★ Awarded the Star Teacher prize (based on students evaluation) 2019, 2022
- ★ Awarded the AESGUL prize for “Teacher of the year” (elected by the undergraduate students) 2019
- ★ Awarded the ADEPUL prize for “Teacher of the year” (elected by the undergraduate students) 2019, 2020, 2021
- ★ Nominated for the AESGUL prize for “Teacher of the year” (elected by the undergraduate students), 2020, 2022

## MENTORING

### Postdoctoral researchers<sup>3</sup>

- Azénor Bideault<sup>‡</sup>, *Université Laval*, 2022–present
- Ilhem Bouderbala, *Université Laval*, 2020–2022 (then postdoc at University of Alberta)
- Marina Vugué Llorente, *Université Laval*, 2020–2022 (then postdoc at Universitat Politècnica de Catalunya)

### Ph.D. students<sup>3,4</sup>

- Gabriel Bergeron<sup>‡</sup>, *Université Laval*, 2022–present
- Simon Lizotte, *Université Laval*, 2022–present
- Charles Murphy, *Université Laval*, 2018–present
- Zahra Yazdani Najafabadi<sup>‡</sup>, *Université Laval*, 2022–present
- Olivier Ribordy, *Université Laval*, 2023–present
- François Thibault, *Université Laval*, 2022–present
- Vincent Thibeault, *Université Laval*, 2020–present
- Guillaume St-Onge\*, *Université Laval*, 2020–2022 ([link to thesis](#); then postdoc at Northeastern University)

<sup>3</sup>Acting/acted as co-advisor denoted by ‡.

<sup>4</sup>Thesis added to the Board of Honor, the highest distinction at Université Laval, denoted by \*.

## M.Sc. students<sup>3,4</sup>

- Jérémie Lesage, *Université Laval*, 2022–present
- Heikel Jarras<sup>‡</sup>, *Université Laval*, 2021–2023 ([link to thesis](#); then data scientist in the private sector)
- Simon Lizotte\*, *Université Laval*, 2020–2022 ([link to thesis](#); then PhD at Université Laval)
- Olivier Ribordy, *Université Laval*, 2020–2022 ([link to thesis](#); then PhD at Université Laval)
- François Thibault, *Université Laval*, 2020–2022 ([link to thesis](#); then PhD at Université Laval)
- Béatrice Désy\*, *Université Laval*, 2019–2022 ([link to thesis](#); then PhD at Victoria University of Wellington)
- Francis Normand<sup>‡</sup>, *Université Laval*, 2019–2022 ([link to thesis](#); then PhD at Monash University)
- Charles Murphy<sup>‡</sup>, *Université Laval*, 2016–2017 ([link to thesis](#); then PhD at Université Laval)

## B.Sc. interns

- Olivier Lapointe-Gagné, *Université Laval*, Summer 2021
- Pierre-Luc Larouche, *Université Laval*, Summer 2021
- Jérémie Lesage, *Université Laval*, Summer 2021
- Bastian Raulier, *Université Laval*, Summer-Fall 2020
- Olivier Ribordy, *Université Laval*, Summer 2019
- François Thibault, *Université Laval*, Summer 2019

## Bachelor's thesis<sup>3</sup>

- Émile Baril, *Université Laval*, 2022
- Simon Lizotte, *Université Laval*, 2020
- François Thibault, *Université Laval*, 2020
- Marta Caveró Lázaro<sup>‡</sup>, *Universitat Autònoma de Barcelona*, 2018

## ORGANIZING ACTIVITIES

### International School and Conference on Network Science ([NetSci 2024](#))

Québec, Canada  
June 2024

Conference co-chair

- In collaboration with the [Vermont Complex Systems Center](#)
- Flagship conference of the Network Science Society; approx. 750 participants

### Complex Networks Winter Workshop ([CNWW 2023](#))

Québec, Canada  
December 2023

Co-organizer

- In collaboration with the [Vermont Complex Systems Center](#)

### Advanced Field School in Computational Ecology ([Ecology 2023](#))

Val Morin, Canada  
May 2023

Co-organizer

- Organized by [Sentinelle Nord](#) and [BIOS<sup>2</sup>](#)

### Complex Networks Winter Workshop ([CNWW 2020](#))

Québec, Canada  
January 2021

Codirector

- In collaboration with [Sentinelle Nord](#) and the [Vermont Complex Systems Center](#)

### Complex Networks Winter Workshop ([CNWW 2019](#))

Québec, Canada  
December 2019

Codirector

- In collaboration with [Sentinelle Nord](#) and the [Vermont Complex Systems Center](#)

### International School and Conference on Network Science ([NetSci 2019](#))

Burlington VT, USA  
May 2019

School, Poster Session, and Satellite Co-chair

- Organized by the [Vermont Complex Systems Center](#)

## Complex Networks Winter Workshop ([CNWW 2018](#))

Codirector

Québec, Canada

December 2018

- In collaboration with [Sentinelle Nord](#), the [Vermont Complex Systems Center](#) and the [Network Science Institute](#)

## Contagion & Networks ([ContNet 2018](#))

Co-organizer

Paris, France

June 2018

- Satellite symposium of the International School and Conference on Network Science (NetSci 2018)
- In collaboration with B. M. Althouse, L. Hébert-Dufresne and S. V. Scarpino

## Contagion & Networks ([ContNet 2017](#))

Co-organizer

Indianapolis IN, USA

June 2017

- Satellite symposium of the International School and Conference on Network Science (NetSci 2017)
- In collaboration with B. M. Althouse, L. Hébert-Dufresne and S. V. Scarpino

## REVIEWING ACTIVITIES

### Editorial board

- Associate editor, [npj Complexity](#) (first issue scheduled for Jan. 2024), 2023–present
- Guest editor, npj Complexity's [Networks and Space](#) collection, 2023–2024

### Grant review

- Discovery Grants, *Natural Sciences and Engineering Research Council of Canada*, 2020, 2023
- OPUS Grants, *National Science Center, Poland*, 2020

### Program committee

- Workshop on Complex Networks in Banking and Finance, 2024
- International Winter Conference of the Network Science Society (NetSciX) 2024
- International Conference on Complex Networks (CompleNet) 2020, 2021, 2024
- International School and Conference on Network Science (NetSci) 2018–2020, 2022, 2023
- French Regional Conference on Complex Systems (FRCCS) 2021, 2023
- International Conference on Complex Networks and their Applications (Complex Networks) 2016–2019, 2021, 2022
- Conference on Complex Systems (CCS) 2022
- 10th Conference on Network Modeling and Analysis (MARAMI) 2019
- Mapping Complexity: Foundations and Applications of Network Geometry workshop (MACFANG) 2017

### Thesis jury

- Cédric Bélanger (PhD thesis, *Université Laval*, 2023)
- Meriem Khalfoun (Master's thesis, *Université Laval*, 2023)
- Jeson Hermans (Master's thesis, *Université Laval*, 2023)
- Boris Gbeasor (Master's thesis, *Université Laval*, 2022)
- Geneviève Boudreau (Master's thesis, *Université Laval*, 2022)
- Marianne Gratton (Master's thesis, *Université Laval*, 2022)
- Xavier Roy-Pomerleau (Master's thesis, *Université Laval*, 2020)
- Vincent Thibeault (Master's thesis, *Université Laval*, 2020)
- Charles Joachim-Paquet (Master's thesis, *Université Laval*, 2020)
- Edward Laurence (PhD thesis, *Université Laval*, 2020)
- Guillaume St-Onge (PhD exam, *Université Laval*, 2019)
- Edward Laurence (PhD seminar, *Université Laval*, 2018)
- Edward Laurence (PhD exam, *Université Laval*, 2017)
- Jaume Palmer Real (Master's thesis, *Universitat Autònoma de Barcelona*, 2017)

### Scholarships

- Larkin Kerwin undergraduate scholarship, *Université Laval*, 2019, 2023
- Marcel-Dessureault undergraduate scholarship, *Université Laval*, 2022
- Byron-T. Darling graduate scholarship, *Université Laval*, 2020

## Scientific journals

Applied Network Science, Bioinformatics, BMC Medicine, Communications Physics, Discrete Dynamics in Nature and Society, Europhysics Letters, IEEE's Transactions on Network Science and Engineering, Nature Communications, Network Neuroscience, Physica A, Physical Review E, Physical Review Letters, Physical Review Research, Physical Review X, PLOS Computational Biology, PLOS ONE, PNAS, Science Advances, Scientific Data, Scientific Reports

## COMMUNITY SERVICES AND ADMINISTRATIVE ACTIVITIES

Centre Interdisciplinaire en Modélisation Mathématique (CIMMUL)  
Board member

Université Laval  
2020–present

New papers in Network Science

Online

Sole webmaster, reviewer and administrator

2017–present

- Systematic aggregator of new publications touching the field of network science
- New publications are publicly available to the community via [Twitter](#), [Mastodon](#), [Bluesky](#), and a [mailing list](#)
- Over 3.2k subscribers as of Aug. 2023

Reconditioning of the research facilities in the Alexandre-Vachon building  
Consulting committee member

Université Laval  
2020

## PUBLICATIONS AND PRESENTATIONS

### Submitted manuscripts and preprints<sup>5,6</sup>

- [P7] *Firing rate distributions in plastic networks of spiking neurons*, M. Veu  , **A. Allard** and P. Desrosiers, [arXiv:2311.05442](#)
- [P6] *A probabilistic methodology to reconstruct biodiversity from implicit interactions with indicator species along latitudinal co-occurrence networks*, I. Bouderbala, J. A. Tremblay, D. Fortin, **A. Allard** and P. Desrosiers, [bioRxiv](#)
- [P5] *Modeling critical connectivity constraints in random and empirical networks*, L. H  bert-Dufresne, M. P  sfai and **A. Allard**, [arXiv:2307.03559](#)
- [P4] *Network Onion Divergence: Network representation and comparison using nested configuration models with fixed connectivity, correlation and centrality patterns*, L. H  bert-Dufresne, J.G. Young, A. Daniels and **A. Allard**, [arXiv:2204.08444](#)
- [P3] *On the accuracy of message-passing approaches to percolation in complex networks*, **A. Allard** and L. H  bert-Dufresne, [arXiv:1906.10377](#)
- [P2] *Duality between predictability and reconstructability in complex systems*, C. Murphy, V. Thibeault, **A. Allard** and P. Desrosiers, *Under consideration at Nature Communications (second round of reviews; manuscript NCOMMS-23-10333)*, [arXiv:2206.04000](#)
- [P1] *The network epidemiology of an Ebola epidemic*, L. H  bert-Dufresne, J.-G. Young, J. Bedson, L. A. Skrip, D. Pedi, M. F. Jalloh, B. Raulier, O. Lapointe-Gagn  , A. Jambai, **A. Allard** and B. M. Althouse, *Under consideration at Nature (second round of reviews; manuscript 2020-10-19457)*, [arXiv:2111.08686](#)

### Refereed research publications<sup>5,6</sup>

- [A60] *Escherichia coli CRISPR arrays from early life fecal samples preferentially target prophages*, M. B. Dion, S. A. Shah, L. Deng, J. Thorsen, J. Stokholm, K. A. Krogfelt, S. Schj  rring, P. Horvath, **A. Allard**, D. S. Nielsen, M.-A. Petit and S. Moineau, ISME J. (in press)
- [A59] *NBS-SNI, an extension of the Network-based statistic: Abnormal functional connections between important structural actors*, F. Normand, M. Gajwani, D. C. C       and **A. Allard**, *Netw. Neurosci.* (2024)
- [A58] *The low-rank hypothesis of complex systems*, V. Thibeault, **A. Allard** and P. Desrosiers, *Nat. Phys.* (2024)  
\* Featured in [Nature Physics' News & Views](#).

<sup>5</sup>Students or postdoctoral researchers who worked under my supervision are underlined.

<sup>6</sup>Equal contributions are denoted by †.



- [A57] *Geometric description of clustering in directed networks*, **A. Allard**, M. Á. Serrano and M. Boguñá, *Nat. Phys.* **20**, 150–156 (2024)
- [A56] *The umbrella value of caribou management strategies for biodiversity conservation in boreal forests under global change*, G. Labadie, I. Bouderbala, Y. Boulanger, J.-M. Béland, C. Hébert, **A. Allard**, M. Hebblewhite and D. Fortin, *Sci. Total Environ.* **907**, 168087 (2024)
- [A55] *Nonlinear bias toward complex contagion in uncertain transmission settings*, G. St-Onge, L. Hébert-Dufresne and **A. Allard**, *Proc. Natl. Acad. Sci. USA* **121**, e2312202121 (2023)
- [A54] *The unintended consequences of inconsistent pandemic control policies*, B. M. Althouse, B. Wallace, B. Case, S. V. Scarpino, **A. Allard**, A. M. Berdahl, E. R. White and L. Hébert-Dufresne, *BMC Global Public Health* **1**, 28 (2023)
- [A53] *Hypergraph reconstruction from uncertain pairwise observations*, S. Lizotte, J.-G. Young and **A. Allard**, *Sci. Rep.* **13**, 21364 (2023)
- [A52] *The D-Mercator method for the multidimensional hyperbolic embedding of real networks*, R. Jankowski, **A. Allard**, M. Boguñá and M. Á. Serrano, *Nat. Commun.* **14**, 7585 (2023)  
★ Featured in [Nature communications' Editors' Highlights](#).
- [A51] *Temporal and probabilistic forecasts of epidemic interventions*, M. C. Boudreau, A. J. Allen, N. J. Roberts, **A. Allard** and L. Hébert-Dufresne, *Bull. Math. Biol.* **85**, 118 (2023)
- [A50] *Hierarchical team structure and multidimensional localization (or siloing) on networks*, L. Hébert-Dufresne, G. St-Onge, J. Meluso, J. P. Bagrow and **A. Allard**, *J. Phys. Complex.* **4**, 035002 (2023)
- [A49] *Exact and rapid linear clustering of networks with dynamic programming*, A. Patania, **A. Allard** and J.-G. Young, *Proc. R. Soc. A* **479**, 20230159 (2023)
- [A48] *Dimension reduction of dynamics on modular and heterogeneous directed networks*, M. Vegué, V. Thibeault, P. Desrosiers and **A. Allard**, *PNAS Nexus* **2**, pgad150 (2023)
- [A47] *Dimension matters when modeling network communities in hyperbolic spaces*, B. Désy, P. Desrosiers and **A. Allard**, *PNAS Nexus* **2**, pgad136 (2023)
- [A46] *Effects of global change on bird and beetle populations in boreal forest landscape: An assemblage dissimilarity analysis*, I. Bouderbala, G. Labadie, J.-M. Leblanc, Y. Boulanger, C. Hébert, P. Desrosiers, **A. Allard** and D. Fortin, *Divers. Distrib.* **29**, 757–773 (2023)
- [A45] *Long-term effect of forest harvesting on boreal species assemblages under climate change*, I. Bouderbala, G. Labadie, J.-M. Leblanc, J. A. Tremblay, Y. Boulanger, C. Hébert, P. Desrosiers, **A. Allard** and D. Fortin, *PLOS Clim.* **2**, e0000179 (2023)
- [A44] *The Role of Directionality, Heterogeneity, and Correlations in Epidemic Risk and Spread*, **A. Allard**, C. Moore, S. V. Scarpino, B. M. Althouse and L. Hébert-Dufresne, *SIAM Rev.* **65**, 471–492 (2023)
- [A43] *Predicting the diversity of early epidemic spread on networks*, A. J. Allen, M. C. Boudreau, N. J. Roberts, **A. Allard** and L. Hébert-Dufresne, *Phys. Rev. Research* **4**, 013123 (2022)
- [A42] *Influential groups for seeding and sustaining nonlinear contagion in heterogeneous hypergraphs*, G. St-Onge, I. Iacopini, V. Latora, A. Barrat, G. Petri, **A. Allard** and L. Hébert-Dufresne, *Commun. Phys.* **5**, 25 (2022)
- [A41] *Limits of Individual Consent and Models of Distributed Consent in Online Social Networks*, J. Lovato, **A. Allard**, R. Harp, J. Onalapo and L. Hébert-Dufresne, *FAccT'22* 2251–2262 (2022)
- [A40] *Universal nonlinear infection kernel from heterogeneous exposure on higher-order networks*, G. St-Onge, H. Sun, **A. Allard**, L. Hébert-Dufresne and G. Bianconi, *Phys. Rev. Lett.* **127**, 158301 (2021)
- [A39] *Deep learning of contagion dynamics on complex networks*, C. Murphy, E. Laurence and **A. Allard**, *Nat. Commun.* **12**, 4720 (2021)  
★ Featured in [Nature communications' Editors' Highlights](#).
- [A38] *Social confinement and mesoscopic localization of epidemics on networks*, G. St-Onge, V. Thibeault, **A. Allard**, L. J. Dubé and L. Hébert-Dufresne, *Phys. Rev. Lett.* **126**, 098301 (2021)
- [A37] *Master equation analysis of mesoscopic localization in contagion dynamics on higher-order networks*, G. St-Onge, V. Thibeault, **A. Allard**, L. J. Dubé and L. Hébert-Dufresne, *Phys. Rev. E* **103**, 032301 (2021)
- [A36] *Beyond  $R_0$ : Heterogeneity in secondary infections and probabilistic epidemic forecasting*, L. Hébert-Dufresne, B. M. Althouse, S. V. Scarpino and **A. Allard**, *J. R. Soc. Interface* **17**, 20200393 (2020)

- [A35] *Superspreading events in the transmission dynamics of SARS-CoV-2: opportunities for interventions and control*, B. M. Althouse, E. A. Wenger, J. C. Miller, S. V. Scarpino, **A. Allard**, L. Hébert-Dufresne and H. Hu, *PLOS Biol.* **18**, e3000897 (2020)
- [A34] *Localization, bistability and optimal seeding of contagions on higher-order networks*, G. St-Onge, **A. Allard** and L. Hébert-Dufresne, *Artificial Life Conference Proceedings*, 567–569 (2020)
- [A33] *Geometric renormalization unravels self-similarity of the multiscale human connectome*, M. Zheng, **A. Allard**, P. Hagmann, Y. Alemán-Gómez and M. Á. Serrano, *Proc. Natl. Acad. Sci. USA* **117**, 20244 (2020)
- [A32] *Navigable maps of structural brain networks across species*, **A. Allard** and M. Á. Serrano, *PLOS Comput. Biol.* **16**, e1007584 (2020)
- [A31] *Genome-scale modeling of metabolism in the polar diatom *Fragilariopsis cylindrus* underscores the strong robustness of growth rate in response to cellular perturbations*, M. Lavoie, B. Saint-Béat, J. Strauss, S. Guérin, **A. Allard**, S. V. Hardy, A. Falcatore and J. Lavaud, *Biology* **9**, 30 (2020)
- [A30] *Mercator: uncovering faithful hyperbolic embeddings of complex networks*, G. García-Pérez<sup>†</sup>, **A. Allard**<sup>†</sup>, M. Á. Serrano and M. Boguñá, *New J. Phys.* **21**, 123033 (2019)
- [A29] *Smeared phase transitions in percolation on real complex networks*, L. Hébert-Dufresne and **A. Allard**, *Phys. Rev. Research* **1**, 013009 (2019)
- [A28] *Percolation and the effective structure of complex networks*, **A. Allard** and L. Hébert-Dufresne, *Phys. Rev. X* **9**, 011023 (2019)
- [A27] *Geometric evolution of complex networks with degree correlations*, C. Murphy, **A. Allard**, E. Laurence, G. St-Onge and L. J. Dubé, *Phys. Rev. E* **97**, 032309 (2018)
- [A26] *The risk of sustained sexual transmission of Zika is underestimated*, **A. Allard**<sup>†</sup>, B. M. Althouse<sup>†</sup>, L. Hébert-Dufresne<sup>†</sup> and S. V. Scarpino<sup>†</sup>, *PLOS Pathog.* **13**, e1006633 (2017)
- [A25] *Asymmetric percolation drives a double transition in sexual contact networks*, **A. Allard**, B. M. Althouse, S. V. Scarpino and L. Hébert-Dufresne, *Proc. Natl. Acad. Sci. USA* **114**, 8969–8973 (2017)
- [A24] *Strategic tradeoffs in competitor dynamics on adaptive networks*, L. Hébert-Dufresne, **A. Allard**, P.-A. Noël, J.-G. Young and E. Libby, *Sci. Rep.* **7**, 7576 (2017)
- [A23] *The geometric nature of weights in real complex networks*, **A. Allard**, M. Á. Serrano, G. García-Pérez and M. Boguñá, *Nat. Commun.* **8**, 14103 (2017)  
 \* Featured in *Nature Physics*' Research highlights.  
 \* Featured in *Nature Communications*' Web collection on complex systems.
- [A22] *The effect of a prudent adaptive behaviour on disease transmission*, S. V. Scarpino, **A. Allard** and L. Hébert-Dufresne, *Nat. Phys.* **12**, 1042–1046 (2016)  
 \* Featured in *Nature Physics*' News & Views.
- [A21] *The hidden hyperbolic geometry of international trade: World Trade Atlas 1870–2013*, G. García-Pérez, M. Boguñá, **A. Allard** and M. Á. Serrano, *Sci. Rep.* **6**, 33441 (2016)
- [A20] *Growing networks of overlapping communities with internal structure*, J.-G. Young, L. Hébert-Dufresne, **A. Allard** and L. J. Dubé, *Phys. Rev. E* **94**, 022317 (2016)
- [A19] *Multi-scale structure and topological anomaly detection via a new network statistic: The onion decomposition*, L. Hébert-Dufresne, J. Grochow and **A. Allard**, *Sci. Rep.* **6**, 31708 (2016)
- [A18] *Constrained growth of complex scale-independent systems*, L. Hébert-Dufresne, **A. Allard**, J.-G. Young and L. J. Dubé, *Phys. Rev. E* **93**, 032304 (2016)  
 \* Featured in the *Editors' Suggestions* section of *Phys. Rev. E*.
- [A17] *Complex networks as an emerging property of hierarchical preferential attachment*, L. Hébert-Dufresne, E. Laurence, **A. Allard**, J.-G. Young and L. J. Dubé, *Phys. Rev. E* **92**, 062809 (2015)
- [A16] *General and exact approach to percolation on random graphs*, **A. Allard**, L. Hébert-Dufresne, J.-G. Young and L. J. Dubé, *Phys. Rev. E* **92**, 062807 (2015)
- [A15] *A shadowing problem in the detection of overlapping communities: Lifting the resolution limit through a cascading procedure*, J.-G. Young, **A. Allard**, L. Hébert-Dufresne and L. J. Dubé, *PLOS ONE* **10**, e0140133 (2015)
- [A14] *Spreading dynamics on complex networks: a general stochastic approach*, P.-A. Noël, **A. Allard**, L. Hébert-Dufresne, V. Marceau and L. J. Dubé, *J. Math. Biol.* **69**, 1627–1660 (2014)



- [A13] *A system-level model for the microbial regulatory genome*, A. N. Brooks, D. J. Reiss, **A. Allard**, W.-J. Wu, D. M. Salvanha, C. L. Plaisier, S. Chandrasekaran, M. Pan, A. Kaur and N. S. Baliga, [Mol. Syst. Biol. 10, 740 \(2014\)](#)
- [A12] *Coexistence of phases and the observability of random graphs*, **A. Allard**, L. Hébert-Dufresne, J.-G. Young and L. J. Dubé, [Phys. Rev. E 89, 022801 \(2014\)](#)  
 \* Featured in the *Editors' Suggestions* section of Phys. Rev. E.
- [A11] *Percolation on random networks with arbitrary  $k$ -core structure*, L. Hébert-Dufresne<sup>†</sup>, **A. Allard**<sup>†</sup>, J.-G. Young and L. J. Dubé, [Phys. Rev. E 88, 062820 \(2013\)](#)
- [A10] *Global efficiency of local immunization of complex networks*, L. Hébert-Dufresne<sup>†</sup>, **A. Allard**<sup>†</sup>, J.-G. Young<sup>†</sup> and L. J. Dubé, [Sci. Rep. 3, 2171 \(2013\)](#)
- [A9] *Bond percolation on a class of correlated and clustered random graphs*, **A. Allard**, L. Hébert-Dufresne, P.-A. Noël, V. Marceau and L. J. Dubé, [J. Phys. A 45, 405005 \(2012\)](#)
- [A8] *Exact solution of bond percolation on small arbitrary graphs*, **A. Allard**, L. Hébert-Dufresne, P.-A. Noël, V. Marceau and L. J. Dubé, [EPL 98, 16001 \(2012\)](#)
- [A7] *Propagation on networks: An exact alternative perspective*, P.-A. Noël, **A. Allard**, L. Hébert-Dufresne, V. Marceau and L. J. Dubé, [Phys. Rev. E 85, 031118 \(2012\)](#)
- [A6] *Structural preferential attachment: Stochastic process for the growth of scale-free, modular and self-similar systems*, L. Hébert-Dufresne, **A. Allard**, V. Marceau, P.-A. Noël and L. J. Dubé, [Phys. Rev. E 85, 026108 \(2012\)](#)
- [A5] *Structural preferential attachment: Network organization beyond the link*, L. Hébert-Dufresne, **A. Allard**, V. Marceau, P.-A. Noël and L. J. Dubé, [Phys. Rev. Lett. 107, 158702 \(2011\)](#)
- [A4] *Modeling the dynamical interaction between epidemics on overlay networks*, V. Marceau, P.-A. Noël, L. Hébert-Dufresne, **A. Allard** and L. J. Dubé, [Phys. Rev. E 84, 026105 \(2011\)](#)
- [A3] *Propagation dynamics on networks featuring complex topologies*, L. Hébert-Dufresne, P.-A. Noël, V. Marceau, **A. Allard** and L. J. Dubé, [Phys. Rev. E 82, 036115 \(2010\)](#)
- [A2] *Adaptive networks: Coevolution of disease and topology*, V. Marceau, P.-A. Noël, L. Hébert-Dufresne, **A. Allard** and L. J. Dubé, [Phys. Rev. E 82, 036116 \(2010\)](#)
- [A1] *Heterogeneous bond percolation on multitype networks with an application to epidemic dynamics*, **A. Allard**, P.-A. Noël, L. J. Dubé and B. Pourbohloul, [Phys. Rev. E 79, 036113 \(2009\)](#)

## Book chapters

- [B2] *A new approach to international trade from Network Geometry: The World Trade Atlas 1870-2013*, G. García-Pérez, M. Boguñá, **A. Allard** and M. Á. Serrano, in [Networks of International Trade and Investment: Understanding globalization through the lens of network analysis](#), S. Gorgoni, A. Amighini and M. Smith (Eds.), Vernon Press, pp. 71–112 (2018) ISBN:978-1-62273-065-0
- [B1] *The Social Zombie: Modeling undead outbreaks on social networks*, L. Hébert-Dufresne, P.-A. Noël, V. Marceau, **A. Allard** and L. J. Dubé, in [Mathematical Modeling of Zombies](#), R. Smith? (Ed.), University of Ottawa Press, pp. 149–170 (2014) ISBN:978-0-77662-210-1

## Other writings

- [O3] *La modélisation mathématique pour cartographier le complexe et l'inconnu*<sup>7</sup>, **A. Allard**, L. J. Dubé and L. Hébert-Dufresne, [ACFAS Magazine \(September 2020\)](#)
- [O2] *COVID-19: Cancel your next large event, and tell your friends to cancel theirs*, G. St-Onge, V. Thibeault, **A. Allard**, L. J. Dubé and L. Hébert-Dufresne, [medium.com \(March 2020\)](#)
- [O1] *Des ponts d'Euler à la grippe aviaire: De l'abstraction mathématique à la réalité sociale des épidémies*<sup>8</sup>, **A. Allard**, P.-A. Noël and L. J. Dubé, [Accromath 4 \(winter-spring 2009\)](#)

## Invited seminars and presentations

<sup>7</sup>Mapping the complex and the unknown with mathematical modeling

<sup>8</sup>From Euler bridges to avian flu: From mathematical abstraction to the social reality of epidemics.

- [I18] *Rethinking interactions among the constituents of complex systems: The case for latent hyperbolic geometry*, Vermont-KIAS Workshop: Group interactions in network science, Vermont Complex Systems Center, University of Vermont, Burlington, USA, 2023
- [I17] *Geometric description of clustering in directed networks*, Institute for Biocomputation and Physics of Complex Systems (BIFI), Universidad de Zaragoza, Zaragoza, Spain, 2023
- [I16] *An introduction to the methodologies for studying complex networks*, BIOS<sup>2</sup>/Sentinelle Nord Advanced Field School in Computational Ecology, Val Morin, Canada, 2023
- [I15] *The role of directionality, heterogeneity & correlations in epidemic risk and spread*, Workshop on Interacting Contagions, Santa Fe Institute, Santa Fe NM, USA, 2023
- [I14] *Dynamics on networks through the lens of spectral and information theories*, Institute of Complex Systems (UBICS), Universitat de Barcelona, Barcelona, Spain, 2022
- [I13] *Graphe poissonnien, un oxymore?*, Centre Interdisciplinaire en Modélisation Mathématique de l'Université Laval (CIMMUL), Québec, Canada, 2022
- [I12] *Contact Network Epidemiology: Heterogeneity and Stochasticity of Disease Spread*, Quantitative Life Sciences, McGill University, Montréal, Canada, 2022
- [I11] *Deep learning of dynamical epidemic processes on complex networks*, Vermont Complex Systems Center, University of Vermont, Burlington VT, USA, 2019
- [I10] *Deep learning of dynamical epidemic processes on complex networks*, Institute of Complex Systems (UBICS), Universitat de Barcelona, Barcelona, Spain, 2019
- [I9] *Chaire de recherche Sentinelle Nord en modélisation mathématique des systèmes et des réseaux complexes*, Official inauguration of the latest Sentinelle Nord research chairs, Lévis, Canada, 2019
- [I8] *An introduction to the methodologies for studying complex networks*, Scientific retreat of the thematic project 1 (TP1) – Sentinelle Nord, Forêt Montmorency, Canada, 2019
- [I7] *Three tales about percolation on real complex networks*, International Conference on Complex Networks (CompleNet 2019), Tarragona, Spain, 2019
- [I6] *Modeling with Random Networks*, Complex Networks Winter Workshop (CNWW18), Québec, Canada, 2018
- [I5] *Les réseaux complexes: un paradigme unificateur et transformateur pour comprendre la relation dynamique/structure des systèmes complexes*, Centre de recherche CERVO, Québec, Canada, 2018
- [I4] *Les réseaux complexes: un paradigme unificateur et transformateur pour comprendre la relation dynamique/structure des systèmes complexes*, Institut de biologie intégrative et des systèmes, Université Laval, Québec, Canada, 2018
- [I3] *The hyperbolic brain: A geometric approach to network neuroscience*, Sentinelle Nord Annual Meeting, Québec, Canada, 2018
- [I2] *Towards an effective structure of complex networks and its contributions to epidemiology and neuroscience*, Network Science Institute, Boston, Massachusetts, USA, 2017
- [I1] *Exploring the hidden metric space of complex networks*, Santa Fe Institute, Santa Fe, New Mexico, USA, 2015

## Contributed presentations

- [C15] *Realistic clustering patterns in directed geometric networks*, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [C14] *Effective structure of complex networks and a second look at message passing approaches* (poster), International School and Conference on Network Science (NetSci 2018), Paris, France, 2018
- [C13] *Double epidemic threshold and the potential of the Zika virus as a sustained STI*, BIFI International Conference, Zaragoza, Spain, 2018
- [C12] *The effective navigable geometry of the brain*, Mapping Complexity: Foundations and Applications of Network Geometry workshop (MACFANG-17), Barcelona, Spain, 2017
- [C11] *The effective navigable geometry of the brain*, International School and Conference on Network Science (NetSci 2017), Indianapolis, Indiana, USA, 2017
- [C10] *The geometric nature of weights in real complex networks*, Conference on Complex Systems (CCS 2016), Amsterdam, The Netherlands, 2016

- [C9] *The hidden geometry of complex weighted networks*, 8th International Conference on Discrete Models of Complex Systems (Summer Solstice 2016), Aveiro, Portugal, 2016
- [C8] *Unveiling the hidden geometry of weighted networks*, International School and Conference on Network Science (TOPONETS15), Zaragoza, Spain, 2015
- [C7] *Percolation on clustered and correlated random graphs: General formalism and applications* (poster), International School and Conference on Network Science (NetSci 2013), Copenhagen, Denmark, 2013
- [C6] *Bond and site percolation on clustered and correlated random graphs*, Joint CRM-Imperial College School and Workshop in Complex Systems, Barcelona, Spain, 2013
- [C5] *Unveiling hidden communities through cascading detection on network structures*, 2nd International Conference on Complex Sciences, Santa Fe, New Mexico, USA, 2012
- [C4] *Exact solution of bond percolation on small arbitrary graphs*, International School and Conference on Network Science (NetSci 2012), Evanston, Illinois, USA, 2012
- [C3] *Using network organization to hinder propagation in structured populations* (poster), International School and Conference on Network Science (NetSci 2012), Evanston, Illinois, USA, 2012
- [C2] *Multitype modular networks as a model of clustered social networks* (poster), International School and Conference on Network Science (NetSci 2010), Boston & Cambridge, Massachusetts USA, 2010
- [C1] *Heterogeneous Bond Percolation on Complex Networks: Application to Epidemiology* (poster), Canadian Association of Physicists Congress, Québec, Canada, 2008  
 ★ Third place at the student competition.

### Contributed presentations by mentees

- [M29] *A Probabilistic Methodology to Reconstruct Biodiversity from Interactions with Indicator Species Along Latitudinal Co-Occurrence Networks*, Ilhem Bouderbala, Sentinelle Nord Scientific Meeting, Québec, Canada, 2023
- [M28] *La géométrie au coeur des systèmes nordiques*, Simon Lizotte, Sentinelle Nord Scientific Meeting, Québec, Canada, 2023
- [M27] *On the reconstructability of complex networks* (poster), François Thibault, Sentinelle Nord Scientific Meeting, Québec, Canada, 2023
- [M26] *On the reconstructability of complex networks*, François Thibault, International School and Conference on Network Science (Netsci2023), Vienna, Austria, 2023
- [M25] *Inherent uncertainty of hyperbolic embeddings of complex networks*, Simon Lizotte, International School and Conference on Network Science (Netsci2023), Vienna, Austria, 2023
- [M24] *Optimal Mesoscopic Structure of General Binary-State Dynamics on Networks*, Jérémi Lesage, International School and Conference on Network Science (Netsci2023), Vienna, Austria, 2023
- [M23] *Inherent uncertainty of hyperbolic embeddings of complex networks* (invited), Simon Lizotte, New England Statistics Symposium (NESS2023), Boston MA, USA 2023
- [M22] *The Low-Rank Hypothesis of Complex Systems: From Empirical and Theoretical Evidence to the Emergence of Higher-Order Interactions*, Vincent Thibeault, SIAM Conference on Applications of Dynamical Systems (DS23), Portland OR, USA, 2023
- [M21] *On the effectiveness of reconstructing biodiversity from indicator species along a climate gradient* (poster), Ilhem Bouderbala, Sentinelle Nord Scientific Meeting, Québec, Canada, 2022
- [M20] *Dimension matters when modeling network communities in hyperbolic spaces*, Béatrice Désy, International School and Conference on Network Science (Netsci2022), Shanghai, China, 2022
- [M19] *Random graph models with fixed centrality patterns and degree sequence*, François Thibault, International School and Conference on Network Science (Netsci2022), Shanghai, China, 2022
- [M18] *On the importance of correlation in graph reconstruction*, Simon Lizotte, International School and Conference on Network Science (Netsci2022), Shanghai, China, 2022
- [M17] *Nonlinear infection rate to compress mechanistic epidemic models*, Guillaume St-Onge, Northeast Regional Conference on Complex Systems (NERCCS 2022), Buffalo NY, USA, 2022
- [M16] *The low-dimension hypothesis implies higher-order interactions in complex systems*, Vincent Thibeault, Northeast Regional Conference on Complex Systems (NERCCS 2022), Buffalo NY, USA, 2022

- [M15] *Dimension reduction on heterogeneous networks*, Marina Vegué Llorente, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [M14] *Information Theory of Dynamics on Networks: Between Predictability and Reconstructability*, Charles Murphy, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [M13] *Universal nonlinear infection kernel from heterogeneous exposure on higher-order networks*, Guillaume St-Onge, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [M12] *Dimension reduction of high-dimensional dynamics on networks with adaptation*, Vincent Thibeault, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [M11] *Firing rate distributions in plastic networks of spiking neurons*, Marina Vegué Llorente, Networks 2021: A Joint Sunbelt and NetSci Conference, Washington DC, USA, 2021
- [M10] *Information Theory of Dynamics on Networks: Quantifying the Structure-Function Relationship*, Charles Murphy, SIAM Conference on Applications of Dynamical Systems (DS21)
- [M9] *Bursty Exposure on Higher-Order Networks Leads to Nonlinear Infection Kernels*, Guillaume St-Onge, SIAM Conference on Applications of Dynamical Systems (DS21)
- [M8] *Dimension Reduction of High-Dimensional Dynamics on Networks with Adaptation*, Vincent Thibeault, SIAM Conference on Applications of Dynamical Systems (DS21)
- [M7] *Firing Rate Distributions in Plastic Networks of Spiking Neurons*, Marina Vegué Llorente, SIAM Conference on Applications of Dynamical Systems (DS21)
- [M6] *Bursty exposure on higher-order networks leads to nonlinear infection kernels*, Guillaume St-Onge, Northeast Regional Conference on Complex Systems (NERCCS 2021)
- [M5] *Dimension reduction of high-dimensional dynamics on networks with adaptation*, Vincent Thibeault, Northeast Regional Conference on Complex Systems (NERCCS 2021)
- [M4] *Dimension reduction on heterogeneous networks*, Marina Vegué Llorente, Northeast Regional Conference on Complex Systems (NERCCS 2021)
- [M3] *Deep learning of stochastic contagion dynamics on complex networks*, Charles Murphy, International School and Conference on Network Science (Netsci 2020), Rome, Italy (2020)
- [M2] *Localization, bistability and optimal seeding of contagions on higher-order networks*, Guillaume St-Onge, Conference on Artificial Life (ALIFE 2020), Montréal, Canada (2020)
- [M1] *Learning dynamical processes on complex networks from time series*, Charles Murphy, International School and Conference on Network Science (Netsci 2019), Burlington VT, États-Unis (2019)

## SELECTED MEDIA COVERAGE

- *Validating the low-rank hypothesis in complex systems*  
Tejasri Gururaj, Phys.org, January 24<sup>th</sup> 2024  
<https://phys.org/news/2024-01-validating-hypothesis-complex.html>
- *Intrinsic simplicity of complex systems*  
Jianxi Gao, Nature Physics, January 10<sup>th</sup> 2024  
<https://www.nature.com/articles/s41567-023-02268-0>
- *Déconfinement : La chasse aux super-propagateurs du covid-19*  
Vincent Nouyrigat, Science & Vie, January 2021  
<https://www.science-et-vie.com/corps-et-sante/deconfinement-la-chasse-aux-super-propagateurs-du-covid-19-2216.html>
- *L'épidémiologie du temps des Fêtes*  
Alexandre Touchette, Les années lumière, November 22<sup>nd</sup> 2020  
<https://ici.radio-canada.ca/ohdio/premiere/emissions/les-annees-lumiere/segments/reportage/210686/covid-19-noel-temps-des-fetes-super-propagation-virus-confinement>
- *Covid-19: comment certains malades deviennent des supercontamineurs*  
Le Monde, August 15<sup>th</sup> 2020  
[https://www.youtube.com/watch?v=\\_2MT1r-Cmsw](https://www.youtube.com/watch?v=_2MT1r-Cmsw)

- *An Obscure Field of Math Might Help Unlock Mysteries of Human Perception*  
Stephen Ornes, Discover Magazine, July/August 2020  
<https://www.discovermagazine.com/the-sciences/an-obscure-field-of-math-might-help-unlock-mysteries-of-human-perception>
- *La pandémie s'alimente de hasard et de superdissémination*  
Jean Hamann, ULaval nouvelles, June 2<sup>nd</sup> 2020  
<https://nouvelles.ulaval.ca/2020/06/02/la-pandemie-s-39-alimente-de-hasard-et-de-superdissemination-a-895b2a35-08a7-43d5-b686-9d0567f42a9b>
- *Voir par-delà le sommet de la courbe*  
Alexis Riopel, Le Devoir, April 21<sup>st</sup> 2020  
<https://www.ledevoir.com/societe/sante/577379/voir-par-dela-le-sommet-de-la-courbe>
- *How large a gathering is too large during the coronavirus pandemic?*  
Dana Mackenzie, Science News, April 2<sup>nd</sup> 2020  
<https://www.sciencenews.org/article/coronavirus-covid19-social-gathering-size-math-pandemic>
- *Disease modelers gaze into their computers to see the future of Covid-19, and it isn't good*  
Sharon Begley, STAT News, February 14<sup>th</sup> 2020  
<https://www.statnews.com/2020/02/14/disease-modelers-see-future-of-covid-19/>
- *Hidden influence*  
Abigail Klopfer, Nature Physics, February 3<sup>rd</sup> 2017  
<https://www.nature.com/articles/nphys4046>
- *Don't call in sick*  
Thilo Gross, Nature Physics, November 3<sup>rd</sup> 2016  
<https://www.nature.com/articles/nphys3939>
- *Going Home Sick? Your Substitute Could Spread Disease More Widely*  
Erin Blakemore, Smithsonian Magazine, August 2<sup>nd</sup> 2016  
<https://www.smithsonianmag.com/smart-news/substitute-workers-could-make-workplace-illness-worse-180959979/>
- *Send your sick colleague home – but don't hire a replacement*  
Ben Johnson, Nature Microbiology, August 1<sup>st</sup> 2016  
<https://microbiologycommunity.nature.com/posts/11048-send-your-sick-colleague-home-but-don-t-hire-a-replacement>