Irene Balelli

Ph.D.

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Summary

After a training in Mathematics carried out in Italy, Spain and France, and a Master's degree dedicated to *Mathematics applied to biological and medical sciences* (UPMC, Paris), I received my Ph.D. from **University Paris 13** (2013-2016, LAGA Laboratory, Sorbonne Paris Cité). My thesis project, embedded in the frame of the **laboratory of excellence Inflamex**, aimed to establish an appropriate graph-based mathematical framework to define and study simplified evolutionary models inspired by antibody affinity maturation (AAM), a biological process that enables the development of a specific antibody response against pathogens attacking our organism. In January 2017 I joined the **SISTM team** (INSERM U1219 Bordeaux Population Health and INRIA) for a post-doc as part of the **EBOVAC project**, launched under the European Innovative Medicines Initiative **(IMI) Ebola+ program**, to support the development, by the pharmaceutical company **Janssen**, of a prophylactic vaccine against Ebola virus disease. I developed and refined mechanistic models of the immune response to the envisaged vaccination strategies, and confronted them with clinical trial data. In 2019 I have integrated the **Epione team** (Inria Center of University Côte d'Azur) as a post-doctoral researcher in the context of the **ANR FedBioMed project**, where I mainly focused on federated learning for the analysis of decentralized heterogeneous multimodal biomedical data. In 2021 I was awarded with an **ISFP (Inria Starting Faculty Position)**, a permanent research position, in the Epione team, with a research project on ***Causal machine learning: from imaging to in silico trials***.
Throughout my research career, I have had the opportunity to investigate several questions from both a theoretical and a medical perspective, acquiring a broad view of the interactions between Mathematics, Statistics and Medicine, whose potential is increasingly recognized and which involves challenges and issues in each of these fields, as well as at their intersections. Since my PhD, I have focused on mathematical and statistical modeling applied to biomedical sciences, with a very **multidisciplinary approach** (I have been led to collaborate with immunologists, physicians, biologists and clinicians throughout my career), seeking a hierarchical, modular and interpretable definition of the developed models. I am currently involved in both **international projects** (EU H2020 SimCardioTest), **national projects** (RHU TALENT) and with **local partners** (Nice CHU, IPMC institute). I have had the opportunity to publish my results in **journals** (*e.g.* Mathematical Biosciences, MELBA) and in **conferences** (IPMI, CINC). I presented my work in several occasions, both nationally and internationally. Finally, I have served as a **reviewer** for several journals (*e.g.* Vaccine Journal, MedIA) and as a **PC member** (ECAI conference). I have been invited to participate to **PhD juries**, and I have always been involved in **teaching** activities (bachelor's and master's degrees, thematic schools). I am currently in charge of the **pedagogical organization** of the AI for Health track of the Data Science&AI Master 2 (University Côte d'Azur), and I am part of the **scientific committee** of the FC3R (French Center for 3Rs - Replace, Reduce, Refine) and the Academy 2 - Complex Systems, University Côte d'Azur. I **supervise students** (Master 2, PhD) and post-doc.

Biographical Information

Birth	**November 3, 1988**, in Forlimpopoli - Italy.
Citizenship	**Italian and French**.
Family situation	**Married. Two children** (2015 and 2018).

Research Interests

Modeling/ Statistics	Bayesian Statistics. Latent variable models. Generative models. Mixed effects models. Identifiability analysis. Sensitivity analysis. Parameter estimation with population approach. Expectation Maximization. PK/PD. In-silico trials. Meta-modeling.

ML & Data governance	Federated learning. Distributed learning. Causal learning. Differential privacy. Large-scale heterogeneous biomedical data. Missing data.
Biomedical Applications	*Immunology:* Immune response dynamics. Immune system. Antibody affinity maturation. B-cells. Immune memory. Vaccination. *Cardiology:* Drugs' cardiac safety. Pro-arrhythmic risk. *Neurodegenerative diseases:* Alzheimer's Disease, Parkinson's Disease, Brain Imaging data.
Applied Probability	Random walks on graphs. Markov chains. Graph theory. Galton-Watson processes. Evolutionary landscapes

Current Position

2021–now **Research scientist (ISFP) in mathematical modeling for computational biomedicine**, EPIONE team - Inria Center of University Côte d'Azur, Valbonne - France.

Experience

2020–2021 **Post-doctoral research fellowship in federated statistical learning for new generation meta-analyses of large-scale and secured biomedical data**, EPIONE team - Inria Center of University Côte d'Azur, Valbonne - France.

2017–2019 **Post-doctoral research fellowship in modeling of the immune response to Ebola vaccine**, SISTM team - Inserm U1219 Bordeaux Population Health, Bordeaux - France.

Education

2017 **Qualification**, CNU section 26: Applied mathematics and applications of mathematics.

2013–2016 **PhD in Applied Mathematics with teaching activities**, LAGA - University Paris 13, Villetaneuse - France.

Title: *Mathematical foundations of antibody affinity maturation*.

Supervisors: Vuk Milišić, Gilles Wainrib, Hatem Zaag.

Defense date: November 30, 2016.

2011–2013 **Master Degree in Mathematics Applied to Biology and Medicine**, *Master thesis:* A mathematical model of somatic hypermutation *(Supervisors: V. Milišić, G. Wainrib)*, University Paris 6, Paris - France.

2010–2011 **Erasmus Program**, Universidad Complutense, Department of Mathematics, Madrid - Spain.

2007–2010 **Bachelor degree in Mathematics**, *Bachelor thesis:* Bressloff and Cowan's model: visual hallucinations as stable states of cortical activation *(Supervisor: G. Citti)*, University of Bologna, Bologna - Italy.

Papers, Book Chapters and Preprints –> ;

I. Balelli, S. Al-Ali, E. Dumas, J. Abecassis, *Causality: fundamental principles and tools*, Trustworthy AI in Medical Imaging, 2024, MICCAI/Elsevier book series (in press).

†S. Al-Ali, M. T. Mora, M. Sermesant, B. Trénor, **I. Balelli**, *Assessing ion channel blockade and electromechanical biomarkers' interrelations through a novel Multi-Channel Causal Variational Autoencoder*, Computing in Cardiology (CinC) 2024, [hal-04607082].

Y. Coudière, M. Leguèbe, **I. Balelli**, A. Baretta, G. Fauré, D. Feuerstein, *A computer model for in-silico trials on pacemaker energy efficiency*, Computing in Cardiology (CinC) 2024.

A. Baretta, Y. Coudière, O. Camara, B. Trenor, H. Arevalo, **I. Balelli**, R. Setzu, L. Geris, S. Benito, M. Barbier, M. Sermesant, *SimCardioTest cloud-based platform: an innovative tool for cardiac in silico trials*, Abstract, VPHi Conference 2024.

S. Al-Ali, **I. Balelli**, *Multi-Channel Causal Variational Autoencoder*, In preparation, [hal-04666466].

†S. Al-Ali, J. Llopis-Lorente, M. T. Mora, M. Sermesant, B. Trénor, **I. Balelli**, *A causal discovery approach for streamline ion channels selection to improve drug-induced TdP risk assessment*, IEEE Xplore2023 - Computing in Cardiology (CinC) 2023 [hal-04105144].

†F. Cremonesi, M. Vesin, S. Cansiz, Y. Bouillard, **I. Balelli**, L. Innocenti, S. Silva, S.S. Ayed, R. Taiello, L. Kameni, R. Vidal, F. Orlhac, C. Nioche, N. Lapel, B. Houis, R. Modzelewski, O. Humbert, M. Onen, and M. Lorenzi, *Fed-BioMed: Open, Transparent and Trusted Federated Learning for Real-world Healthcare Applications*, [hal-04081557].

†**I. Balelli***, A. Sportisse*, F. Cremonesi, P.A. Mattei, M. Lorenzi, *Fed-MIWAE: Federated Imputation of Incomplete Data via Deep Generative Models*, In preparation, [hal-04069795].

Q. Clairon, C. Pasin, **I. Balelli**, R. Thiébaut, M. Prague, *Parameter estimation in nonlinear mixed effect models based on ordinary differential equations: an optimal control approach*, Accepted for publication in Computational Statistics (COST), [arXiv: 2102.11543].

M. Lorenzi, M. Deprez, **I. Balelli**, A. L. Aguila, A. Altmann, *Integration of Multimodal Data*, Machine Learning for Brain Disorders, 2023, 573-597, Springer Nature.

†**I. Balelli**, S. Silva, M. Lorenzi, *A Differentially Private Probabilistic Framework for Federated Heterogeneous Multi-View Datasets Variability*, Journal of Machine Learning for Biomedical Imaging (MELBA). 2022:012.

†**I. Balelli**, S. Silva, M. Lorenzi, *A Probabilistic Framework for Modeling the Variability Across Federated Datasets of Heterogeneous Multi-View Observations*, International Conference on Information Processing in Medical Imaging (IPMI). Springer, Cham, 2021. p. 701-714.

M. Prague*, J. Gerold*, **I. Balelli**, C. Pasin, J. Li, D. Barouch, J. Whitney, A. Hill, *Viral rebound kinetics following single and combination immunotherapy for HIV/SIV*, [bioRxiv 700401].

I. Balelli, C. Pasin, M. Prague, F. Crauste, T. Van Effelterre, V. Bockstal, L. Solforosi, R. Thiébaut, *A model for establishment, maintenance and reactivation of the immune response after vaccination against Ebola virus*, Journal of Theoretical Biology, 2020, DOI: 10.1016/j.jtbi.2020.110254.

C. Pasin, **I. Balelli**, T. Van Effelterre, V. Bockstal, L. Solforosi, M. Prague, M. Douoguih, R. Thiébaut, *Dynamics of the humoral immune response to a prime-boost Ebola vaccine: quantification and sources of variation*, Journal of Virology, 2019, **DOI:** 10.1128/JVI.00579-19.

I. Balelli, V. Milišić, G. Wainrib, *Multi-type Galton-Watson processes with affinity-dependent selection applied to antibody affinity maturation*, Bulletin of Mathematical Biology, 2019, vol. 81, no 3, p. 830-868.

I. Balelli, V. Milišić, G. Wainrib, *Random walks on binary strings applied to the somatic hypermutation of B-cells*, Mathematical Biosciences, 2018, vol. 300, p. 168-186.

I. Balelli, V. Milišić, G. Wainrib, *Branching random walks on binary strings for evolutionary processes in adaptive immunity*, [arXiv: 1607.00927].

† This paper is listed within the 3IA Côte d'Azur collection.

Conferences, Meetings and Seminars

2024 **IABM 2024**, *Invited talk*, Grenoble.
i2m Seminar, *Invited talk*, Marseille.
HeKa Seminar, *Invited talk*, Online.

2023 **Innovaheart 2023**, *Invited talk*, Bordeaux.
3IA Seminar, *Invited talk*, Sophia Antipolis.

2022 **Inria-DFKI workshop 2022**, Bordeaux.
BoostUrCareer Doctoriales 2022 – AI in HEALTHCARE, *Invited talk*, Nice.

2021 **Information Processing in Medical Imaging (IPMI) 2021**, Online event.

2020 **3IA Scientific Days**, Nice - France.
SophI.A Summit 2020, Sophia Antipolis - France.

2019 **4$^{\text{th}}$ EBOVAC1/2 Annual meeting**, *Invited talk*, Nairobi - Kenya.

VRI Annual meeting, *Invited talk*, Paris - France.

2018 **IMI 10$^{\text{th}}$ Anniversary Scientific Symposium**, 3$^{\text{rd}}$ committee prize "best presentation", Brussels - Belgium.

CROI 2018, *Poster (J.M. Gerold, C. Pasin,* ***I. Balelli****, S. Lim, C. Osuna, J.B. Whitney, D.H. Barouch, M. Prague, A.L. Hill)*, Boston - United States.

3$^{\text{rd}}$ EBOVAC1/2 Annual meeting, *Invited talk (with C. Pasin)*, Amsterdam - Nederland.

2017 **Systems Immunology and Vaccine design**, Heidelberg - Germany.

2016 **Probabilities and Statistics seminar (LAGA)**, *Invited talk*, Villetaneuse - France.

1$^{\text{st}}$ Challenges in inflammation meeting, Florence - Italy.

Les probabilités de demain, *Invited talk*, IHÉS - Bures-sur-Yvette - France.

Summer school: "PDE and Probability for Life Sciences", CIRM - Marseille - France.

2015 **EDP-Normandie**, Havre - France.

2014 **InflaConf: Mathematical modeling in immunology and inflammation**, *invited talk*, Paris - France.

CANUM 2014, Carry-le-Rouet - France.

Inflamex day, *Invited talk*, CIEP Sèvres - France.

2013 **GDR Métice: Inflammation and Treatment Resistance**, *invited talk*, Lyon - France.

Thematic schools: contribution

2022 **AI4Health Winter School**, *Workshop (teaching materials and presentation):* Fed-BioMed, an open source framework for federated learning in real world healthcare applications, Online event.

2021 **AI4Health Winter School**, *Workshop (teaching materials and presentation):* Handling heterogeneity in the analysis of biomedical information, Online event.

First Inria-DFKI European Summer School on Artificial Intelligence, *Workshop (teaching materials and presentation):* Federated learning methods and frameworks for collaborative data analysis, Online event.

Supervision activities

Post-Doc **S. Al-Ali**, *Causal data analysis of in-silico trials*, Projet SimCardioTest, Since Oct. 2022 (100% supervision).

PhD **W. Kahtir**, *Integromics analysis: a new angle for studying the pathophysiology of Fragile X Syndrome*, co-directed with C. Gwizdek (IPMC) and M. Lorenzi, Since Mar. 2024 (50% supervision)[‡].

E. Gaymard, *Innovative mathematical methodologies in pharmacometric meta-modeling from highly heterogeneous sources*, industrial PhD (CIFRE) with Exact-Cure, co-directed with M. Sermesant, Nov. 2022 - Jun. 2023 (50% supervision).

Master 2 **B. Ramudu Manam**, *PPCA-based disease progression modeling*, Since Apr. 2023 (50% supervision).

A. Senacheribbe, *Longitudinal PPCA*, Sept. 2020 - Feb. 2021 (50% supervision).

M. Alexandre, *Mechanistic modeling applied to vaccinology*, Feb. 2019 - Aug. 2019 (20% supervision).

[‡] I am committed with the doctoral school ED SVS and the University Côte d'Azur to defend my HDR (*habilitation à diriger des recherches*) by 2026.

Teaching Activities

2020-2024 **Bayesian learning**, *Lectures and tutorials (10h/year)*, M2 MSc Data Science & Artificial Intelligence, University Côte d'Azur, Sophia Antipolis - France.

2023-2024 **Advanced statistical modeling**, *Lectures and tutorials (20h/year)*, 3rd year bachelor's degree (BUT Data science), University Côte d'Azur, Sophia Antipolis - France.

Statistical modeling for complex data and Big Data, *Lectures and tutorials (33h/year)*, 3rd year bachelor's degree (BUT Data science), University Côte d'Azur, Sophia Antipolis - France.

2020-2023 **Modeling of biological systems**, *Lectures and tutorials (10h/year)*, M2 BIM, University Côte d'Azur, Nice - France.

2022-2023 **Statistics and Modeling**, *Tutorials (24h/year)*, 3rd year bachelor's degree, University Côte d'Azur, Nice - France.

2021-2022 **Analysis and Modeling**, *Tutorials (20h/year)*, 1st year bachelor's degree, University Côte d'Azur, Nice - France.

2013-2016 **Teaching mission proposed to PhD students (*Monitorat* - Tutorials 64h/year)**.

Probability and Statistics 2, *Tutorials*, 2nd year bachelor's degree in Mathematics and MIEF, University Paris 13, Villetaneuse - France.

Probability and Statistics 1, *Tutorials*, 2nd year bachelor's degree in Mathematics, University Paris 13, Villetaneuse - France.

Probability and Statistics, *Tutorials*, 1st year Engineering degree (Apprentissage énergétique), Engineering School Sup Galilée, Villetaneuse - France.

Statistics, *Tutorials*, 1st year Engineering degree MACS (Mathématiques Appliquées et Calcul Scientifique), Engineering School Sup Galilée, Villetaneuse - France.

Probability, *Tutorials*, 2nd year IUT-Info, University Paris 13, Villetaneuse - France.

Inferential statistics, *Tutorials*, 2nd year DUT-GEA, University Paris 13, Bobigny - France.

Review Activities

2024 PC Member for the ECAI 2024 conference (Outstanding PC Member Award)

2020-2023 Vaccine (Elsevier), Medical Image Analysis (Elsevier), Neuroimage (Elsevier), SMAI J. of Computational Mathematics

Softwares

MC^{2}VAE Variational causal disentanglement from multimodal data: design and code.

Fed-mv-PPCA Bayesian framework for federated multi-view heterogeneous datasets assimilation based on Probabilistic PCA: design and code.

Fed-BioMed Open-source federated learning framework: participation to research and development.

Responsabilities and Management

Administration In charge of the pedagogical organization of the AI for Health track of the Data Science&AI Master 2 since 2023, Université Côte d'Azur, Sophia Antipolis - France

Part of the Data Science&AI Master 2 jury (M2 recruitment panel and end-of-semester/end-of-year evaluation jury) since the 2023-2024 academic year.

Projects WP leader in the EU H2020 project SimCardioTest (In-silico trials & Data science). (2021–2025)

WP co-leader in the RHU project TALENT (Multimodal risk prediction model). (2024–2029)

SC Part of the scientific committee of the GIS (scientific interest group) FC3R since Jul. 2023.

Part of the scientific committee of the Academy 2 (Complex Systems) since Nov. 2023.

Juries Member of the PhD jury of H. Liu (Paris - May 2024).

Member of the PhD jury of V. Montalibet (Bordeaux - scheduled September 2024).

National & International Projects and Collaborations

2024-now **TALENT**, *RHU France 2030 programme*, 8 French partners, 1 USA.

2021–now **SimCardioTest**, *EU H2020 programme*, 10 organizations, 6 EU countries and USA.

Academic: Center for Research and Innovation in Bioengineering (Ci2B), Universitat Politècnica de València (Spain).

Industry: InSilicoTrials (Italy).

2018–2019 **DYNAM-HIC**, *Inria Associate team*, France and USA.

Academic: Harvard Program for evolutionary Dynamics (USA).

2017–2019 **Ebovac**, *IMI Ebola+ programme*, 6 partners, EU, UK, Sierra Leone, Burkina Faso.

Academic: Oxford Vaccine Group (UK).

Industry: Janssen Vaccines & Prevention B.V. (Belgium).

Clinic: Vaccine Research Institute (VRI, France).

2013–2016 **Inflamex**, *Laboratory of Excellence (LabEx)*, France.

Clinic: Inserm UMR-U978 Signaling Adapters in Hematology (ASIH, France).

Outreach activities

2022 1 scientifique 1 classe: Chiche!, to encourage the pursuit of scientific studies and explain research activities to high school students. 3 classes, Lycée Tocqueville, Grasse.

Computer Skills

Programming Languages	**Python, Matlab, R**	Parameter estimation softwares	**Monolix, NIMROD**
Others	**IdentifiabilityAnalysis (Mathematica), DAISY (Reduce3.8)**		

Languages

Italian	**Mother tongue**	English	**Fluent**
French	**Bilingual**	Spanish	**Fluent**

Misc

Editing & Office	**OpenOffice, Office, LaTeX**	Operating Systems	**Mac 0SX, Linux, Windows**