

BENJAMIN MAUROY

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Generalities

POSITIONS

DR2 CNRS Section 51 Laboratoire JA Dieudonné, Université Côte d'Azur, Nice	from 10/2022 - ...
CRCN CNRS Section 41, HDR (2014) Laboratoire JA Dieudonné, Université Côte d'Azur, Nice Visiting researcher in Auckland Bioengineering Institute Laboratoire Matière et Systèmes Complexes, Université Paris Diderot	2005 - 2022 2010 - 2022 2015 2005 - 2010
Director of VADER Center, Université Côte d'Azur	2017 - ...
Post-doc CNRS (Mathematics) Laboratoire JL Lions, Université Pierre et Marie Curie	2004 - 2005

EDUCATION

Habilitation à Diriger des Recherches, Université de Nice Sophia Antipolis <i>Viscosity: an architect for the respiratory system?</i>	2014
PhD in Applied Mathematics, CMLA - ENS Cachan, <i>Hydrodynamics in the lungs, interplay between flows and geometries,</i> under the supervision of B. Sapoval and L. Desvillettes	2000 - 2004
Mathematics agregation ENS Cachan	2000 1997 - 2001

RESEARCH SUMMARY

My research aims at understanding the properties of the mammals' respiratory system and more particularly the geometries of its organ. I am looking for the underlying optimisations and robustness induced by evolution. I am studying the links between evolution dynamics, the involved physical processes and the constraints induced by biology, physiology and development. To analyse these systems, I am developing mathematical and numerical models, with multi-scale approaches, from the organ size (such as lungs) downwards the cell (such as red blood cells). These topics enters the frame of Darwinian medicine and allows a deep understanding of the organs properties and potential limits (due to constraints). Typically, thanks to several modeling approaches, I proposed a highly plausible scenario that explains how the lung's geometry could have been selected by linking the function of adults' lung to the behaviour of lungs' cells during development. My results have many implications in the understanding of lung's function and pathologies and I am now developing mathematical and numerical models applied to medical questions. I am studying the motion of mucus in the lungs to understand its behavior in healthy and pathological lungs. This research topic aims at giving a scientific basis to chest physiotherapy at a time where the efficiency and range of application of this empirical technique is debated.

My work involves deep interdisciplinary approaches and is based on the interplays between Mathematics, Biology, Medicine and Physics. My research is based on dealing with partial derivative equations, understanding

their properties (fluid mechanics, fluid-structure interaction, reaction-diffusion), optimization theory, dynamical systems and scientific computing.

AWARDS

Prize La Recherche 2005, Research Ministry mention	2005
Award from the College of Pneumology Professors in France	2004

Research direction

PROJECTS DIRECTION

(*in progress*) Director of the VADER Center - Center for virtual modeling of respiration (federation in Université Côte d'Azur - UCA)

(*in progress*) Direction of the project *Modelling of chest physiotherapy - VirtualChest*, 2010 - Present (ABI, Auckland (NZ); Hôpital R. Debré, Paris; LJAD, INΦNI, INRIA, CHU Lenval, Nice; MSC, Paris Diderot; SYMME, Univ. Savoie; Chest physiotherapists, Paris, Grenoble; private companies RespInnovation and IMape)

(*in progress*) Direction of the project *Selection of the lung's geometry*, 2005 - Present (LJAD, UCA; MSC, Paris Diderot; IRMA, Strasbourg; Hôpital Européen Georges Pompidou, Paris; TIPs, ULB Bruxelles).

Direction of the project *Modelling the lung's development*, 2012 - 2014 (LJAD, UCA; MSC, Paris Diderot)

Direction of the project *Arterial network optimization*, 2008 - 2012 (LJAD, UCA; MSC, Paris Diderot)

PEOPLE SUPERVISIONS

Current supervisions

Co-supervision of 4 PhD students

- R. Di Dio (CoFund H2020, LJAD, Nice) - 2019-2023 - supervision with A. Mantzafaris, INRIA, Nice and L. Giovanini-Chami, CHU Lenval, Nice - *Localization of bronchial obstructions in the lung*
- T. Laporte (Doctoral school funding) - 2019-2022 - supervision with L. Giovanini-Chami, CHU Lenval, Nice - *Modeling the lung during free diving*
- V. Mons (PACA Région/VADER Center) - 2019-2023 - supervision with G. Blain, LAMHESS, STAPS Nice - *Ventilation des master athlètes*
- C. Meziane (Orsay doctoral school funding) - 2020-2023 - supervision with A. Decoene, IMB, Bordeaux and S. Martin, MAP5, Paris - *Modélisation micro-macro de l'écoulement mucociliaire*

Past supervisions

Supervision of 15 Master or engineer students

Full supervision of 4 PhD students

- M. Brunengo (CIFRE, LJAD, Nice) - 2018-2021 - *Study of a visco-elastic model of the human lung and application to the High Frequency Chest Wall Oscillation*, now engineer in the private company RespInnovation.
- F. Noël (ANR, LJAD, Nice) - 2018-2021 - *Influence of the ventilation on the transport properties of the healthy and inflamed lung*, **thesis award from the Institut des Systèmes Complexes de Paris IDF, 2021**, now researcher in CNRS (LJLL, Paris).
- J. Stéphano (CNRS, LJAD, Nice) - 2017-2021 - *Conséquences de l'asymétrie et de la compliance des bronches sur les propriétés hydrodynamiques du poumon, applications à la kinésithérapie respiratoire.*, **finalist for the thesis award from the Institut des Systèmes Complexes de Paris IDF, 2022**, now post-doc in University Cote d'Azur.

- B. Moreau (CNRS, Lab MSC, Paris 7) - 2008-2012 - *Optimisation du transport de l'oxygène dans la circulation artérielle (Link to report)*, engineer in the German Aerospace Center.

Full supervision of 3 post-docs

- C. Karamaoun (Univ. Côte d'Azur/Vaincre la mucoviscidose/ANR) - 2019-2021 - *Transfers through the bronchi walls*
- M. Lin (EMMA program) - 6 months in 2015 - *Air/mucus interaction in a rigid tree*
- R. Clément (Univ. Nice-Sophia Antipolis/Ville de Nice) - 2011-2013 - *Models of the lung's development*

Full supervision of 2 engineers

- N. Pottier - 2019-2020 - *Simulation of water plugs in the large bronchi*
- S. Rachidi (RespInnovation company, Sophia Antipolis) - 2013-2014 - *Lung's mechanics*

Non official partial supervision of two PhD students (a chapter in the PhD thesis)

- Y. Privat - 2005-2008 - *Some shape optimization problems in Life sciences*
- P. Bokov - 2008-2011 - *Description expérimentale et numérique de l'interaction entre un stent biodégradable et la paroi artérielle*

FUNDINGS

19 as principal investigator

- 2022-2023: MITI CNRS, "Role of the mechanical environment on the human adocarcinome", with IRCAN (Nice) (23K/year).
- 2020: association Vaincre La Mucoviscidose (VLM), one year post-doctoral support on the project "Développement d'un prototype in silico d'un système de diagnostic de l'encombrement du patient atteint de la mucoviscidose basé sur l'analyse des flux de monoxyde d'azote à la bouche" (51k).
- 2019-2023: one PhD funding from CoFund Marie Skłodowska-Curie program H2020 (3.5 years of PhD funding, plus 21k for research environment)
- 2019: one year post-doctoral support from UCA on the project "Linking lung's evolution and development" (51k).
- 2018-2021: CIFRE thesis and research contract with the company RespInnovation (Sophia Antipolis), project "Modelling of high frequency chest wall oscillations" (15k).
- 2017-2022: ANR PRC VirtualChest (Défi Santé Bien-être, 440k)
- 2017-2020: initiator and head of the VADER Centre (Centre for VirtuAl modelling of rEspiRation), in the frame of the IDEX JEDI of Université Côte d'Azur (initial founding of 280k for four years).
- 2016: GDRI funding for developing a collaboration with Yeugnam University in South Korea (1.8 k)
- 2016: IDEX JEDI support for my project "modelling of chest physiotherapy" through the Academy Complex Systems (25k).
- 2016: PEPS INSIS "Modélisation de la kinésithérapie respiratoire : mise en réseau" (7k)
- 2015-2016: PEPS CNRS InPhyniti, Projet Structurant, project "Influence de la géométrie des bronches pulmonaires sur les écoulements d'air et de mucus" (2015: 15k, 2016:10k)
- 2014: PEPS CNRS, INSIS, frame Biological Flows, project "Modelling of respiratory physiotherapy" (10k).
- 2013: PEPS CNRS, frame Physique Théorique et Interfaces (PTI), project "Morphogenesis of the bronchial vascular network" (4k)
- 2012-2015: research contract with the company RespInnovation (Sophia Antipolis), project "Respiratory physiotherapy modeling" (15k).
- 2012: PEPS PTI "Morphogenesis of the bronchial vascular network" (3k).
- 2012-2013: 24 months post-doctoral support from the city of Nice, project "Lung's morphogenesis".
- 2010: modelling part of an Inserm/DHOS, project "Polytrac" (10k)
- 2008-2011: Funding for a PhD thesis from the CNRS on the project "Arterial network hematocrit optimization".

As a collaborator

- 2022-2026: head of the LJAD work package for the ANR BronchoClogDrain (PRCE, 108k for the LJAD)
- 2011: Management of the funding for the development of a biology and mathematics hub in Nice (90k)
- 2005-2009: Member of the ANR funding "Transport and transfer through the human pulmonary system" (12k).

INVITATIONS IN OTHER LABORATORIES

- regular invitations for seminars and brainstormings in numerous French and foreign laboratories (mathematics, physics or biology/medicine)
- regular invitations in the laboratory Matière et Systèmes Complexes, University of Paris
- regular visits of the R&D department of the private company IMape since 2017, Villeneuve-Loubet
- associate member of Inphyni (Institut Physique de Nice, ex-INLN) since 2012, University Côte d'Azur, Nice
- one week in the laboratory TIPs in the Université Libre de Bruxelles, Belgium (2018)
- one semester in the Auckland Bioengineering Institute, New-Zealand (2015)
- two invitations for one week each in the Zentrum Für Interdisziplinäre Forschung (ZIF) in Bielefeld, Germany (2013, 2014)
- one week to attend the seminar of Percussionaire (private USA company) in Sandpoint, Idaho, USA (2013)
- two weeks in Yeungnam University, South Korea (2013)
- associate member of the Pneumology Department in La Pitié Salpêtrière Hospital from 2003 to 2005, Paris
- three days in the Physiology Department of Bern University, Swiss (2004)
- two weeks in the Chemistry Department of the Federal University of Ceará, Brazil (2003)

SELECTION OF PUBLICATIONS

I am the author of **27 peer-reviewed interdisciplinary** papers: 26 reviewed papers in international journals and 1 reviewed paper in a French journal specialized for physiotherapists. I have published **15 reviewed interdisciplinary** proceedings or abstracts. I have been invited in more than **twenty conferences or workshops**.

My full publications and conferences lists are available on <http://benjamin.mauroy.free.fr/publis.pdf>.

Since my recruitment at the CNRS in 2005, **I am the principal investigator of all the researches that I have published as first or last author.**

Selection of publications

Allometry, evolution of the lung, development

- The origin of the allometric scaling of lung's ventilation in mammals. F. Noël, C. Karamaoun, J. Dempsey, B. Mauroy. 2020. Peer Community Journal, vol 2, 2022 / Recommended by *PCI Math Comp Biol*.
- Allometric scaling of heat and water exchanges in the mammals' lung. B. Sobac, C. Karamaoun, B. Haut, B. Mauroy. 2019. Preprint arxiv.
- An archetypal mechanism for branching organogenesis. R. Clément and B. Mauroy. Phys. Biol. 11 016003, 2014.
- Don't fall off the adaptation cliff: when do asymmetrical fitness costs select for suboptimal traits?. E. Vercken, M. Wellenreuther, E. I. Svensson and B. Mauroy. PLoS ONE 7(4): e34889, 2012.

Physiology of the lung

- *Optimal efficiency of high frequency chest wall oscillations and links with resistance and compliance in a model of the lung.* M. Brunengo, B. R. Mitchell, A. Nicolini, B. Rousselet, B. Mauroy, 33, 121909, Physics of Fluids, 2021.
- *Wall shear stress distribution in a compliant airway tree.* J. Stephano and B. Mauroy, Physics Of Fluids, 33, 031907, 2020.
- Interplay between optimal ventilation and gas transport in a model of the human lung. F. Noël, B. Mauroy, Frontiers in Physiology (10) 488, 2019.
- Towards the modeling of mucus draining from human lung : role of airways deformation on air-mucus interaction. B. Mauroy, P. Flaud, D. Pelca, C. Fausser, J. Merckx, B. R. Mitchell. Frontiers in Physiology, 6:214, 2015.

Blood network

- Murray's law revisited with Quémada's fluid model and fractal trees. B. Moreau, B. Mauroy. *Journal of Rheology*, 59, 1419, 2015.

Responsibilities

TEACHINGS

Life Science Master, Univ. de Nice-Sophia Antipolis participant to the UE Physiopathology	2018 - Present
Master 1 training, Modelling with Matlab, Univ. de Nice-Sophia Antipolis	2016 - 2017
Projects' supervision, Polytech'Nice	2013 - Present
Master 2 course, ENS Cachan and INSTN	2006 - 2010
Trainings in Master 2 and agregation of Mathematics, ENS Cachan	2001 - 2006

RESEARCH MANAGEMENT

In Université Côte d'Azur

- member as a representative for mathematics in the steering committee of the IDEX JEDI federative program "Modélisation, Physique et Mathématique du vivant", now member of the scientific committee.
- former member of the scientific committee of the academy "Living systems Complexity and Diversity" of Université Côte d'Azur, as representative for mathematics.

In Université de Nice-Sophia Antipolis

- former member of the scientific committee of the PhysBio axis in University Nice-Sophia Antipolis.
- elected member of the "Commission Permanente de Ressources Humaines".

In laboratoire JA Dieudonné

- representative of the interactions between Mathematics and Biology/Medicine in laboratoire JA Dieudonné.
- former co-organiser of the Interfaces team seminar in laboratoire JA Dieudonné.
- member of two commissions in laboratoire JA Dieudonné.
- participation to the animation of several interdisciplinary GDRs as member of the scientific committee or local contact.

Other

- recommender for *Peer Community In Mathematical Computational Biology*.
- co-organizer of the research school VentiCorse (Cargèse, November 2019) in the frame of Vader Center
- interdisciplinary conferences and days co-organisation
- member of juries for 4 assistant professor positions, for 5 PhD thesis defence and for 1 HDR (in biology). Reviewer of 5 PhD thesis.
- reviewer for international project calls (Canada, Belgium), international journals (mathematics, fluid mechanics, biophysics).

POPULARISATION

Co-organizer and participant in 2022 of "la fête de la science" and "la nuit des chercheurs", activities about mathematics and lungs.

Co-organizer with C. Karamaoun and M. Monticelli of the 2019 science days, activities about respiration on the Mathematics stand, October 2019.

Co-organizer with A. Corinus of the popularization day *Les Multiples challenges de la respiration à l'activité physique* for the science days, October 2018.

Co-organizer with A. Corinus and A. Guyon of the popularization VADER day *Apprendre à respirer : la science du bien-être* for the science days, head of the lungs' modelling booth, October 2017.

Popularisation article on the website of INSMI, *La modélisation mathématique en soutien à la kinésithérapie respiratoire*, June 2016.

Popularisation talk (high school, general public), *Poumon, paratonnerres et mathématiques*, Valrose, Nice, June 2013.

Publication of a popularisation paper in the journal "La Recherche" in 2005, republished in "La Recherche" in 2007 and in the book "Débusquer le hasard" (La Recherche-Dunod, 2011).

Introduction of the Mathematics to elementary school children in the frame of the science days (CNRS délégation Paris A).

Co-realisation of posters on the topic *What are the mathematics?* for the "Palais de la Découverte" in Paris.