What is the ExposUM Doctoral Nexus?

The Doctoral Nexus proposed by the ExposUM Institute are networks of 3 to 4 PhD students from different disciplines and affiliated to at least two different research units.

Compared with a traditional PhD, taking part in a Doctoral Nexus will encourage the ability to work in a team and to design projects in a transdisciplinary way while deepening one's own field of expertise.

A specific teaching programme will be offered and the doctoral students concerned will also have the opportunity to organise a seminar within the Nexus network.

Theses are funded from the outset for 4 years, including the PhD student's salary and an environmental allowance.

Summary of the overall project

The epidemiological and evolutionary dynamics of infectious diseases are affected by many environmental, ecological and social factors. In order to understand and anticipate the public health consequences of an epidemic, and the evolution of the pathogen, we need to precisely model the pathogen's environment. In this project, we plan to study a specific aspect of this environment, which is age structure. Motivated by the realisation, during the COVID-19 pandemic, that age structure was a crucial modelling ingredient to make public health predictions (hostpitalisation peak, vaccination), anticipate viral evolution (variant dynamics) or understand physiopathology (intra-host kinetics).

The EMIPSA project brings together biologists, mathematicians, statisticians and medical doctors who propose to use age-structured models to analyse the epidemiological (change in the number of cases) and evolutionary (change in variant frequencies) dynamics of pathogens. Our Nexus project will allow interactions between 4 distinct PhD projects on (1) the evolution of pathogen life-history strategies, particularly respiratory viruses, in population structured by infection age and vaccination status [evolutionary ecology], (2) the rigorous mathematical justification of the structured models used in evolutionary epidemiology [mathematics and modelling], (3) modelling intra-host evolutionary dynamics in malaria, taking into account the age structure of red cells [mathematics and modelling], and (4) the anticipation of the impact of epidemics on the French critical care system, taking into account the dynamics of the distribution of risk factors, and more specifically age [biology and health].

Preparing the critical care system for future health crises

PhD project

The COVID-19 pandemic highlighted the fragility of our healthcare system, and in particular the risk of overload of intensive care units (ICU)[1]. ICUs were kept running solely by reorganising their staff and equipment, and in particular by cancelling postponable activities (such as elective surgery)[2]. Given the ageing population, the increasing frequency of co-morbidities and their associations, and the risk of pathogen emergence amplified by global change[3], the pressure on ICUs is expected to increase, both chronically and acutely. An important contribution to anticipating these needs, and to guiding hospital strategy over the long term, consists in modelling the activity of an intensive care unit subject to regular and crisis regimes having in sight the French healthcare population of the next few decades, based on the critical care activity for the last years described beforehand.

The first step will be to use data from the PMSI database (*Programme de Médicalisation des Systèmes d'Information*) to draw up a national overview of existing critical care activities over the past ten years, including pre-pandemic activity, the COVID-19 health crisis, and post-pandemic dynamics, while analysing inter-regional heterogeneity[4]. In addition, the fraction of the general population likely to be admitted to critical care will be inferred using hidden Markov models[5]. Secondly, the results of these analyses will be cross-referenced with demographic projections[6], epidemiological data on co-morbidities[7] and scenarios of epidemic outbreaks of emerging and re-emerging pathogens, in order to produce a national projection of critical care needs over the next 30 years[8]. Finally, in a third phase, a virtual ICU will be subjected by simulation to this health pressure, in regular and crisis activity[9,10], which will make it possible to identify numerically the weaknesses and potential organisational levers to ensure the future resilience of the national critical care system.

Keywords: Projected epidemiology; demographic forecasts; pandemic preparedness; hospital optimisation; intensive care modelling.

References

[1] Sofonea *et al.* (2021) Memory is key in capturing COVID-19 epidemiological dynamics. *Epidemics*. **[2]** Lefrant *et al.* (2021) ICU bed capacity during COVID-19 pandemic in France: From ephemeral beds to continuous and permanent adaptation. *Anaesth Crit Care Pain Med*. **[3]** Mora *et al.* (2022) Over half of known human pathogenic diseases can be aggravated by climate change." *Nat Clim Change* **[4]** Boulet *et al.* (2023) Intensive care unit activity in france from the national database between 2013 and 2019: more critically ill patients, shorter stay and lower mortality rate. *Anaesth Crit Care Pain Med*. **[5]** Gimenez *et al.* (2012) Estimating demographic parameters using hidden process dynamic models. *Theor Popul Biol*. **[6]** Algava & Blanpain (2021) 68,1 millions d'habitants en 2070 : une population un peu plus nombreuse qu'en 2021, mais plus âgée. *Insee première*. **[7]** Bagein et al. (2022) L'état de santé de la population en France. *Les Dossiers de la DREES*. **[8]** Sofonea & Alizon (2021) Anticipating COVID-19 intensive care unit capacity strain: A look back at epidemiological projections in France. *Anaesth Crit Care Pain Med*. **[9]** Lefrancq et al. (2021) Evolution of outcomes for patients hospitalised during the first 9 months of the SARS-CoV-2 pandemic in France: A retrospective national surveillance data analysis. *The Lancet Regional Health-Europe*. **[10]** Melman et al. (2021) Balancing scarce hospital resources during the COVID-19 pandemic using discrete-event simulation. *Health Care Manag Sci*.

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Application procedure

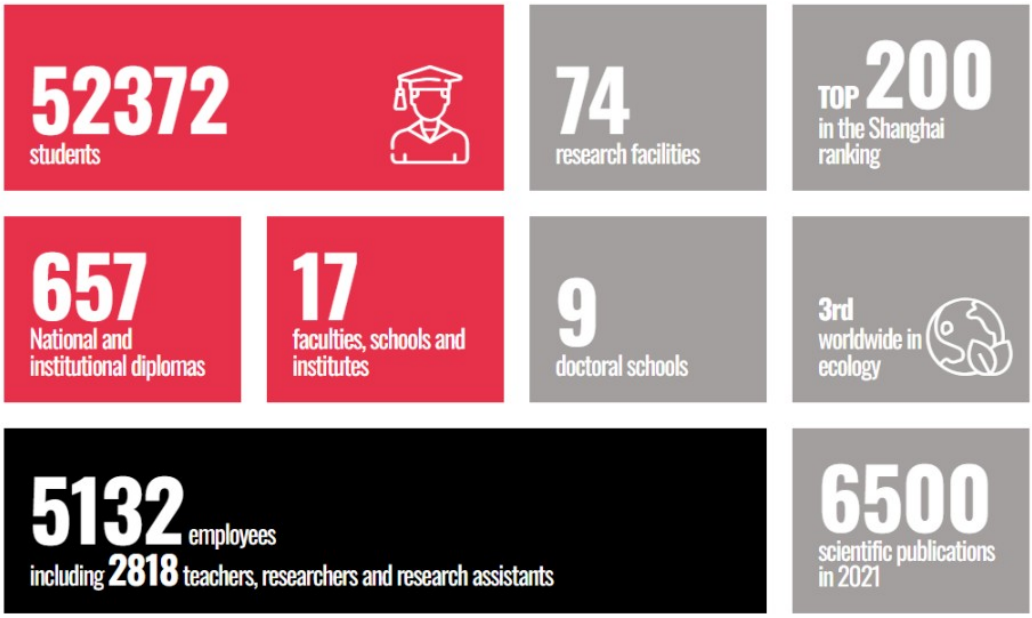
The application must include the following

- a CV
- a letter of motivation
- a copy of the degree required for registration
- any additional specific information requested by the doctoral school CBS2

If you would like to apply for this position, please send an e-mail to Mircea T. Sofonea (mircea.sofonea@umontpellier.fr), Jean-Yves Lefrant (jean.yves.lefrant@chu-nimes.fr), Rémi Choquet (remi.choquet@cefe.cnrs.fr), by copying Sébastien Lion (sebastien.lion@cefe.cnrs.fr) and exposum-aap@umontpellier.fr to inform them of your interest.

Before Sunday 21 April, 8pm CET

KEY FIGURES



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