amU Mechanical engineering institute Aix Marseille Université

# Human resources call - 2025

***Call 2025 (****up to 2* ***post-docs)***
*-**17/ 11/ 2025 Submission deadline**: project/applicant files (CV + covering letter)*
*- **11/2025** (exact date to be determined): Interviews by the Scientific Committee*
*- **12/2025** (exact date to be determined): Final ranking by the Institute Council*

**The project (template in attachment) + CV+ covering letter of the candidate will be send to cedric.fages@univ-amu.fr**

**Project title :** Biomechanics of Tumor Cell transport in deFormabLe pOrous netWorks (TC-FLOW)

**Laboratories :** IRPHÉ, M2P2

**Investigators :** Ankur D. Bordoloi (**ADB**), Isabelle Cheylan (**IC**)

**IMI axis(es) :** Health engineering

**Disciplinary fields:** Circulating tumor cells, metastasis, biophysics, computational fluid dynamics, fluid structure interaction, microfluidics, particulate flow





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**1/ Scientific project** (2 pages max)

*Context and objectives*: Cancer metastasis, the spreading of a tumor from one part of the body to another, is the cause of approximately 90% of cancer related deaths [1]. During metastasis, tumor cells navigate through the extracellular matrices (ECM) of surrounding tissues and enter the vascular networks where confinement and interstitial fluid flow create complex mechanical cues [2][3]. Although a primary tumor releases up to 3-4 million cells per gram every day, fewer than 0.01% of these shed cells can eventually form a metastasis, bypassing the constricting network of the ECM and vasculature, interstitial fluid shear stress and immune surveillance [1]. Factors contributing to the metastatic success of the minority of cells are both biological and mechanical [1][2][3]. Whereas, the biological underpinnings of metastasis have been extensively studied, the mechanical aspects of this process and their link to cell biology remain poorly understood.

From a purely mechanical perspective, a metastatic cancer cell can be modelled as a soft viscoelastic object, with typical Young's modulus around 0.1-10.0 kPa and viscosity around 5 Pa.s, moving through diverse porous microenvironments made up of ECM and vascular capillaries (see Fig. 1A,B) [3][4][5][6]. These confining environments themselves are deformable, with ECM modulus ranging 0.1-1.0 kPa and capillary modulus measured as 1-80 kPa depending on vessel type [7][8][9]. Although the transport of cancer cells through rigid channels has been studied in detail in the past, the role of microenvironmental stiffness, and more broadly network compliance on the dynamics of cell transport and its impact in the metastatic process is unknown. Furthermore, stiffness of the constricting environment can exert a mechanobiological effect on tumor cells (see Fig. 1C); for example, in static conditions the biological state of a cell can change depending on substrate stiffness and channel dimensions [10][11][12]. This underscores the need of a quantitative understanding of how cell-substrate mechanical interactions, in particular how the relative compliance between the cell and the network, independently influence the mechanical and biological cell behaviours under fluid flow.

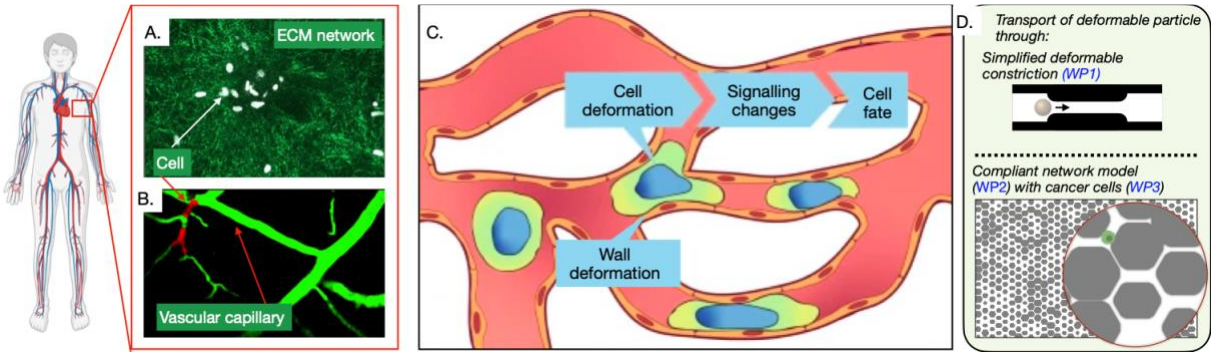


**Fig. 1**: Images of a tumor cell in an ECM network (A) and in a vascular network (B) [13][14]. (C) Illustration of a tumor cell in a vascular network and the key components of the system [2]. (D) The work packages for the proposal.

In the context of the above scenarios, the **TC-FLOW project aims to investigate the coupling between the mechanics of cell transport under flow and their mechanobiology, under the influence of relative cell-substrate compliance**. Building upon the expertise of two supervisors in experimental bio-microfluidics (ADB) and fluid-structure interaction simulation (IC), we will use an interdisciplinary approach combining biophysical experiments and physics-based modelling. The TC-FLOW project will address the following objectives with increasing level of complexity to decouple the cell-substrate relative compliance, network complexity and the biology of the system:

1. Investigate the role of cell-substrate relative compliance on the transport of inert viscoelastic particles in simplified channels.
2. Investigate the effect of a network complexity on the transport of inert viscoelastic particles.
3. Extend this investigation to tumor cells to investigate the biological factors influencing cell transport.





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*Approach*: The TC-FLOW project will employ a combined numerical and experimental approach via three strategically designed work-packages (see Fig.1D). Our strategy is to first explore the parameter space of a viscoelastic particle transport under flow through a simplified constriction channel by systematically varying the elasticity of the channel wall and the transported particle. This numerical method will be validated against specific experimental cases. Based on this parameter space, we will then design research to examine the complexity of network compliance on the transport of first inert particles and then cancer cells.

The numerical method will leverage the expertise of IC [15][16] and past experience of the postdoctoral candidate [17][18] to reproduce the mechanical aspects of the system, a deformable inert particle flowing through a compliant channel. Physically, the fluid will be modelled as a continuous Newtonian fluid, the particle will be modelled as either a hyperelastic or viscoelastic capsules [19][20], and the deformable wall will be modelled as a hyperelastic material [21]. These will be resolved numerically, respectively for the fluid and solid components, with the lattice-Boltzmann method and the finite element method [18][19]. The coupling of the fluid to the deformable solid components will be done through the immersed-boundary method [18][21]. This physical model and its numerical implementation are suitable and proven for this application [18][19][21].

ADB brings his expertise in microfluidics, quantitative live-cell imaging and data analysis, providing the experimental framework to recreate the cell transport through compliant network under flow [2][4]. We will use microfluidics to recreate the transport of both inert and cancer cells first through simplified channels and then complex networks [22]. The microfluidic devices will be made using polydimethylsiloxane (PDMS), wherein the stiffness of the channel walls will be fine-tuned using strategic mixture of two different elastomers: Sylgard 184 and 527, allowing control of the modulus between 5 – 1000 kPa [23]. To decouple mechanical aspects, we will use inert polyethylene glycol diacrylate (PEGDA) particles, complemented by model cancer cells (cell lines MCF-7 and MDA-MB-231) of different mechanical properties [4].

*Work package 1*: During the preparatory stage, the postdoc will receive training in microfluidic design and fabrication using soft lithography, as well as mammalian cell culture, fluorescence microscopy, and early-stage data analysis. In parallel, the candidate will extend existing numerical model from IC's group for a deformable particle in a straight channel with a constriction (see Fig. 1D), followed by experimental validation. Next, the numerical model will be used to explore the parameter space of particle transit time, maximum deformation etc. as a function of wall stiffness, particle stiffness, geometric conditions, and flow conditions. This will fundamentally inform the role of channel compliance on the transport of inert particles in straight channels.

*Work package 2*: Following validation of the numerical model in a straight channel, we will explore more complex geometries. We will create compliant porous media of different levels of complexity (see Fig.1D) and quantify the transport of inert particles through it via macroscopic metrics, such as breakthrough curves and trapping distribution. Using the insights gained for single constriction channel, we will develop quantitative models that link the macroscopic measurement across the network to microscopic transport within individual pores [24].

*Work package 3*: Once the flow-physics has been characterised in both pore-scale and system-scale with respect to inert particles, we will introduce tumor cells into our microfluidic circuits. We will characterise how the biological component of the cells changes the macroscopic transport metrics of the system compared to inert particles. This will elucidate on mechanosensitivity of tumor cells to substrate stiffness under flow.

*Summary*: In this project we will study the biomechanics of cell transport in deformable porous media. We will decouple the mechanics of the relative cell-substrate compliance, porous media complexity, and the biology of the system through experimental and numerical approaches. Through three inter-related work packages, we will: 1) quantify the transport of deformable particles through simplified compliant microchannels; 2) extend this investigation to compliant porous networks; and 3) explore the biological implications of tumor cell behavior under flow through porous media. The TC-FLOW project will help identifying new strategies to reduce metastatic potential of tumor cells.





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**2/ Funding added-value**
(Complementarity of skills and methods, multi-disciplinarity, risk-taking in the research project, pooling of equipment, etc...)

This proposal will combine the complementary expertise of two supervisors: ADB in experimental microfluidics involving live cells and IC in numerical modelling using lattice-Boltzmann and immersed-boundary methods. The interdisciplinary collaboration between experimental and numerical work will enable validation of the numerical model, facilitate rapid numerical prototyping, and ease parameter space exploration, creating a virtuous feedback loop between the two approaches. Additionally, the proposed candidate's previous research has been focussed on blood flow in the tumor microcirculation, an expertise directly related to this research. The TC-FLOW project is divided into three work packages of growing, yet realistic, level of difficulty. This synergistic collaboration between two labs (IRPHÉ and M2P2), will not only bring new mechanistic insights into tumor cell transport, but also foster new avenues of cross-talks between the two institutes in addressing biophysical and engineering problems.

**3/ Impact and spin-offs**
(Scientific impact and potential economic, social or cultural impact, strategy for disseminating and exploiting results, including promotion of scientific, technical and industrial culture)

The TC-FLOW project will contribute to *engineering for health* research, one of the societal challenges from the 2024-2027 IMI roadmap. Scientifically it will advance understanding of mechanical determinants of cancer metastasis, opening new avenues for predictive modelling and microfluidic technologies in oncology. Results will be disseminated through peer-reviewed publications, international conferences, and workshops, ensuring visibility across biophysics, fluid mechanics and biomedical engineering communities. In the broader context, improving our understanding of tumor cell transport has long-term potential to inform therapeutic strategies, benefiting public health and contributing to the scientific and technical culture around cancer research.

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**Points d'attention**

- Le budget alloué par l'IMI sera géré par l'UMR du porteur de projet. Par conséquent avant de répondre à cet AAP, il est demandé au porteur de remonter son intention de dépôt auprès de la direction de son laboratoire pour s'assurer notamment de la capacité de gestion de son projet s'il était lauréat.
- Le porteur, en soumettant un projet à cet AAP, s'engage à fournir 1 an après l'achat du ou des équipement(s), un court rapport d'une page maximum synthétisant les principaux résultats obtenus dans le cadre du projet et une photo en 300 dpi du ou des équipement(s) installé(s).
- Toute publication résultant de cet AAP, devra mentionner les remerciements suivants : " *Ce travail a bénéficié d'une aide du gouvernement français au titre de France 2030, dans le cadre de l'Initiative d'Excellence d'Aix-Marseille Université - A*MIDEX (AMX-19-IET-013 – IMI).*"

Il s'agira d'un indicateur important dans l'évaluation de l'impact de l'Institut sur sa communauté scientifique et nous comptons sur votre collaboration pour nous accompagner dans cette démarche de suivi.

- Par ailleurs, il sera nécessaire de :
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