# Computational methods for assessing the forces transmitted to the cartilage microstructure of the lower limb during daily activities

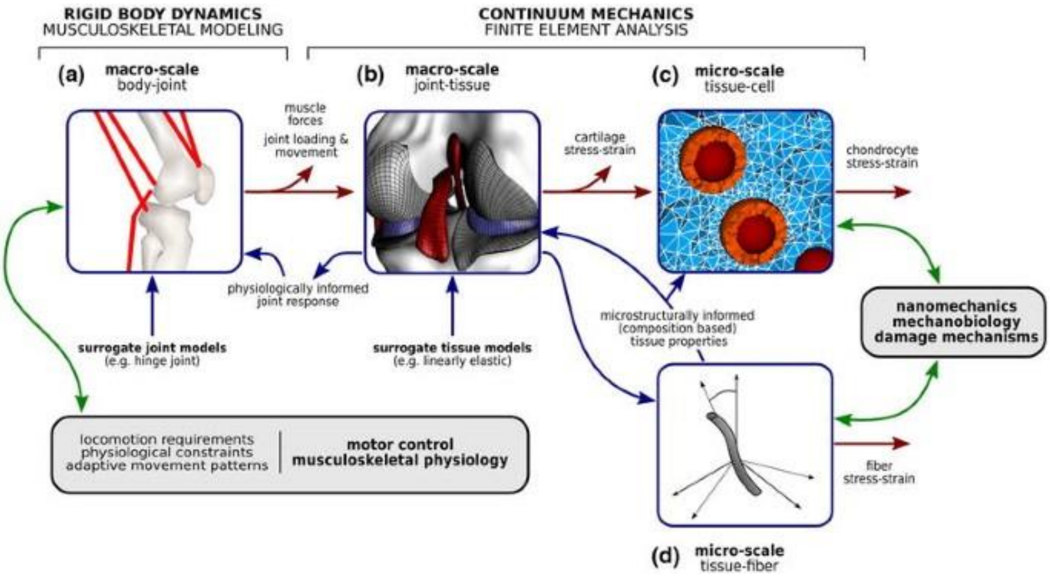
**Name of the graduate program (Master 2):** Mécanique - Modélisation et applications en mécanique (MAM)
**Laboratory for the internship**: LBMC UMR_T9406 – Laboratory of biomechanics and impact mechanics
**Principal Investigator** : Petitjean Noémie (noemie.petitjean@univ-lyon1.fr)

**Summary**:
Osteoarthritis (OA) is a well-known joint disease caused by multiple factors such as aging, obesity, and overloading. Clinical experience has shown that movement is essential to prevent OA and slow its progression. However, recommendations, including those from the World Health Organization, mainly focus on reducing overuse and promoting a healthy lifestyle. The optimal frequencies and intensity levels of activity, which may vary based on age and health status, remain unclear. This uncertainty arises from the incomplete understanding of how loads are transmitted to the cartilage microarchitecture and how cells perceive them. This load estimation is essential for the development of biomaterials. Currently, there is a wealth of data on the dynamics of daily human activity and the mechanical behavior and properties of articular cartilage. Additionally, musculoskeletal and finite element models have seen significant advancements. The present challenge is to link these models at different scales. Therefore, the aim of this project is to develop a numerical tool that can merge a musculoskeletal model with a finite element model, thereby connecting the body scale to the tissue (and cellular) scale.

**Project**:

Osteoarthritis (OA) is a well-known joint disease caused by multiple factors such as aging, obesity, and overloading. The knee is the most affected joint by the disease. Clinical experience has shown that movement is essential to prevent OA and slow its progression (Zeng et al., 2021). However, recommendations, including those from the World Health Organization, mainly focus on reducing overuse and promoting a healthy lifestyle. The optimal frequencies and intensity levels of activity, which may vary based on age and health status, remain unclear. This uncertainty arises from the incomplete understanding of how loads are transmitted to the cartilage microarchitecture and how cells perceive them. This load estimation is essential for the development of biomaterials. Currently, there is a wealth of data on the dynamics of the lower limb during daily human activity and the mechanical behavior and properties of articular cartilage (Petitjean et al., 2023; Reznick et al., 2021). Additionally, musculoskeletal and finite element models have seen significant advancements (Pierce, 2022; Silva et al., 2021). The present challenge is to link these simulation models at different scales.

Objective: the aim of this project is to develop a tool that can merge a musculoskeletal model of the lower limb with a finite element model of the knee.




*Computational models at different spatial scale* (Halloran et al., 2012)

Methods: the development of this multi-scale model will require the following steps:
- Review the state of the art of numerical models used in the literature
- Establish Python code for simulation coupling (boundary conditions, software communication, etc.)
- Analyze the simulation data obtained
- Compare results from the models with experiments (results of the literature).
- Communicate results

Expected results: This project will contribute to improving the prediction of the articular cartilage strain of the knee during human daily activities. These parameters will then be used in experimental set up to evaluate the model and investigate cellular response to physiological loads.

Internship duration: 6 months, Location: Lyon

Candidate profile: the candidate will have a background in solid mechanics, Python programming and numerical simulation. Knowledge of anatomy would be a plus.

Application: Please send your CV, covering letter, grades for the last 3 years and a letter of recommendation (if possible) to noemie.petitjean@univ-lyon1.fr.

References:

Halloran, J.P., Sibole, S., van Donkelaar, C.C., van Turnhout, M.C., Oomens, C.W.J., Weiss, J.A., Guilak, F., Erdemir, A., 2012. Multiscale Mechanics of Articular Cartilage: Potentials and Challenges of Coupling Musculoskeletal, Joint, and Microscale Computational Models. Ann. Biomed. Eng. 40, 2456–2474. https://doi.org/10.1007/s10439-012-0598-0

Petitjean, N., Canadas, P., Royer, P., Noël, D., Le Floc'h, S., 2023. Cartilage biomechanics: From the basic facts to the challenges of tissue engineering. J. Biomed. Mater. Res. A 111, 1067–1089. https://doi.org/10.1002/jbm.a.37478

Pierce, D.M., 2022. Multi-phase, large-strain constitutive models of cartilage for finite element analyses in 3-D. Arch. Appl. Mech. 92, 513–528. https://doi.org/10.1007/s00419-021-01959-5

Reznick, E., Embry, K.R., Neuman, R., Bolívar-Nieto, E., Fey, N.P., Gregg, R.D., 2021. Lower-limb kinematics and kinetics during continuously varying human locomotion. Sci. Data 8, 282. https://doi.org/10.1038/s41597-021-01057-9

Silva, M., Freitas, B., Andrade, R., Carvalho, Ó., Renjewski, D., Flores, P., Espregueira-Mendes, J., 2021. Current Perspectives on the Biomechanical Modelling of the Human Lower Limb: A Systematic Review. Arch. Comput. Methods Eng. 28, 601–636. https://doi.org/10.1007/s11831-019-09393-1

Zeng, C.-Y., Zhang, Z.-R., Tang, Z.-M., Hua, F.-Z., 2021. Benefits and Mechanisms of Exercise Training for Knee Osteoarthritis. Front. Physiol. 12. https://doi.org/10.3389/fphys.2021.794062