RESEARCH ACTIVITY SHEET

2025 PhD selections

YOUR DETAILS

* Name & Surname: Gaia Pigino

* Affiliation HT

PHD PROJECT DETAILS

* Title of the proposed project

Structural and Functional Characterization of Primary Cilia Diversity in Health and Disease.

* Short description of the project (up to 300 words)

Primary cilia are microtubule-based organelles that play essential roles in sensing and transducing extracellular signals. Although traditionally viewed as a uniform structure, emerging evidence suggests that primary cilia exhibit remarkable diversity in morphology, molecular composition, and function across tissues and cell types. This diversity is increasingly recognized as a determinant of cilia-specific signaling and dysfunction in ciliopathies. However, a comprehensive understanding of this heterogeneity remains elusive.
We aim at systematically characterize the structural and molecular diversity of primary cilia in healthy and diseased tissues. We want to establish a high-resolution map linking ultrastructural features to molecular identity and functional specialization of primary cilia, thereby uncovering mechanistic insights into their roles in health and disease.
To achieve this, we will employ a multidisciplinary strategy combining state-of-the-art imaging and spatial omics technologies:
- Cryo-Electron Tomography will provide molecular-resolution 3D reconstructions of primary cilia, capturing structural diversity in situ.
- Ultrastructural Expansion Microscopy will complement cryo-ET, enabling high-throughput, multiplexed imaging of ciliary architecture and associated proteins across diverse cellular contexts.
- Spatial Proteomics we will define the proteomic landscape of primary cilia in various tissues, identifying cell type–specific markers and disease-associated alterations.
- Spatial Transcriptomics will correlate structural and proteomic features with gene expression profiles, linking ciliary heterogeneity to cellular identity and signaling context.
This integrated approach will create an unprecedented multidimensional atlas of primary cilia diversity. It will identify novel structural and molecular signatures, offering insights into the pathogenesis of ciliopathies.

* Indicate the main research area for the project described above -

If needed indicate a second research area for the project described above -

* Provide up to 3 key words for project:

Primary cilia diversity, structure to function, molecular composition

YOUR LABORATORY ACTIVITIES DETAILS

* Main topic/s of the lab

Cilia biology in health and disease

* Short description of the lab activity (up to 500 words)

In our research, we integrate structural biology methodologies with advanced cell biology techniques to uncover the molecular mechanisms governing the assembly and function of motile and primary cilia—microtubule-based organelles essential for eukaryotic life and human health. Over the years, my team has expanded its expertise to encompass a diverse array of cutting-edge tools, including genome engineering, in situ cryo-electron tomography (cryo-ET), single-particle cryo-EM, AlphaFold2-based structure prediction, structural proteomics, correlated light and electron microscopy (CLEM), expansion microscopy, high-resolution fluorescence imaging, in vitro reconstitution assays, mechanical manipulation of cells and cytoskeletal components, and mass spectrometry. By leveraging this multifaceted approach, we have elucidated the molecular structure, dynamics, and mechanisms of Intraflagellar Transport (IFT)—the universally conserved bidirectional transport system required for cilia and flagella assembly across all ciliated cells. Understanding the structural and functional complexity of IFT -and of other processes involved in ciliary assembly and functions- is critical, as defects in this system can lead to severe ciliopathies. Perhaps the most audacious aspect of my research is my relentless pursuit of visualizing dynamic cellular processes at the highest possible resolution, often pushing technological boundaries and developing custom methodologies to capture these intricate molecular events in unprecedented detail.

* Recent bibliography (max 5 references)

Kiesel P, Alvarez Viar G, Tsoy N, Maraspini R, Gorilak P, Varga V, Honigmann A, Pigino G. The molecular structure of mammalian primary cilia revealed by cryo-electron tomography. Nat Struct Mol Biol. 2020 Dec;27(12):1115-1124. doi: 10.1038/s41594-020-0507-4. Epub 2020 Sep 28. PMID: 32989303; PMCID: PMC7610599.

Müller, A., Klena, N., Pang, S. et al. Structure, interaction and nervous connectivity of beta cell primary cilia. Nat Commun 15, 9168 (2024). https://doi.org/10.1038/s41467-024-53348-5.

Lacey SE, Pigino G. The intraflagellar transport cycle. Nat Rev Mol Cell Biol. 2025 Mar;26(3):175-192. doi: 10.1038/s41580-024-00797-x. Epub 2024 Nov 13. PMID: 39537792.

Lacey SE, Graziadei A, Pigino G. Extensive structural rearrangement of intraflagellar transport trains underpins bidirectional cargo transport. Cell. 2024 Aug 22;187(17):4621-4636.e18. doi: 10.1016/j.cell.2024.06.041. Epub 2024 Jul 26. PMID: 39067443; PMCID: PMC11349379.

https://rupress.org/jcb/article/220/9/e202108043/212596/Gaia-Pigino-Inside-the-cellGaia-Pigino-Inside-the

* Group composition: total members, and roles distribution (PhD, postdoc, technician, etc.)

1 PI, 1 Senior Technical assistant, 6 Postdocs, 1 PhD student, 1 Master student

Institutional page link

https://humantechnopole.it/it/gruppi-di-ricerca/pigino-group/

Lab website link, if any

https://humantechnopole.it/it/gruppi-di-ricerca/pigino-group/

Social media links, if any

@gaiapigino.bsky.social

If you prepare a video to promote your lab/project, please include the link below