APPEL A PROJETS DE THÈSE 2026
CONCOURS DE L'ED 658 – Sciences du vivant

Formulaire à compléter et déposer par les porteurs du projet de thèse HDR via l'adresse mail suivante :
ed658@univ-amu.fr OU/ET romane.haddadi@univ-amu.fr
MERCI DE METTRE EN SUJET DU MAIL : Concours ED 658 2026 porteur de projet
Ces dossiers seront publiés pour que les candidats postulent.

au plus tard le 3 mars 2026.

INTITULÉ DU PROJET
Multimodal modelling of mitochondrial content, metabolism and shape transitions during cellular differentiation

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SPECIALITE : (Rayer les mentions inutiles)

Bio-informatique et Génomique / Biologie du Développement /

SOUS JURY POUR LE CONCOURS : (Rayer les mentions inutiles)
JURY 2 : MICROBIOLOGIE – GENOMIQUE

MERCI DE REMPLIR TOUTES LES INFRORMATIONS EN FRANÇAIS ET EN ANGLAIS

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Description de la problématique de recherche - Project description

Mitochondria are vital for eukaryotic life, powering cells through ATP production, metabolism, and signaling. Their role in bioenergetics and cell fate decisions is central to organ development. During differentiation—for instance in striated muscle (e.g., heart, Drosophila flight muscle)—mitochondria undergo dramatic changes in their content, they undergo a metabolic shift from glycolysis to oxidative phosphorylation (OXPHOS) and morphological changes (e.g., from smaller, tubular structure to large, cristae-dense structures)(Jaakko 2017; Sánchez-Díaz 2020; Zhang 2024). These transformations are well-documented in literature, where a rich body of work can be found on mitochondrial composition, mitochondrial metabolic changes and shape transitions during development (Jaakko 2017; Sánchez-Díaz 2020; Avellaneda 2021 ; Zhang 2024), however these three aspects are typically studied separately.

Our goal is to integrate the changes in composition, metabolism and shape of mitochondria during mitochondrial maturation and cellular differentiation to obtain a holistic understanding of mitochondrial maturation during cellular differentiation. We will develop a multi-modal framework consistent of the following three aims:

Aim 1: We will use (published) multi-omics data and biological networks to identify key genes and pathways for the maturation of mitochondria in striated muscle differentiation.
Aim 2: We will model mitochondrial metabolic states in progenitor and differentiated cells using constraint-based metabolic modelling approaches.
Aim 3: We will develop a Neural Cellular Automaton (mitoAutomaton) to simulate mitochondrial shape changes, incorporating metabolic, regulatory, and spatial data.

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Mots clés – Keywords

Mitochondria, mitochondrial metabolism, mitochondrial maturation, mitochondrial shape transition, cellular differentiation, muscle cells, biological networks, metabolic modelling, neural cellular automata.

Thématique / Domaine / Contexte - Theme / Field / Context

Mitochondrial biology, metabolism and function in the context of cellular differentiation ; integrative analysis of mitochondrial composition, metabolism and shape using multi-omics data in combination with imaging data (still and time-lapse imaging) using a combination of biological network analysis methods, metabolic modelling, and AI with neural cellular automata.

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Objectifs

We want to get a holistic understanding of mitochondrial maturation and its function in cellular differentiation. We will investigate the compositional changes during muscle cell differentiation using complex biological networks integrating multi-omics data, we will unravel metabolic shifts during differentiation using metabolic modelling. This will yield key players and pathways required for mitochondrial maturation and cellular differentiation. Finally, we will integrate this information together with imaging data in neural cellular automata to characterize the shape transitions during mitochondrial maturation.

Méthode – Method

In Aim 1, we will use complex networks in combination with the wealth of publicly available multi-omics data to identify the compositional changes of mitochondria during tissue development and identify key molecules and pathways important for mitochondrial maturation in the development of striated muscle.
In Aim 2, we will characterize mitochondrial metabolic and bioenergetic states of progenitor and differentiated striated muscle cells via constraint-based modeling using the mitoMammal model (Chapman 2024), and a derived fly model, contextualized with multi-omics data. This will provide detailed insights into potential mitochondrial metabolic switches during striated muscle or neuronal differentiation.
In Aim 3, we will develop a Neural Cellular Automaton, the mitoAutomaton, that incorporates time-resolved spatial imaging data and information on key molecular drivers identified in Aims 1 and 2. We will adapt the mitoAutomaton to model mitochondrial maturation in striated muscle cells, integrating metabolic and regulatory information from Aims 1 and 2, and spatial constraints from the local micro-environment as forces acting on mitochondria. The mitoAutomaton will help us investigate regulatory networks and inter-mitochondrial signalling.

Références bibliographiques

Avellaneda, Nat Comm 2021, 10.1038/s41467-021-22058-7
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Conditions scientifiques matérielles et financières du projet de recherche - Scientific, material, and financial conditions of the research project

All materials, publication and travel costs will be covered by the host team, personal and compute servers will be provided.

Profil et compétences recherchées - Profile and skills required

The candidate will have a strong background in bioinformatics and programming, be highly motivated and have a strong interest in cellular metabolism in development and in disease. She/he will have basic knowledge of biochemistry and ideally have experience in either network biology, metabolic modelling, in AI or in working with cellular automata.

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