

## PhD position 3-years

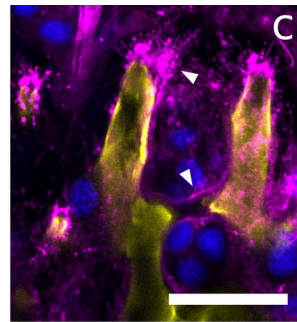
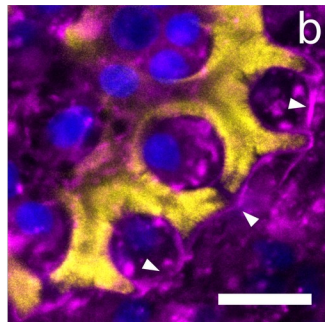
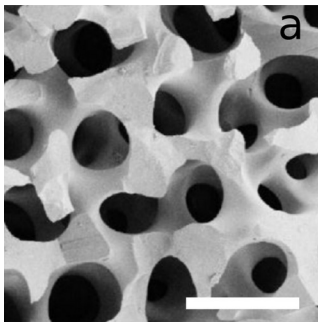
# Morphogenesis of the sea urchin skeleton microstructure

**Location:** Matière et Systèmes Complexes Laboratory (MSC), UMR 7057, rue A. Domon et L. Duquet, 75013 Paris.

**Supervisor:** Giulio Facchini (MSC, Paris) **Co-supervisor:** Jenifer Croce (LBDV, Villefranche-sur-mer)

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**Keywords :** morphogenesis, self-organisation, mechanobiology, cytoskeleton



**Caption:** **a :** sea urchin spine electron micrograph (Yang et al. 2020); **b :** close-up on a J2 juvenile shell plate, newly formed stereom in yellow, actin in magenta nuclei in blue; **c :** close-up on a 10-days regenerating adult spine, labeling as in b. Scale bars are 100  $\mu\text{m}$  (a), 10  $\mu\text{m}$  (b,c). White symbols denote actin structures.

**The context:** Echinoderms, like sea urchins and sea stars, and sea cucumbers build a calcite skeleton whose porous microstructure, called **stereom**, bears a characteristic saddle-shaped curvature signature<sup>1</sup> (Fig. a) that provides optimal mechanical properties<sup>2</sup>. Stereom growth has been addressed at different levels<sup>3-5</sup> and was shown to rely on the progressive addition of small bids of mineral ( $\sim 100$  nm) at the tips of micro-spines, successively branching and looping to form a complex meshwork of much larger characteristic scale (10-50  $\mu\text{m}$ ). Recently, it was also shown that the cytoskeleton may guide localized skeletal growth in sea urchin larvae<sup>6</sup>, cucumber juveniles<sup>7</sup>. Despite these findings, **many fundamental questions remain**: how does tip growth happen in the first place? how and when does branching take place? Why is the final structure bearing such a peculiar geometry? Does stereom growth relies on a simple self-organized mechanism?

**The research:** We will investigate the origin of saddle-shaped curvature of the stereom and model its emergence in the sea urchin *P. lividus*. In particular we will investigate the role of the cytoskeleton, and explore how its spatial organisation (i) depends on the shape of the pre-existing skeleton and (ii) affects the shape of the skeleton that is built successively, following our recent study on sea stars<sup>8</sup>. The candidate will **characterise experimentally** the morphology of the growing stereom and the spatial organization of the cytoskeleton (arrows in Fig. b,c) in the vicinity of it (yellow, Fig. b,c). The applicant will use a variety of experimental techniques, including immunochemistry, confocal microscopy (Fig. b, c) and *in vivo* observations, working with two model systems which are adult spine regeneration and juvenile shell growth. The student will also develop a numerical workflow to **analyse** and **quantify** experimental images, and will participate to develop a **growth model** that couples skeleton growth and cytoskeleton organisation. This is an **highly interdisciplinary** project and the candidate will interact with Physicists and Biologists, between two laboratories in Paris (MSC) and Villefranche-sur-mer (LBDV). This is an **experimental PhD** but according to the skills, curiosity, and motivations of the candidate, the internship may be more or less oriented towards experiments and data analysis or theoretical modelling.

**References:** [1] Yang, T. et al. *Acta Biomater.* **107**, 204–217 (2020); [2] Yang, T. et al. *Science* **375**, 647–652 (2022); [3] Heatfield, B. M. *J. Morphol.* **134**, 57–89 (1971); [4] Politi, Y. *Science* **306**, 1161–1164 (2004); [5] Gorzelak, P. et al. *J. Struct. Biol.* **176**, 119–126 (2011); [6] Hijaze, E. et al. *eLife* **12**, (2024); [7] Vyas, P. et al. *bioRxiv* (2024); [8] Humański, K. et al. *Acta Biomater.* **212**, 516–526 (2026);

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