

Morphogenesis of the sea urchin skeleton microstructure: the role of the cytoskeleton - *Experiments*

Location: Laboratoire Matière et Systèmes Complexes (MSC), UMR 7057, 75013 Paris

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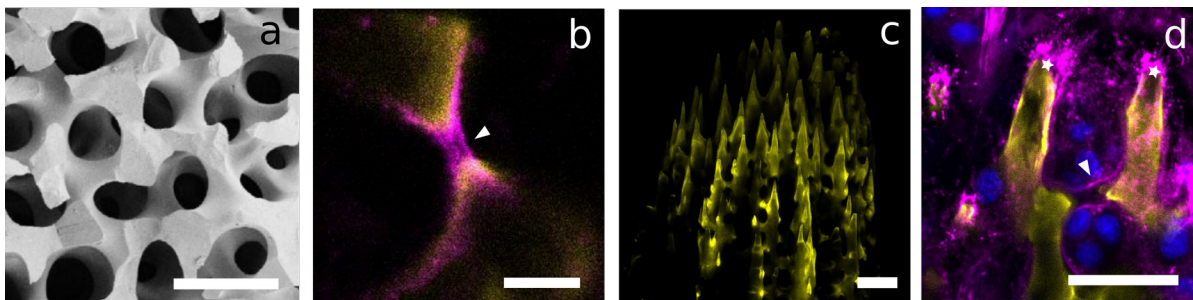
Thesis possibility after internship: YES

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Context: Echinoderms, like sea urchins, sea stars, and sea cucumbers, build a calcite endoskeleton whose porous microstructure, called **stereom**, bears a characteristic saddle-shaped curvature signature^{1,2} (Fig. **a**), which displays optimal mechanical properties³. Stereom growth has been addressed at different levels⁴⁻⁶ and was shown to rely on the progressive addition of small bids of mineral (~100 nm) at the tips of microspines, successively branching and looping to form a complex meshwork of much larger characteristic scale (10-50 μ m). More recently, it was also proposed that the cytoskeleton may guide localized skeletal growth in sea urchin larvae⁷. In a very recent study on sea stars we confirmed that hypothesis and produce the first evidence that stereom geometry, may be inherited from saddle-shaped precursors (Fig. **b**) made of actin fibers that attach to tips of the growing stereom and self-organize under tension⁸.

Despite these findings, many fundamental questions remain: how does tip growth happen in the first place? how and when does branching take place? What is the dynamics of actin fibers? How they attach to the growing stereom?



Caption: **a:** sea urchin spine electron micrograph (Yang et al. 2020); **b-d:** Stereom confocal micrographs - freshly added mineral in yellow, actin in magenta, nuclei in blue. White symbols denote actin structures. **b:** close-up on a sea star arm plate (Humanski et al. 2026). **c:** 10-days regenerating sea urchin spine **d:** close-up on a 10-days regenerating adult spine. Scale bars are 100 μ m (c), 50 μ m (a) and 10 μ m (b,d).

Goal of the internship: The internship's aim will be to study the origin of the special geometry of the stereom, working on the sea urchin *P. lividus*. In particular, the candidate will investigate the role of the *F-actin* cytoskeleton, and explore how its spatial organization (i) depends on the shape of the pre-existing skeleton and (ii) affects the shape of the skeleton that is built successively.

The candidate will **characterize experimentally** the spatial organization of the cytoskeleton (Fig. **d**, magenta) in the vicinity of the growing stereom (Fig. **d**, yellow), and quantify the stereom growth in in the regenerating spines of wild specimen (Fig. **c**). A comparison will then be made with specimen treated with drugs that perturb actin contractility and actin polymerisation. Next, the candidate will work at a new experimental protocol to observe cytoskeleton dynamics **in vivo** to monitor how F-actin fibers structures can evolve from disordered bundles (Fig. **d**, stars) to tube-like precursors (Fig. **b**, **d**, triangles). The internship will be the opportunity to learn a variety of experimental techniques, including immunochemistry and confocal microscopy. The student will also develop a numerical workflow to analyze and quantify experimental images. This project is highly **interdisciplinary** and the candidate will interact with distinct scientific profiles spanning from Physics to Biology. This is an **experimental** internship but according to the skills, and motivations of the candidate, it may be more or less oriented towards experiments or data analysis.

References: [1] Smith, A. B. *Spec. Pap. Palaeontol.* 1–81 (1980); [2] Yang, T. et al. *Acta Biomater.* **107**, 204–217 (2020); [3] Yang, T. et al. *Science* **375**, 647–652 (2022); [4] Heatfield, B. M. *J. Morphol.* **134**, 57–89 (1971); [5] Politi, Y. *Science* **306**, 1161–1164 (2004); [6] Gorzelak, P. et al. *J. Struct. Biol.* **176**, 119–126 (2011); [7] Hijaze, E. et al. *eLife* **12**, RP89080 (2024); [8] Humański, K. et al. *Acta Biomater.* **212**, 516–526 (2026);