A thresholding method to understand the locomotion of the sea star *Asterias rubens*.

Amandine Deridoux[1,2], Patrick Flammang[2] Sylvain Gabriele[1*]

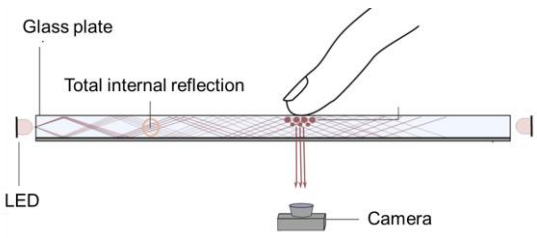
[1] Laboratory for Complex Fluids and Interfaces, Mechanobiology and Soft Matter Group, Research Institute for Biosciences, University of Mons, Mons, Belgium

[2] Biology of Marine Organisms and Biomimetics Unit, Research Institute for Biosciences, University of Mons, Mons, Belgium

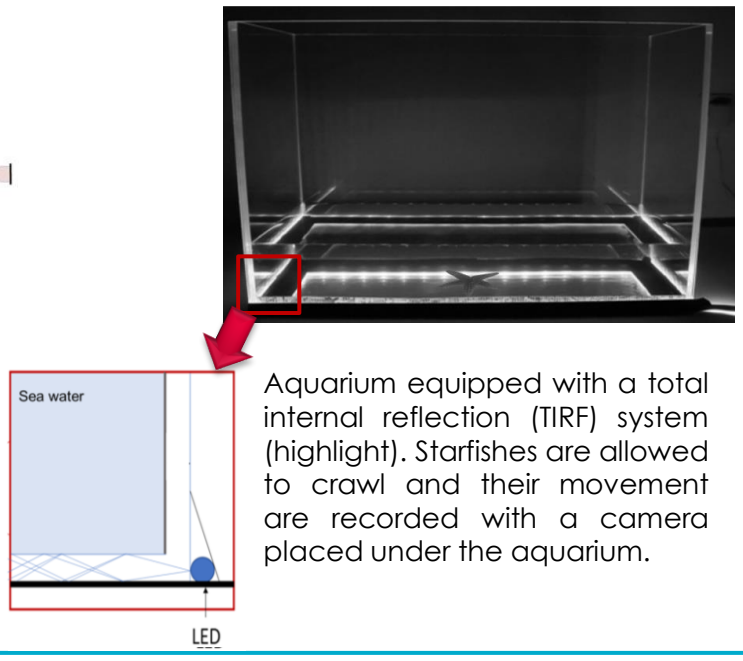
*Contact: sylvain.gabriele@umons.ac.be

Sea stars use a multitude of small hydraulic organs (i.e., the tube feet or podia), to locomote, to attach strongly to the substrate, and to pry open the mussels on which they feed. Podia are secretory organs in which two types of adhesive cells co-secrete a blend of adhesive proteins to form the adhesive layer joining the tube foot to the substrate [1]. Despite the importance of podia in the sea star locomotion mechanism, the regulation of the number of podia sticking to a surface during movement is still poorly understood. In this study, we designed an aquarium equipped with a total internal reflection (TIRF) system and developed a robust technique to quantify the number of sticking podia during the locomotion of sea star.

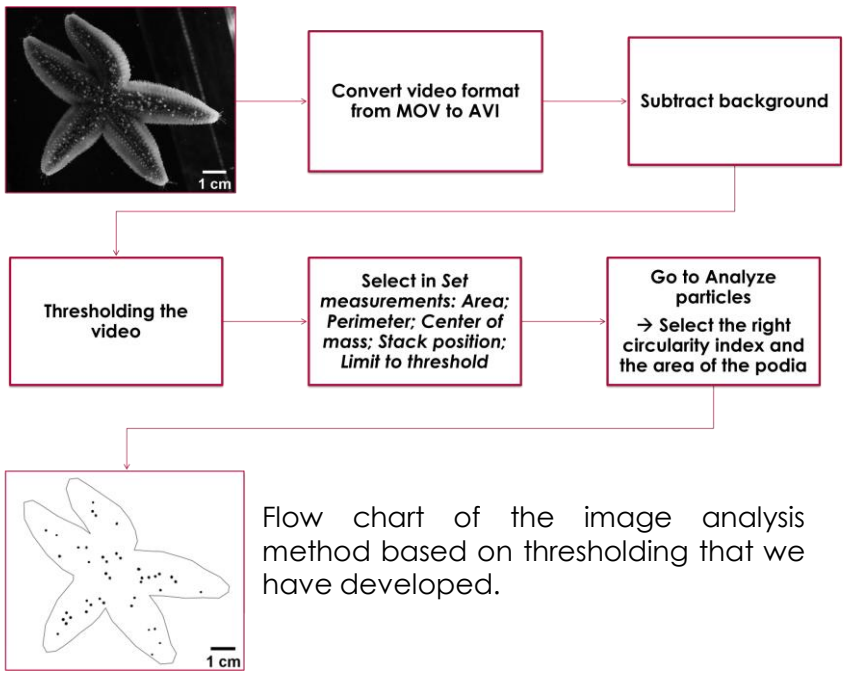
Experimental setup and analytical method



Schematic of the phenomenon of total internal reflection. The object which comes into contact with a surface provided with the TIRF will diffuse the light and this contact area will be illuminated.

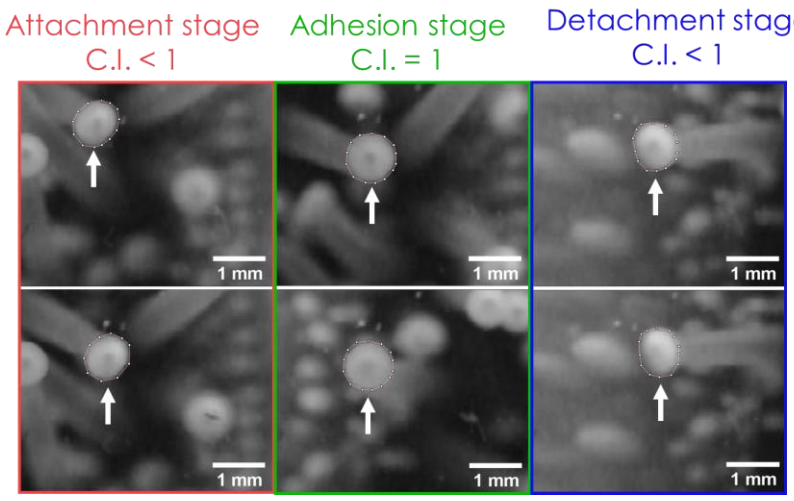


Aquarium equipped with a total internal reflection (TIRF) system (highlight). Starfishes are allowed to crawl and their movement are recorded with a camera placed under the aquarium.



Flow chart of the image analysis method based on thresholding that we have developed.

Characterization of the adhesion mechanism during locomotion

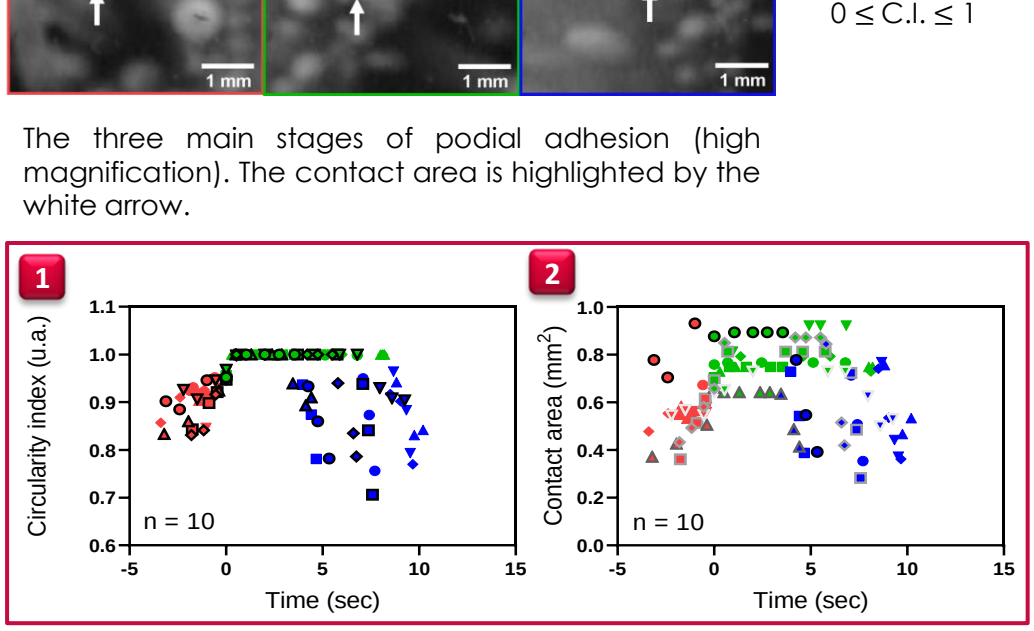


Attachment stage
Adhesion stage
Detachment stage

Circularity index (C.I.) = $4\pi \frac{area}{perimeter^2}$

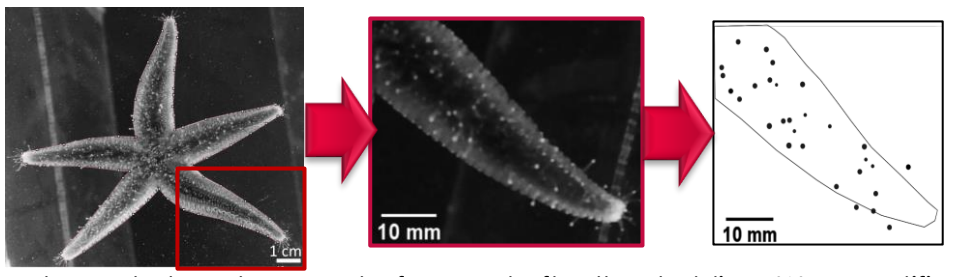
$0 \leq C.I. \leq 1$

The three main stages of podial adhesion (high magnification). The contact area is highlighted by the white arrow.

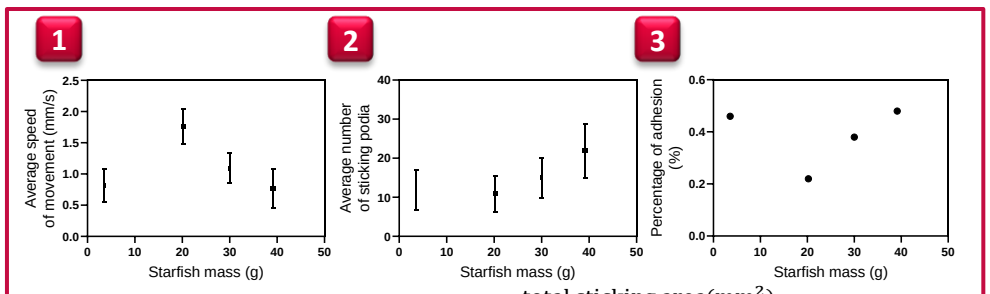


Variation of the circularity index during the adhesion dynamics (1) shows that during the entire second stage (i.e. adhesion stage) the podia circularity index is equal to one. The variation of the contact area during the adhesion dynamics (2) shows a large increase in area during the attachment stage.

Asterias rubens locomotion

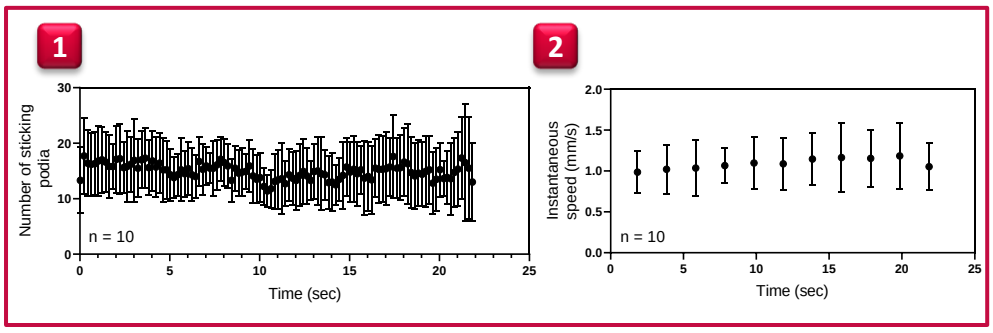


Sea star ambulacral groove before and after thresholding. We quantified the number of podia in close contact with the substrate during locomotion (black dot on the screen).



Percentage of adhesion = $\frac{\text{total sticking area}(mm^2)}{\text{oral surface area}\ (mm^2)} * 100$

Locomotion parameters are influenced by the mass of the starfish. Except for the smallest individual, the average speed of movement decreases with starfish mass (1). Conversely, both the number of sticking podia (2) and the percentage of adhesion (3) increase with increasing mass of the individuals.



Number of sticking podia (1) and instantaneous speed (2) remain both constant during the locomotion of *Asterias rubens*.

Conclusion and perspectives

In this project, we developed a robust technique for quantifying the number of podia sticking to the substrate during locomotion. We observed an influence of the size of the sea star *Asterias rubens* on various parameters of locomotion (average speed, number of sticking podia).

Based on these preliminary results, we plan to study the role of important environmental factors, such as substrate angle and temperature of the environment on sea star locomotion, and we will determine the adhesion energy exerted by a starfish according to the number of sticking podia.

References

1. P. Flammang, A. Michel, A. Van Cauwenberge, H. Alexandre and M. Jangoux, Journal of Experimental Biology, 201, 2383–2395 (1998).

Acknowledgments

Amandine Deridoux was supported by the *Research Institute for Biosciences* and the *Research Institute for Materials Sciences and Engineering* of the University of Mons.