Mechanical description of the podia in sea star locomotion

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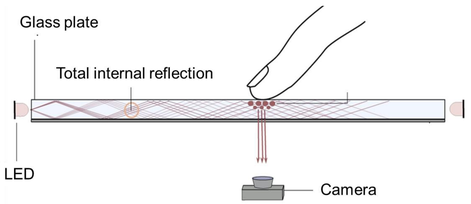
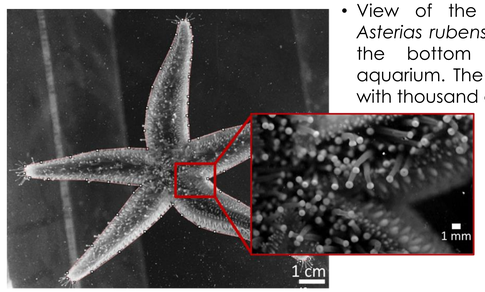
Sea stars use a multitude of small hydraulic organs (i.e., the tube feet or podia), to locomote, to strongly attach to the surrounding, and to pry open the mussels on which they feed. Podia are secretory organs in which two types of adhesive cells co-secrete a blend of adhesive proteins to form the adhesive layer joining the podia to the substrate (1). Despite the paramount importance of podia in sea star locomotion, the regulation of the number of podia sticking to a surface during movement is still poorly understood.

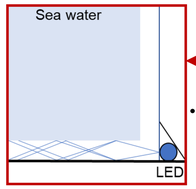
Experimental setup and analytical method

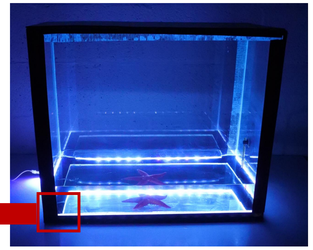


- Schematic of the phenomenon of total internal reflection. The object which comes into contact with a surface provided with the TIRF will diffuse the light and this contact area will be illuminated.

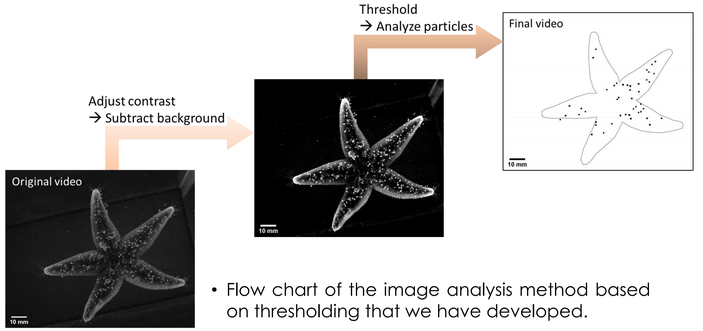


- View of the oral surface area of *Asterias rubens* when it is crawling on the bottom of our experimental aquarium. The oral surface is covered with thousand of podia (highlight).



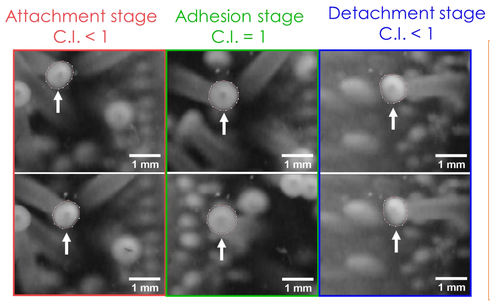


- Experimental aquarium equipped with a total internal reflection (TIRF) system (highlight). Starfishes are allowed to crawl and their movement are recorded with a camera placed under the aquarium.

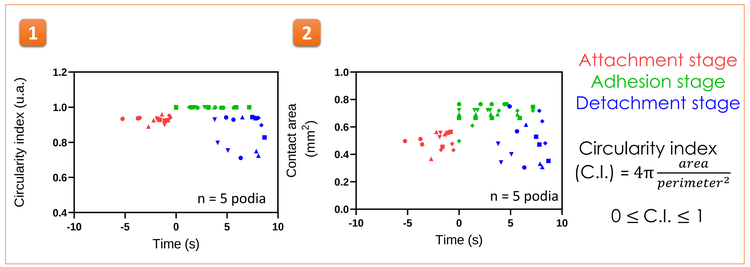


- Flow chart of the image analysis method based on thresholding that we have developed.

Characterization of the adhesion mechanism during locomotion

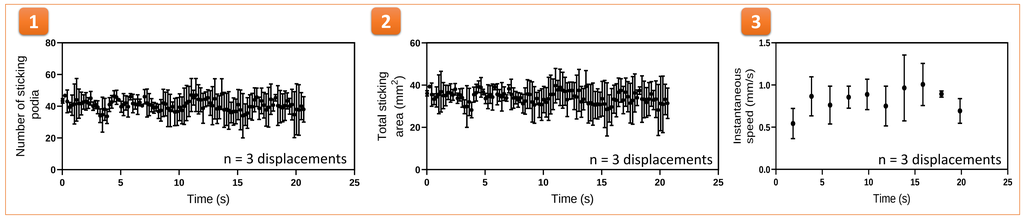


- The three stages of podial adhesion during the movement of the starfish have been demonstrated thanks to videos at high magnification. The contact area is highlighted by the white arrow.



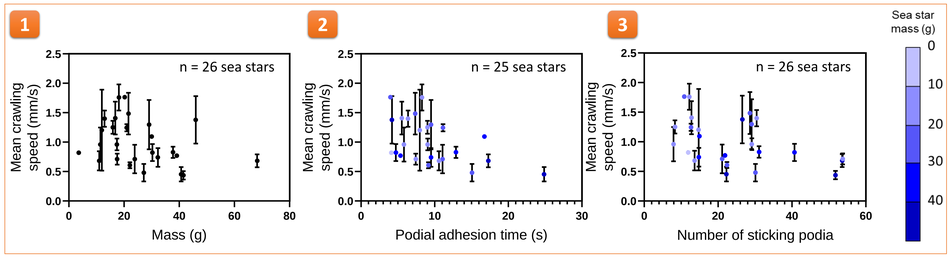
- The variation of the circularity index during the adhesion dynamics (1) shows that during the entire second stage, the adhesion stage, the podia circularity index is equal to one = a perfect circle. The variation of the contact area during the adhesion dynamics (2) shows a large increase in area during the attachment stage.

Asterias rubens locomotion



- The number of sticking podia (1), the total sticking area (2) as well as the instantaneous speed (3) remain constant during the locomotion of *Asterias rubens*.

- The mean crawling speed is independent of the sea star mass (1). In contrast, this speed decreases with the increase of the podial adhesion time (2) and the increase of the number of sticking podia (3).



Conclusion and perspectives

In this project, we developed a robust technique for quantifying the number of podia sticking to the substrate during locomotion. Contrary to what is observed in other animals, it seems that the size of *Asterias rubens* has no impact on the mean crawling speed. A long-term goal for this project is to develop a biomechanical model of sea star locomotion based on the measurement of the adhesion energy exerted by a sea star 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.