MARINE ADHESIVES:
FROM BIOLOGY TO BIOMIMETICS

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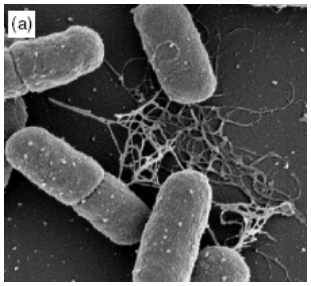
Challenges for new adhesives

- enable attachment to a variety of surfaces, also in fluid environments, for a broad range of applications
- be environment-friendly
- be reusable, allowing multiple attachments and detachments
- be reversible (or switchable), so that detachment can occur at will with negligible force

Biological adhesives



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Biological adhesives: from biology to biomimetics

The **main objective** is to gain new understanding relating to the mode of action of biological adhesives so as to facilitate the development of synthetic counterparts with improved function.

- So far 10 countries (AT, BE, CH, DE, FI, FR, IE, IT, PT, UK) have accepted the MoU.

- Kick-off Management Committee meeting will take place on May 18th.

Poster #1

Biological attachment devices








Patterned adhesives

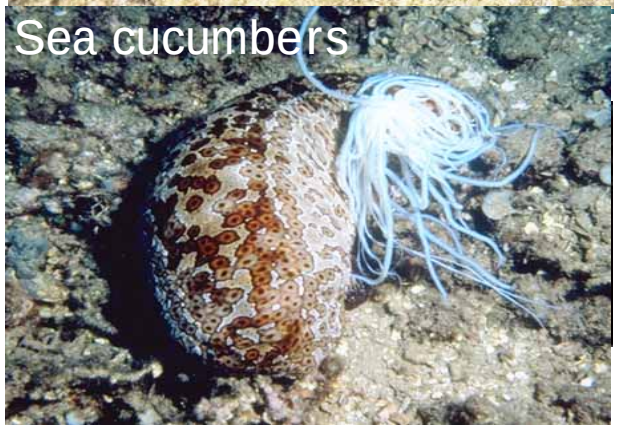
Biological glues

Types of adhesion

1) **Permanent adhesion**
by secretion of a cement

2) **Non-permanent adhesion**
by secretion of a visco-elastic adhesive

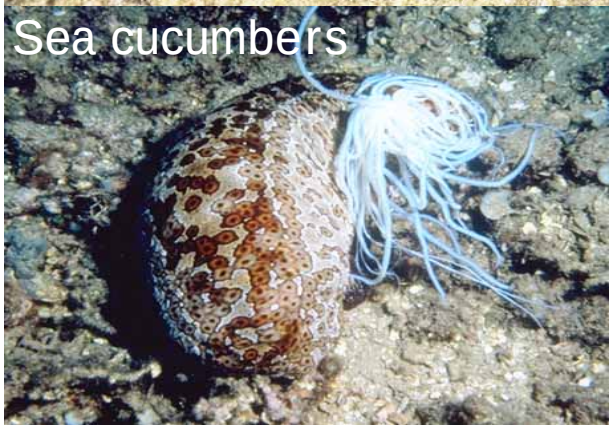
3) **Instantaneous adhesion**
allowing very fast attachment



Permanent adhesion

Non-permanent adhesion

Instantaneous adhesion

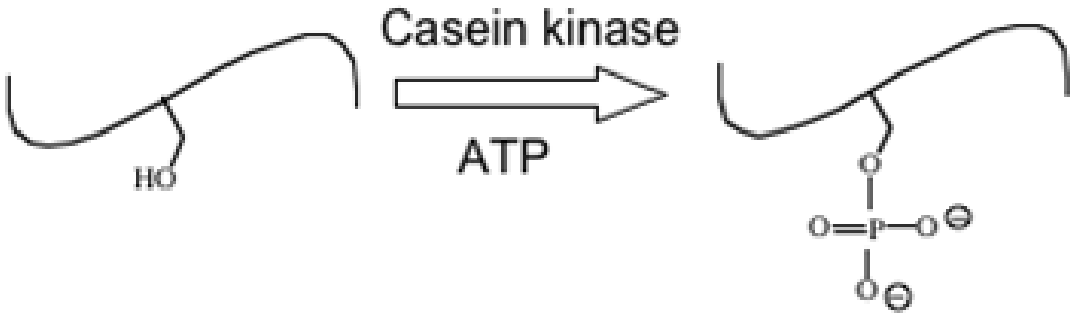


All biological glues from marine invertebrates are based on specialized proteins, the marine adhesive proteins

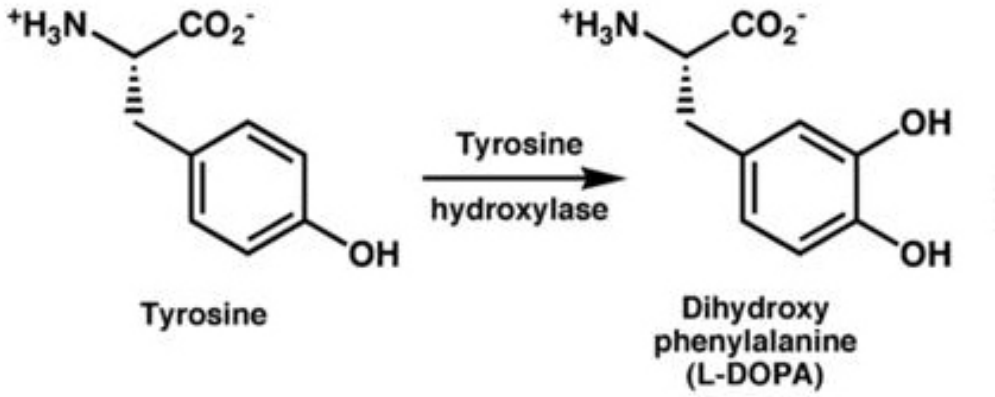
Adhesive motifs

Post-translational modifications of marine adhesive proteins

1) Phosphorylation of serine residues ⟶ pSer

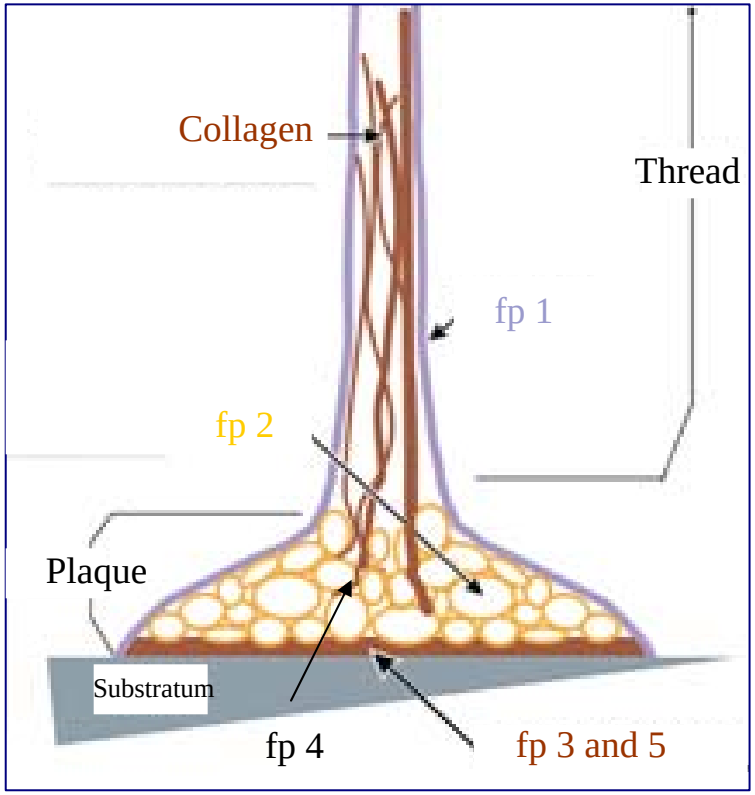


2) Hydroxylation of tyrosine residues ⟶ DOPA



Current state of knowledge

One model systems has inspired most biomimetic approaches for biological glues: the mussel byssus.



Waite (2002), Integr Comp Biol 42:1172-1180

Waite et al. (2005), J Adhesion 81: 297-317

Production of biomimetic or bio-inspired adhesives

Mussel adhesive proteins

Extraction **Biotechnology** **Synthesis**

BD

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Applications

- **Tissue adhesives for *in vivo* use**

- **Adhesive coatings to functionalize surfaces and interfaces (e.g., in composite materials)**

- **…**

Three models are investigated in our laboratory

The tubeworm
Permanent adhesion

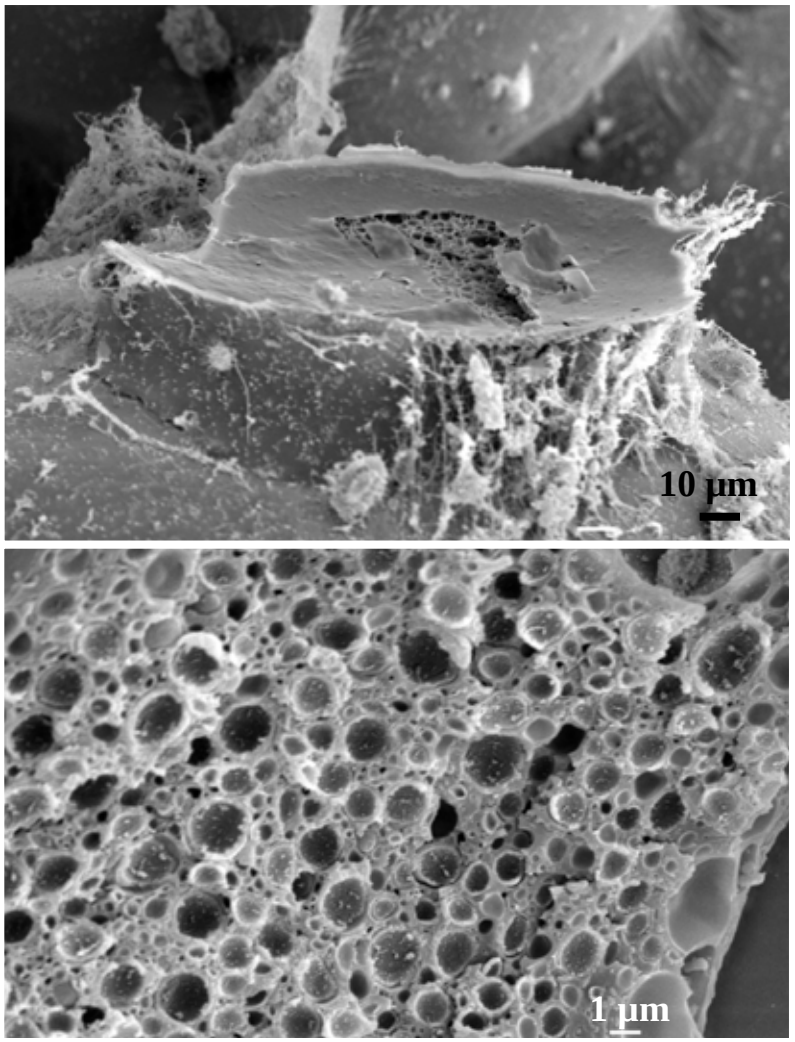
The sea star
Non-permanent adhesion

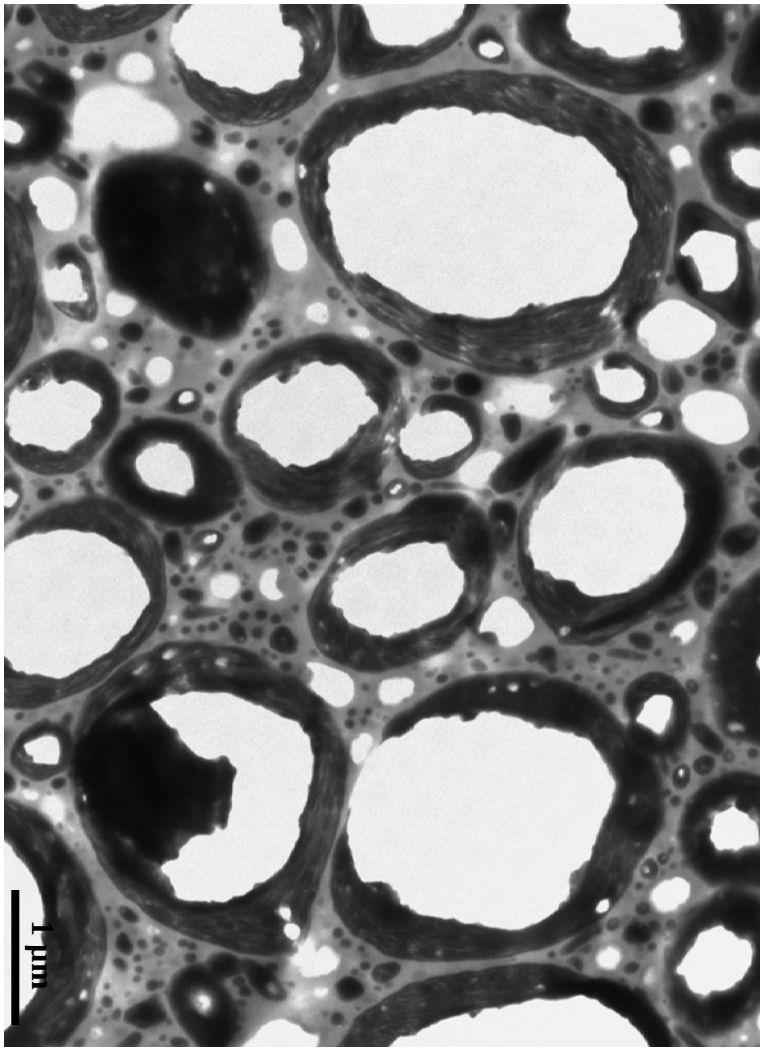
The sea cucumber
Instantaneous adhesion

Permanent adhesion: Tubeworms

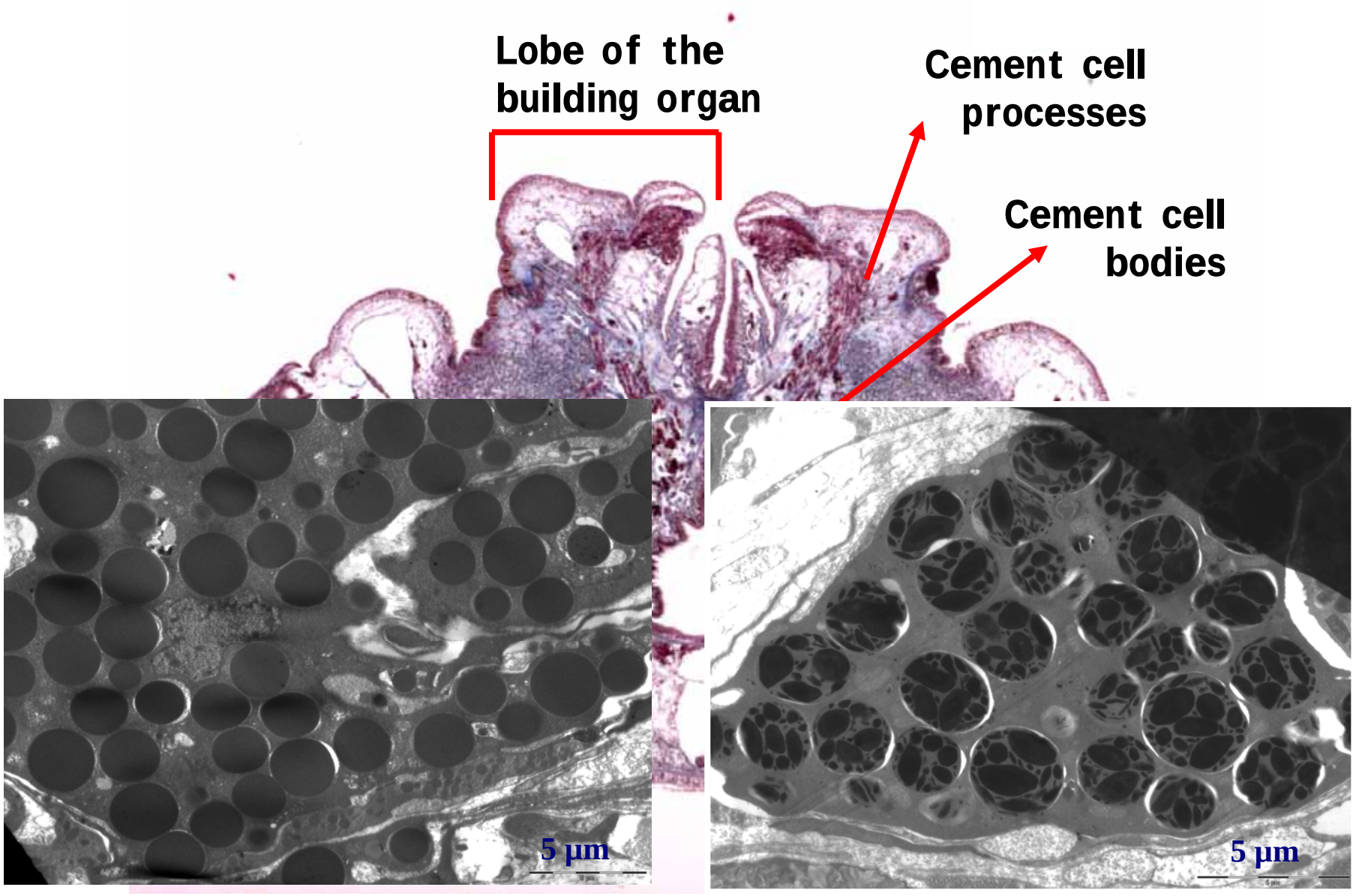
***Sabellaria alveolata*, the honeycomb worm, is a tube-dwelling polychaete**

The cement is a complex composite material





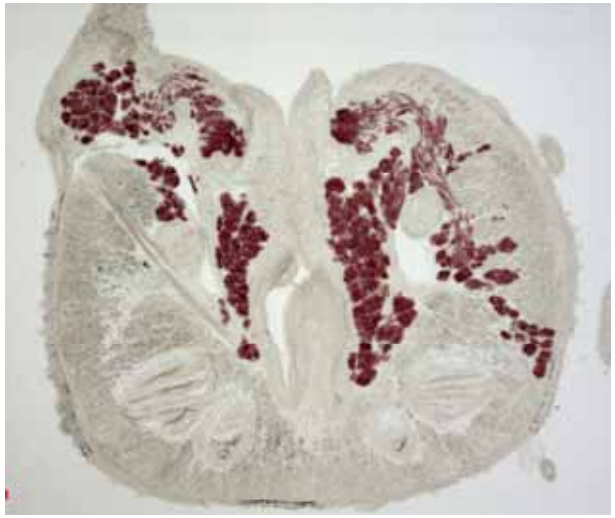
The building organ of the tubeworm *Sabellaria alveolata*

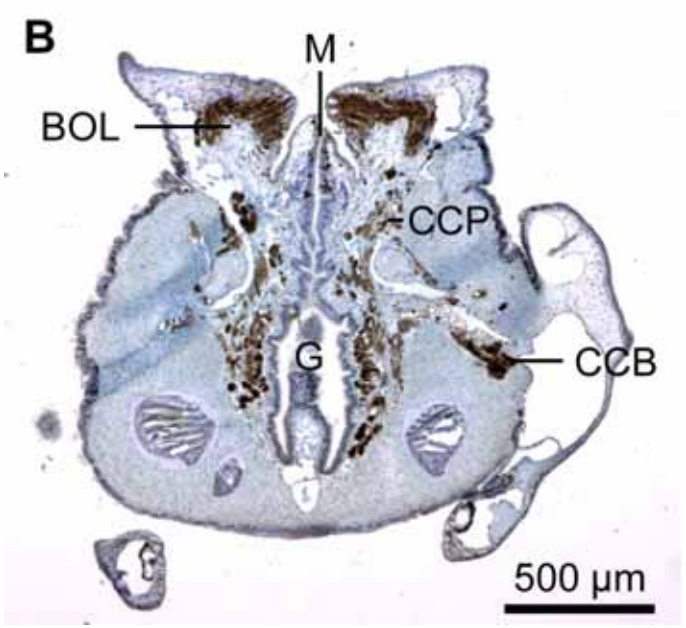


The adhesive proteins of *Sabellaria alveolata*

Sa-1, fragment of 217 amino acids, repeated sequences rich in tyrosine residues (DOPA)

Sa-3, fragment of 178 amino acids, 75% serine residues (phosphoserine)

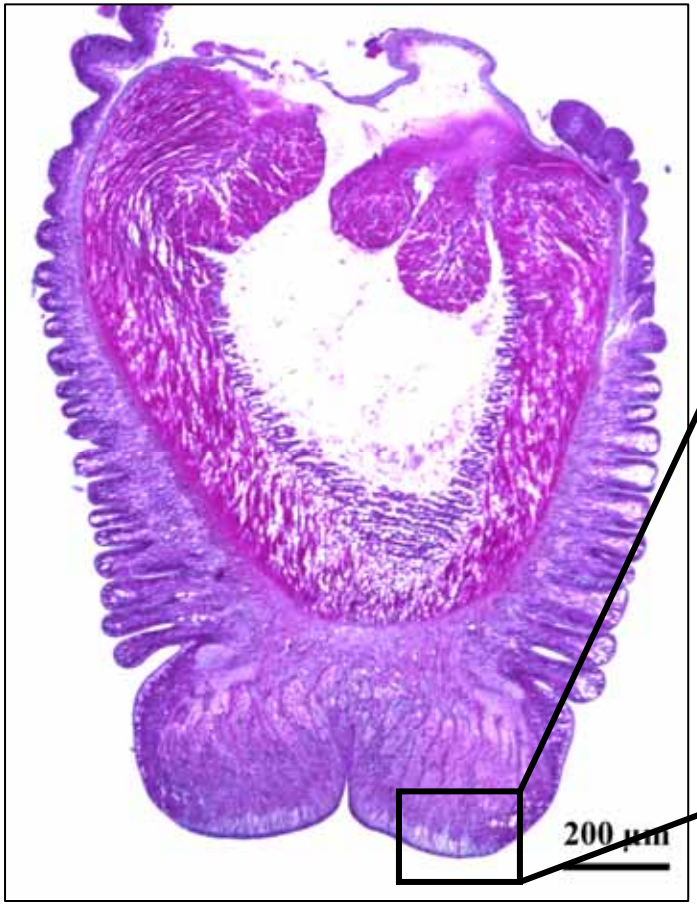


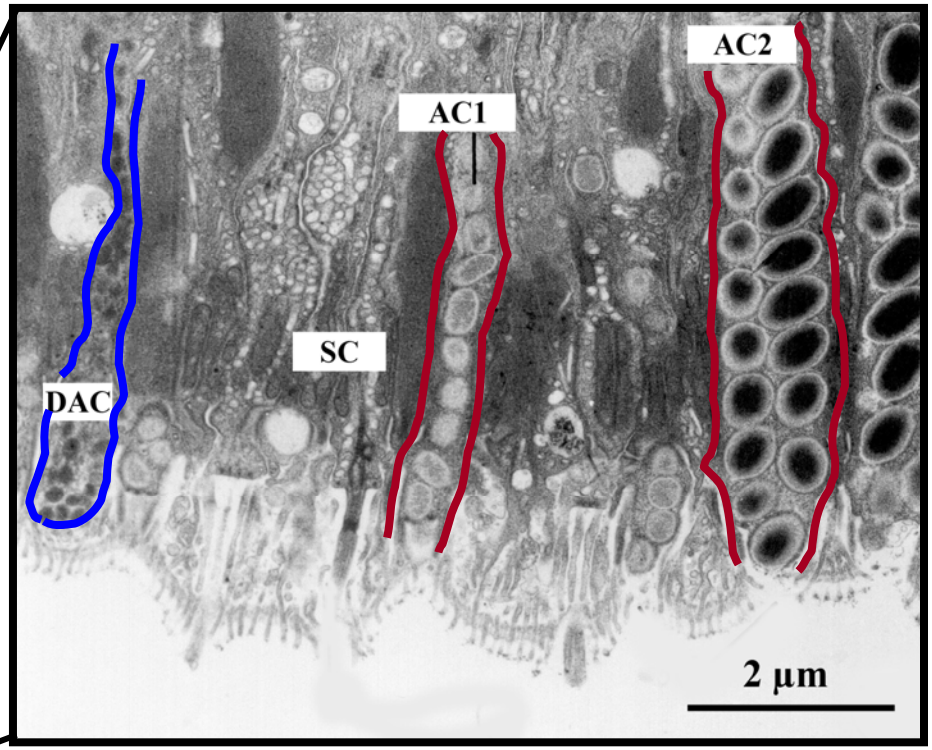


Non-permanent adhesion: Sea stars

The sea star *Asterias rubens* can attach strongly but temporarily to the substratum with a multitude of tiny appendages, the TUBE FEET

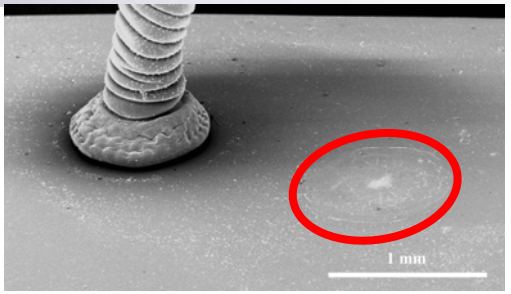
Tube feet rely on a duo-gland adhesive system

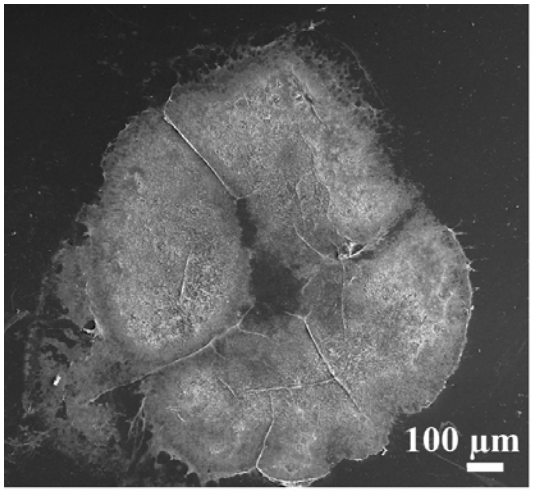


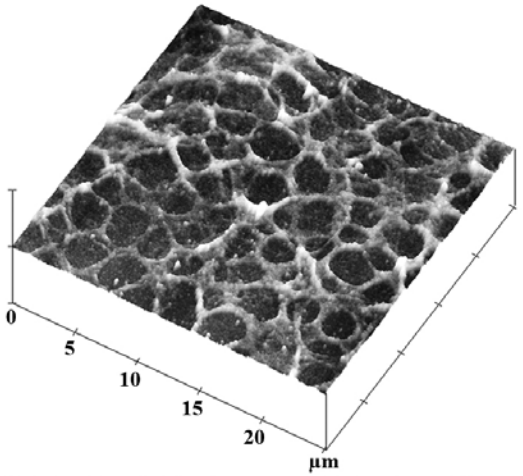


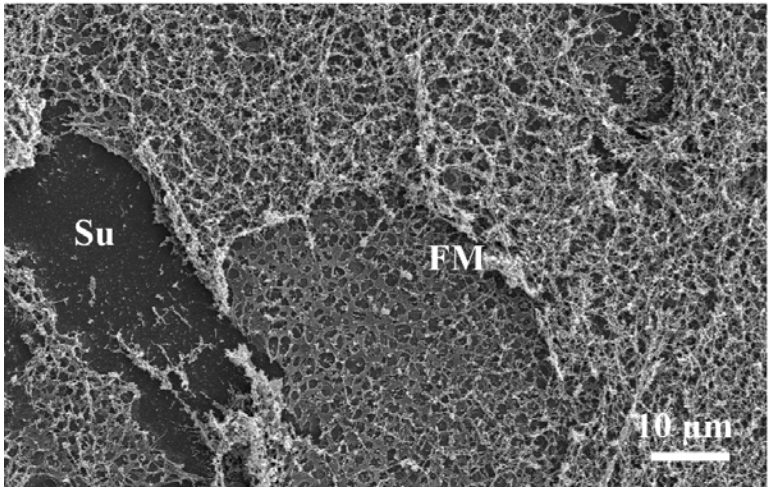
AC1: Type 1 adhesive cell
AC2: Type 2 adhesive cell
SC: Sensory cell
DAC: de-adhesive cell

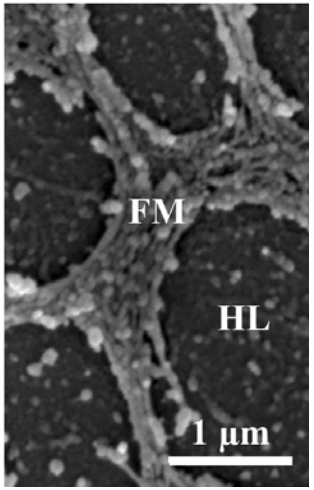
Sea star footprints

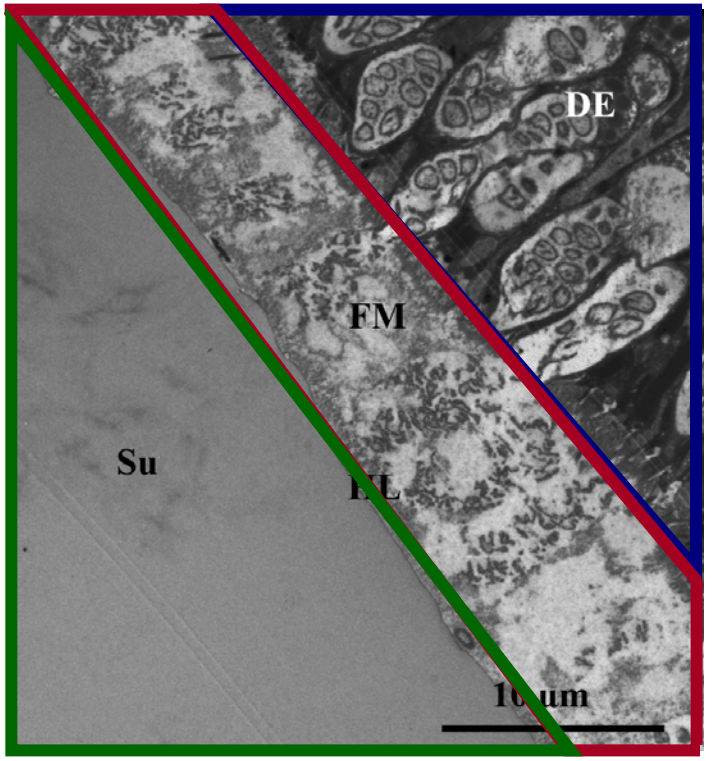












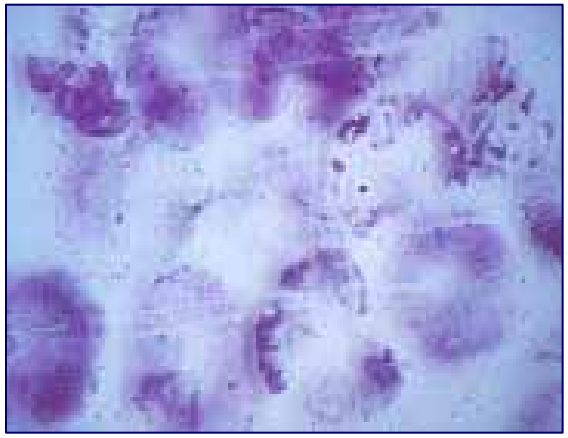
DE: Disc epidermis

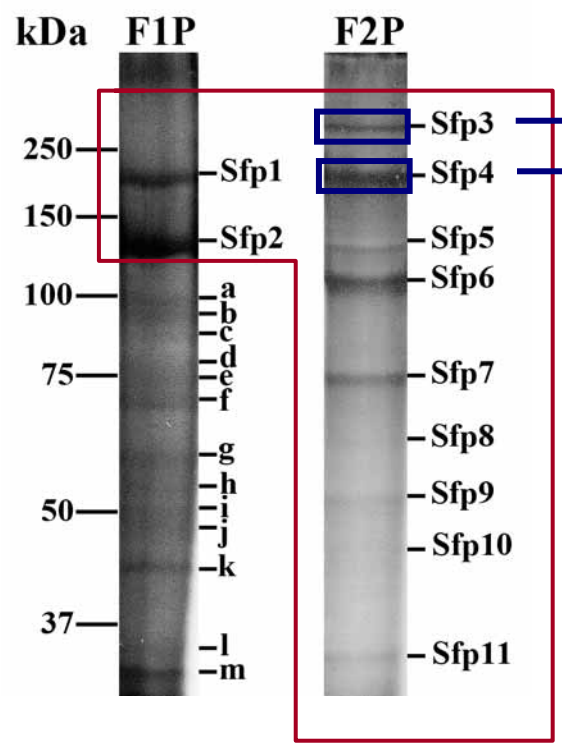
FM: Fibrillar material

HL: Homogeneous layer

Su: Substratum

Characterization of adhesive footprints





Novel proteins
Sea star footprint proteins (**Sfps**)

Glycoprotein

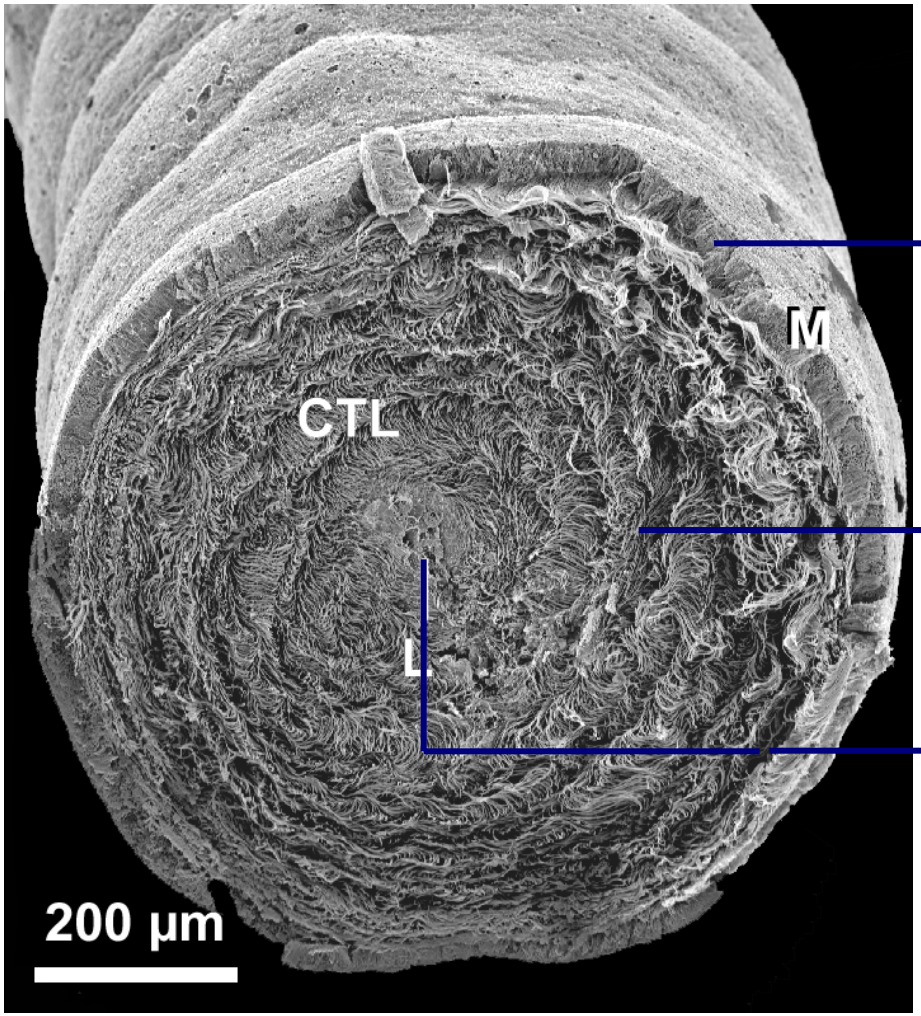
Phosphoglycoprotein

40 *de novo* generated peptide sequences

Instantaneous adhesion: Sea cucumber

Several species possess a peculiar defence system, the **Cuvierian tubules**

Morphology of Cuvierian tubules

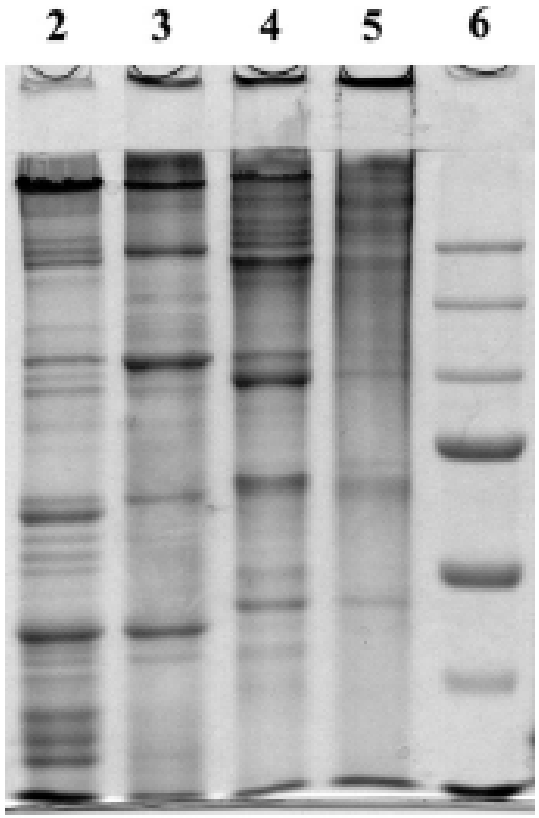


Adhesive epithelium

Connective tissue layer

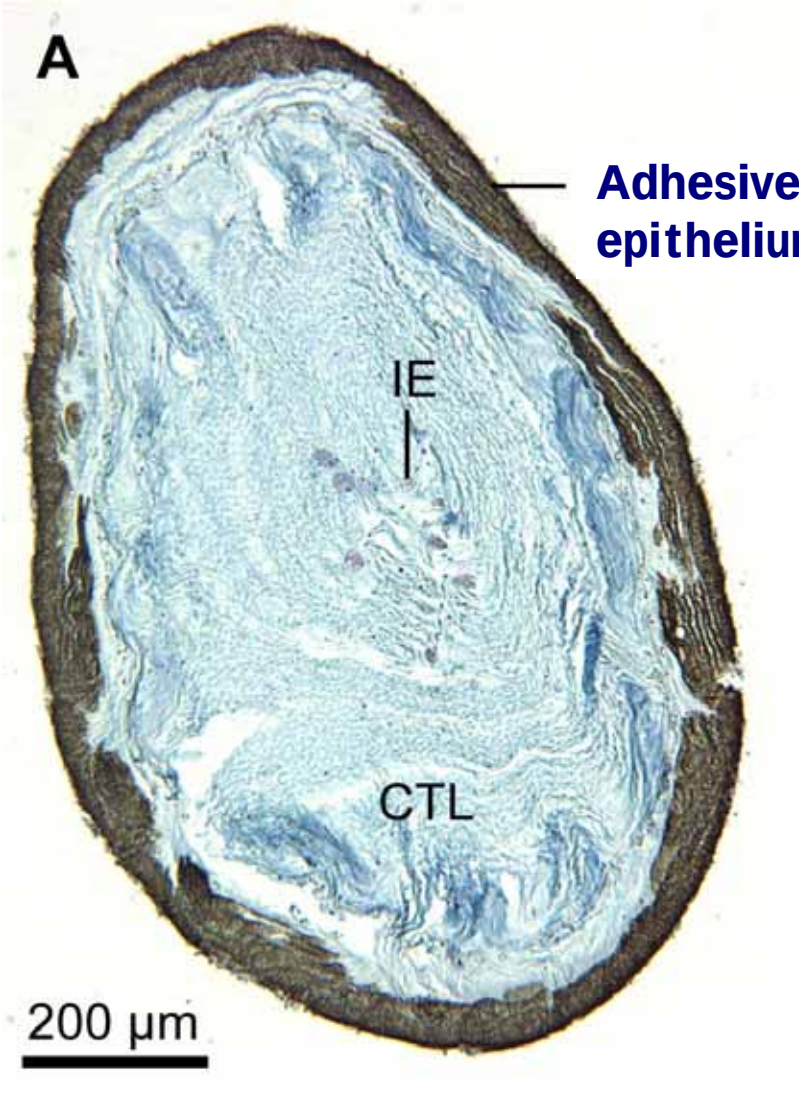
Lumen

Proteins extracted from Cuvierian tubule glue prints

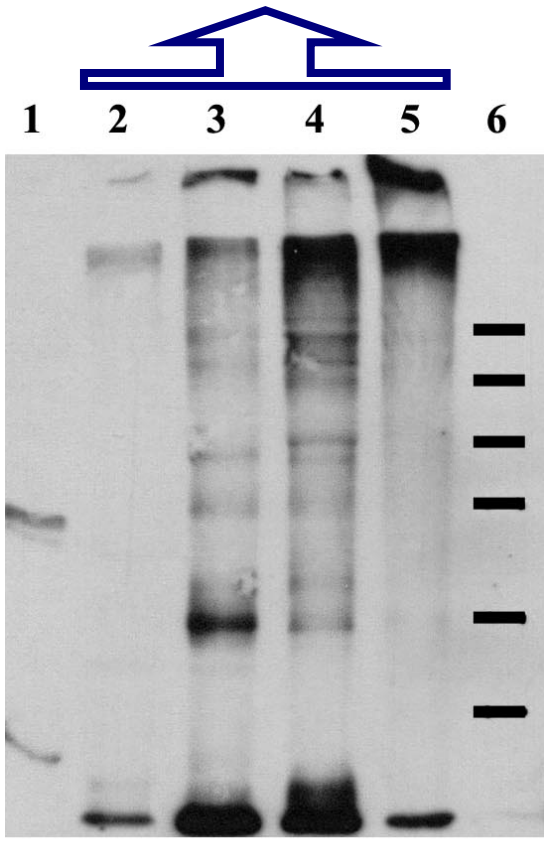


- Some contaminant proteins
- Several novel proteins

The adhesive of Cuvierian tubules contains polyphosphoproteins



Proteins extracted from the Cuvierian tubule glue



Casein control (milk polyphosphoprotein)

Production of biomimetic or bio-inspired adhesives


Marine adhesive proteins

Biotechnology **Synthesis**

Novel adhesives or coatings

Acknowledgements

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