Bio-Inspired Design

Wb2436-05

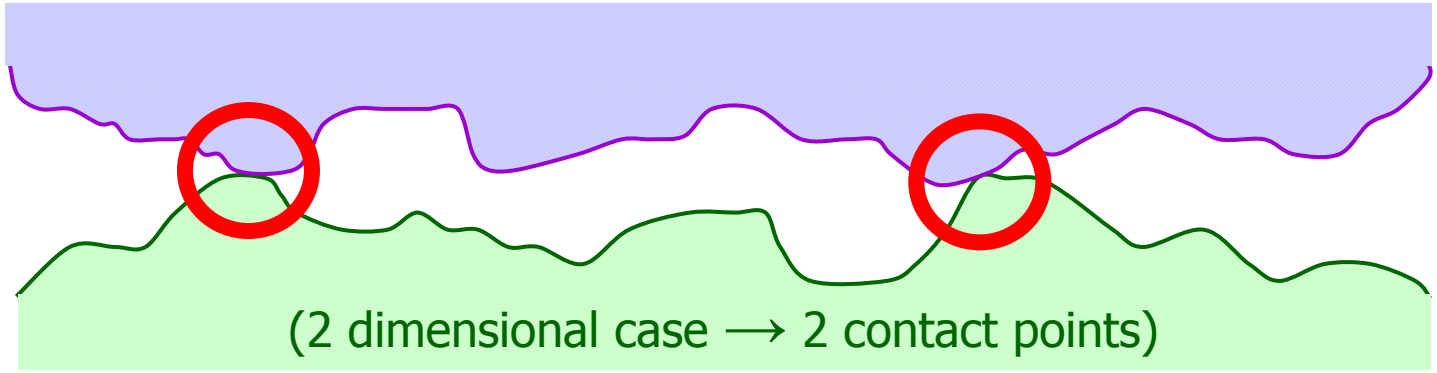
TU Delft

Overview

Biological Clamping Method	Technical Counterpart
Grasping	Large number of examples
Suction	
Adhesion	
No biological counterparts (?)	Electro-Magnetism
	Freezing & Melting
	...

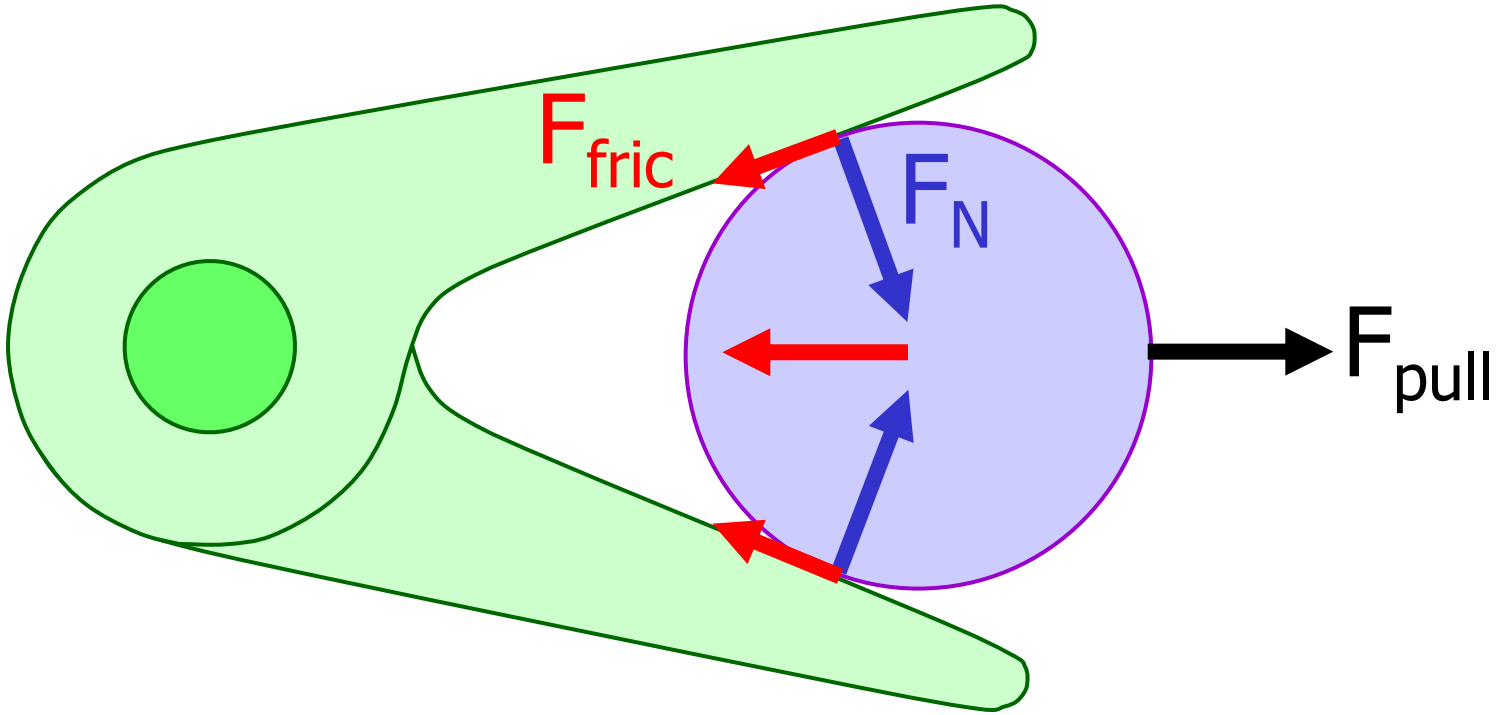
Grasping	Suction	Adhesion

Grasping | Suction | Adhesion



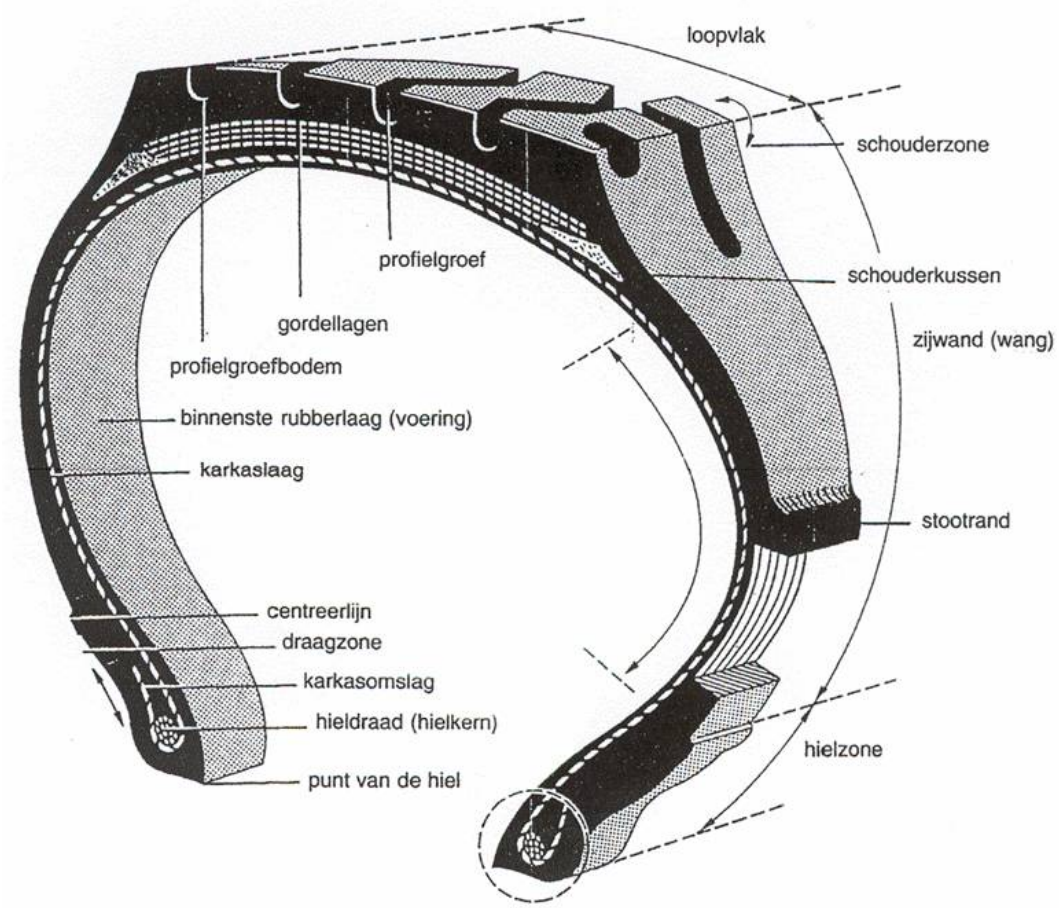
Case 1: Two rigid surfaces

- Grip stays equal when surface area changes
- Grip can be increased by increasing normal force & friction coefficient



Increasing grip by
increasing friction coefficient …

Grasping | Suction | Adhesion



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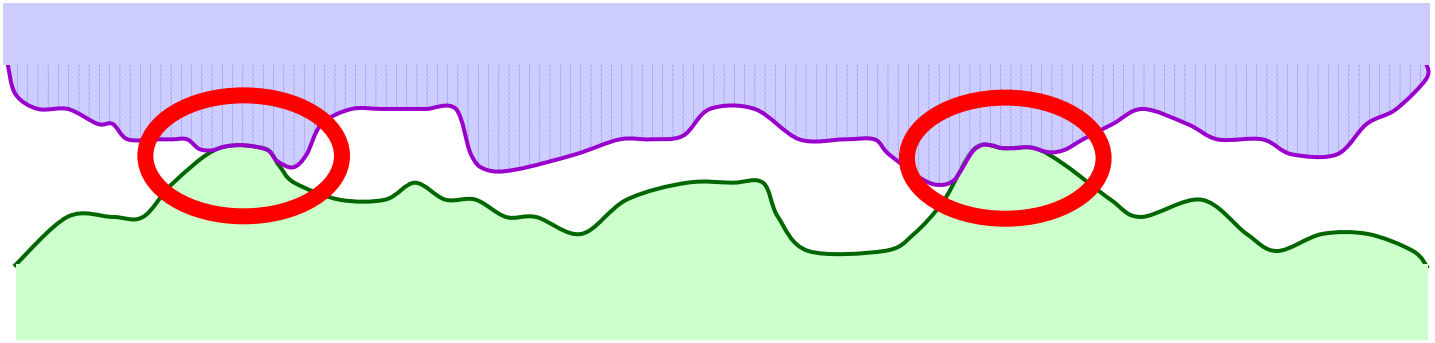
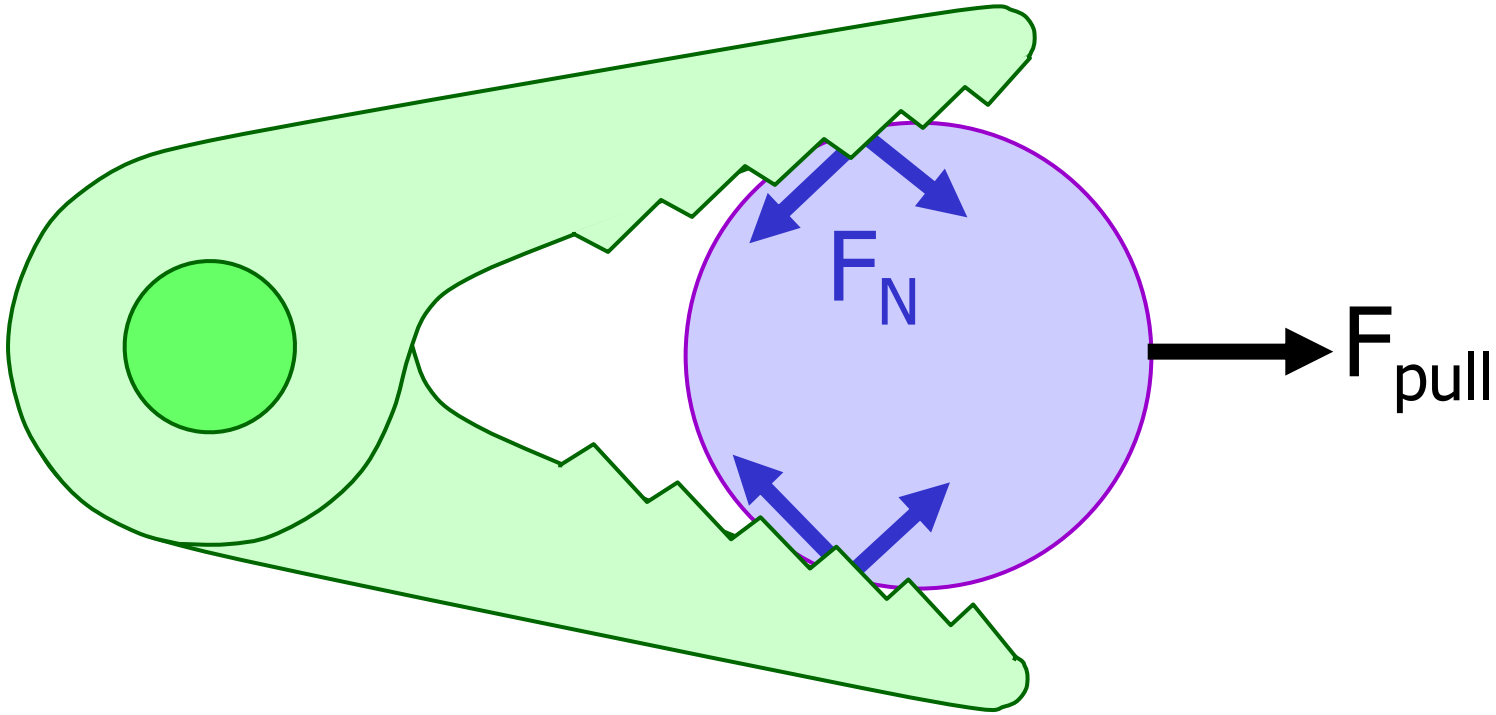
Grasping | Suction | Adhesion



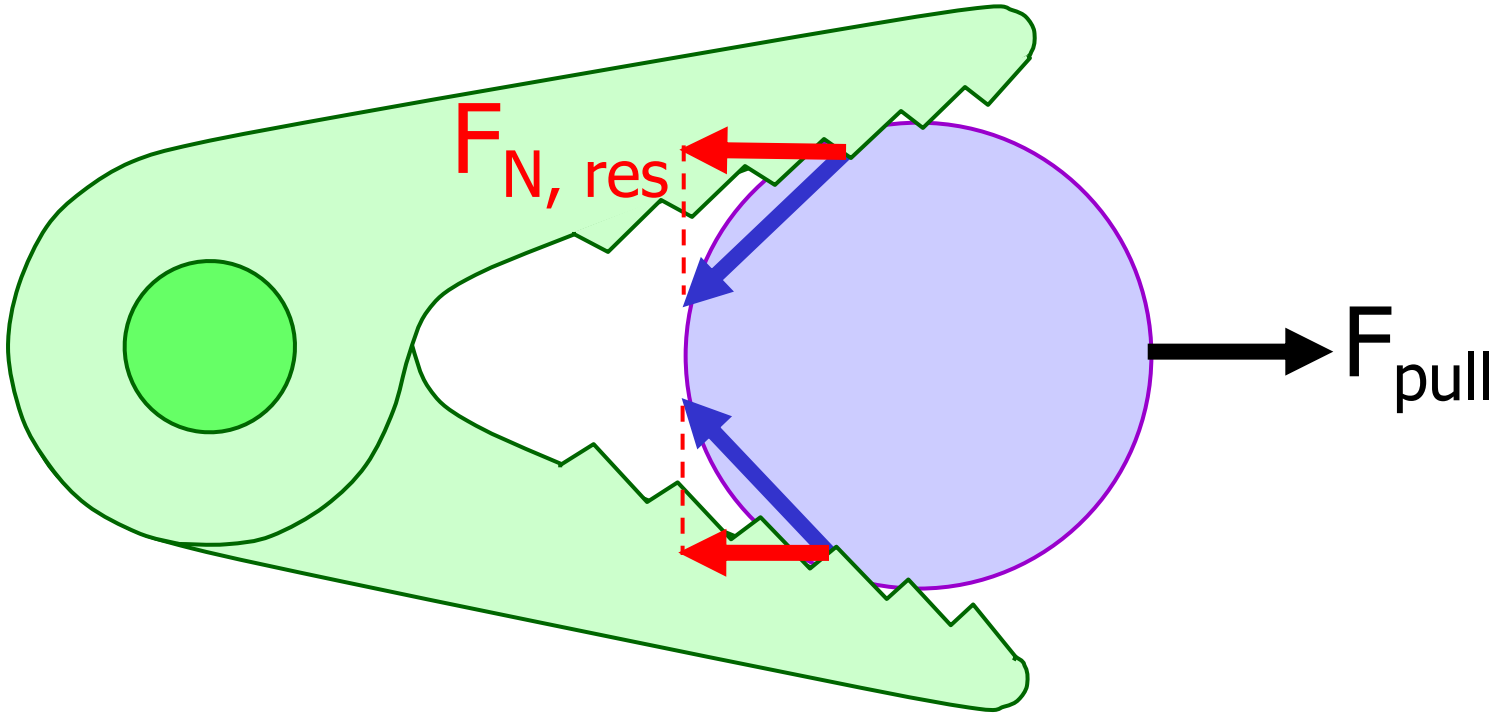
Case 2: One or two deformable surface(s)

- Friction much larger because of increased contact surface
- Normal forces in different directions can help to increase grip
- Friction not necessary for achieving grip!

Grasping | Suction | Adhesion

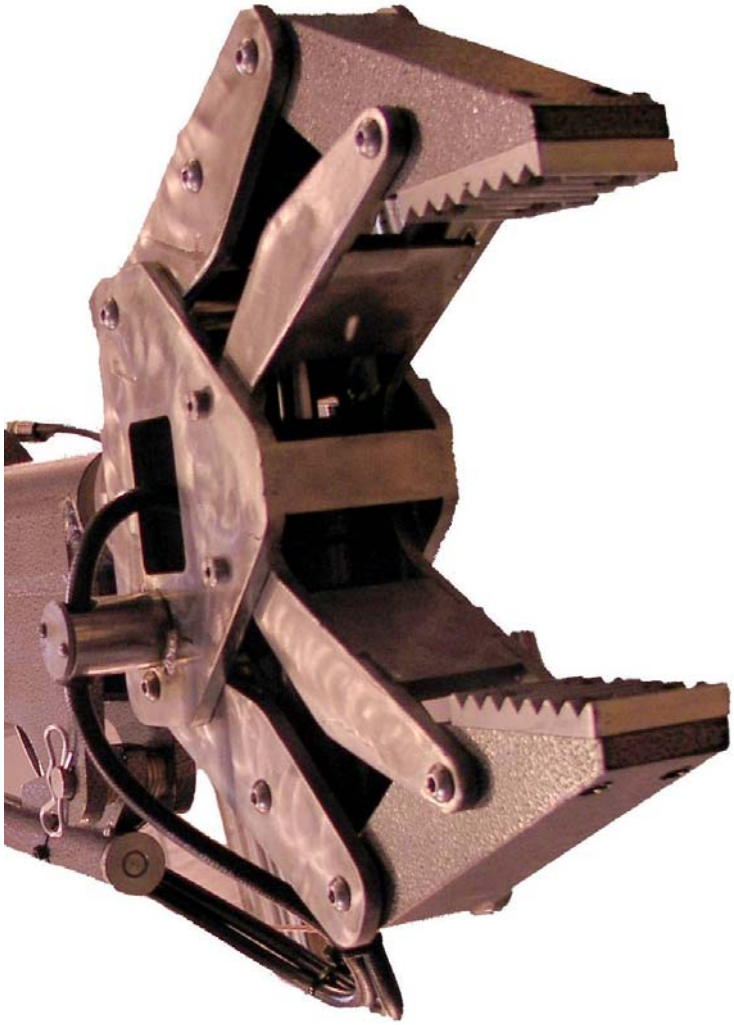


Increasing grip by
varying the direction of the normal forces …



Increasing grip by
varying the direction of the normal forces …

Grasping | Suction | Adhesion



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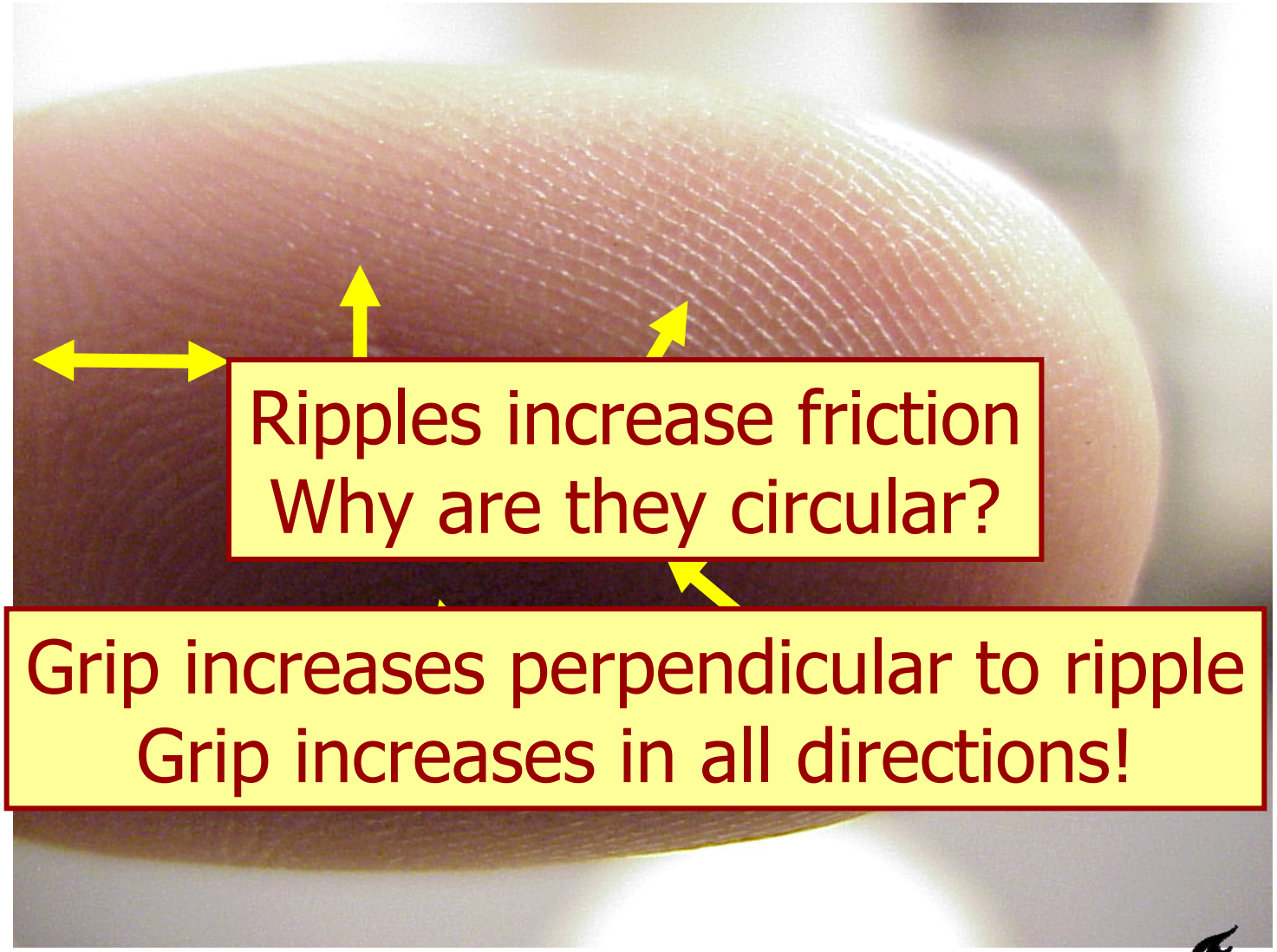
Grasping | Suction | Adhesion

Grasping | Suction | Adhesion



Grasping | Suction | Adhesion

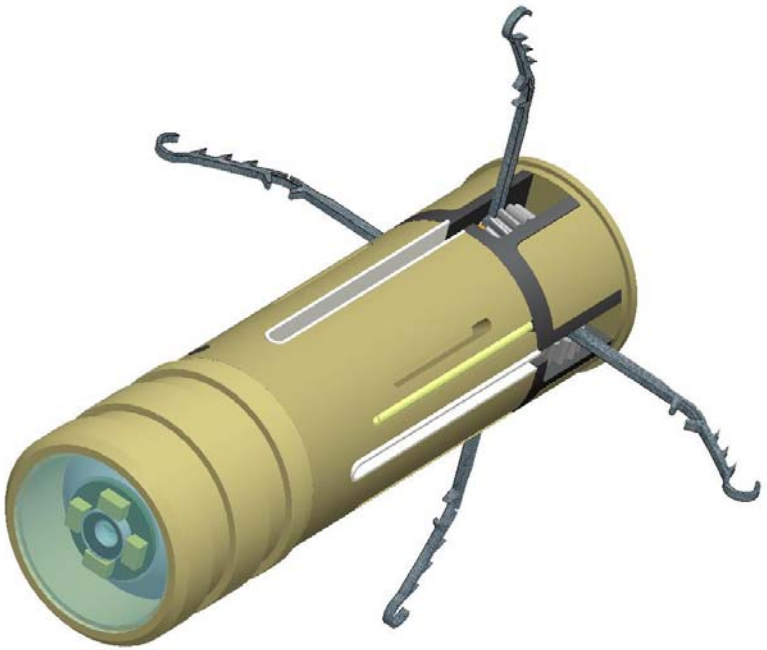
Grasping | Suction | Adhesion

Grasping | Suction | Adhesion

Friction not necessary to achieve grip! (normal forces ~parallel to pulling forces)

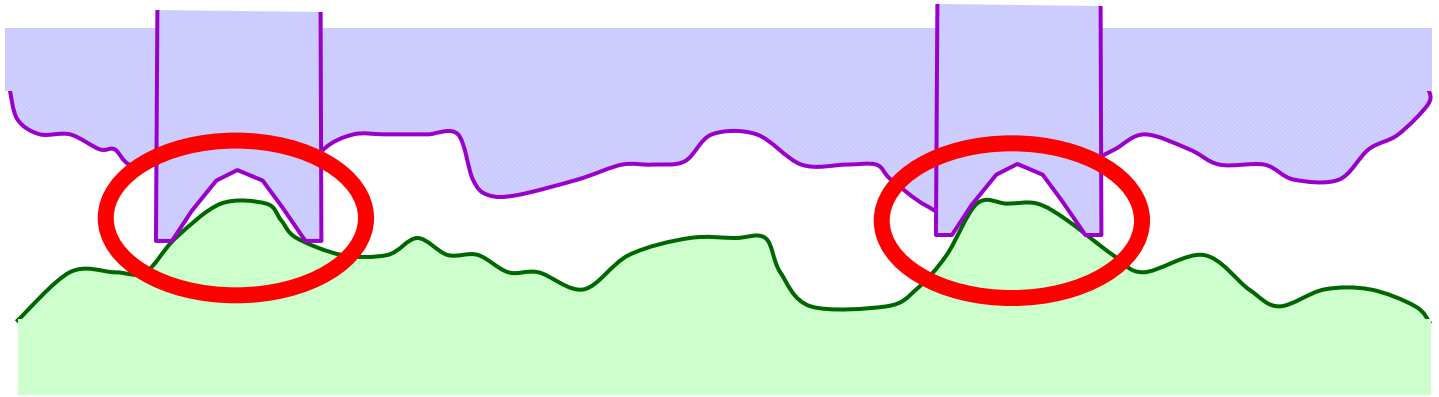
Grasping | Suction | Adhesion

Spikes



Intestine Inspection Device
Paolo Dario, Pisa

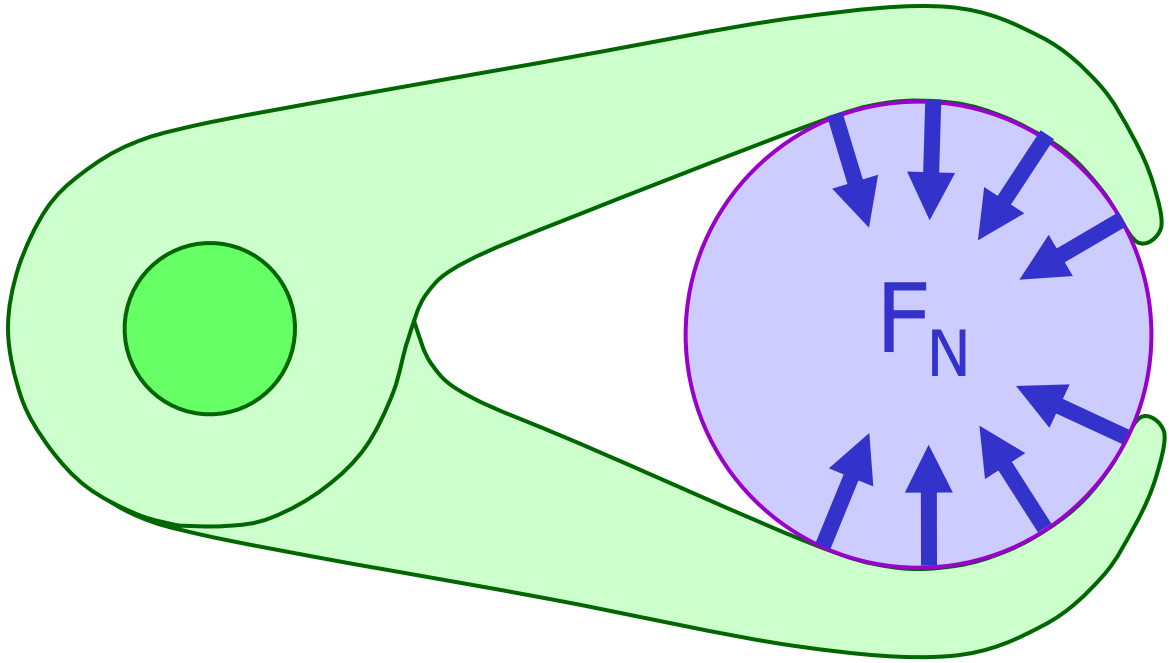
Grasping | Suction | Adhesion



Case 3: Shaping around an object

- Normal forces in direction you want
- Strong increase of grip
- Role of friction less and less

Grasping | Suction | Adhesion



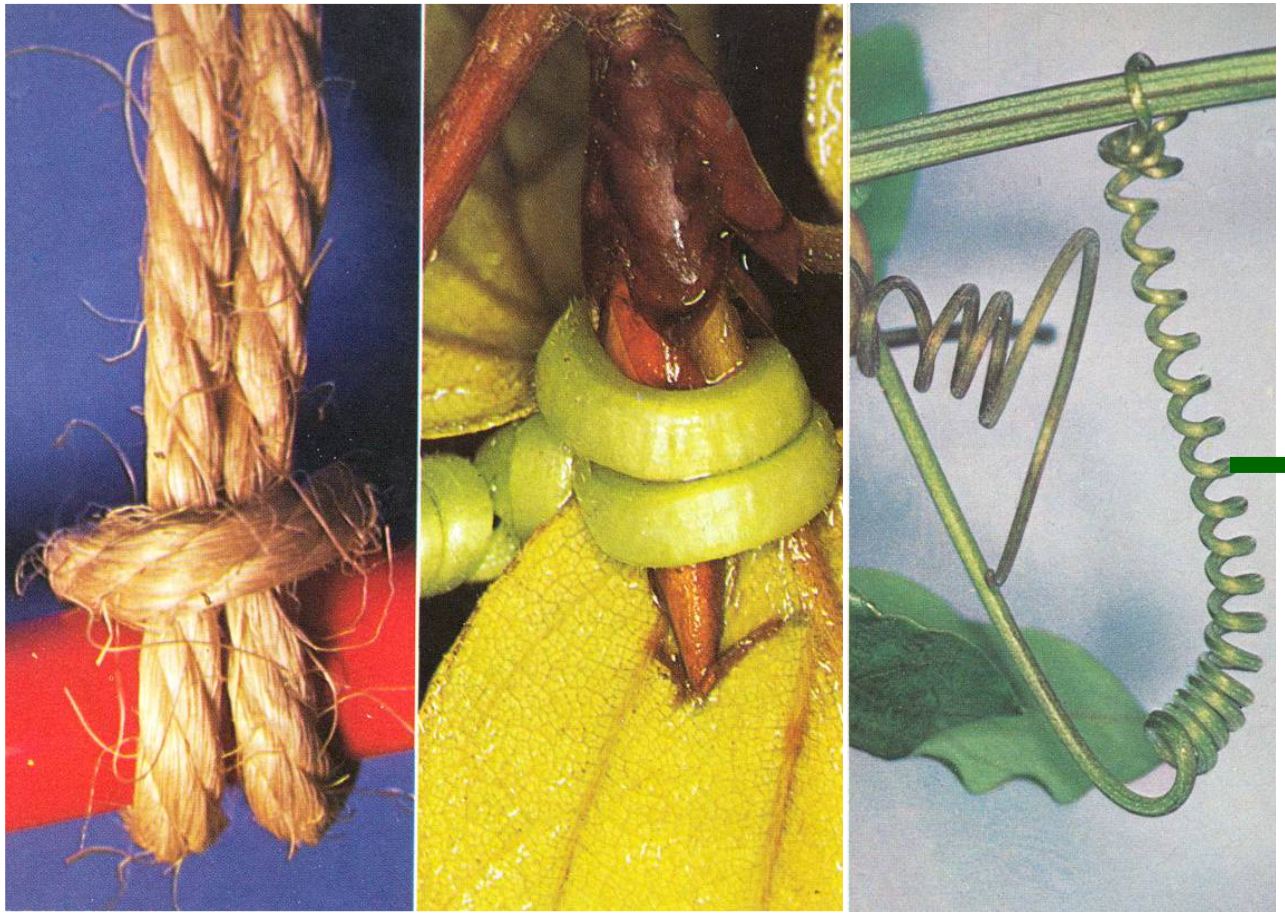
Increasing grip by
shaping around an object …

Grasping | Suction | Adhesion

Curved Forceps & Hooks

Grasping | Suction | Adhesion

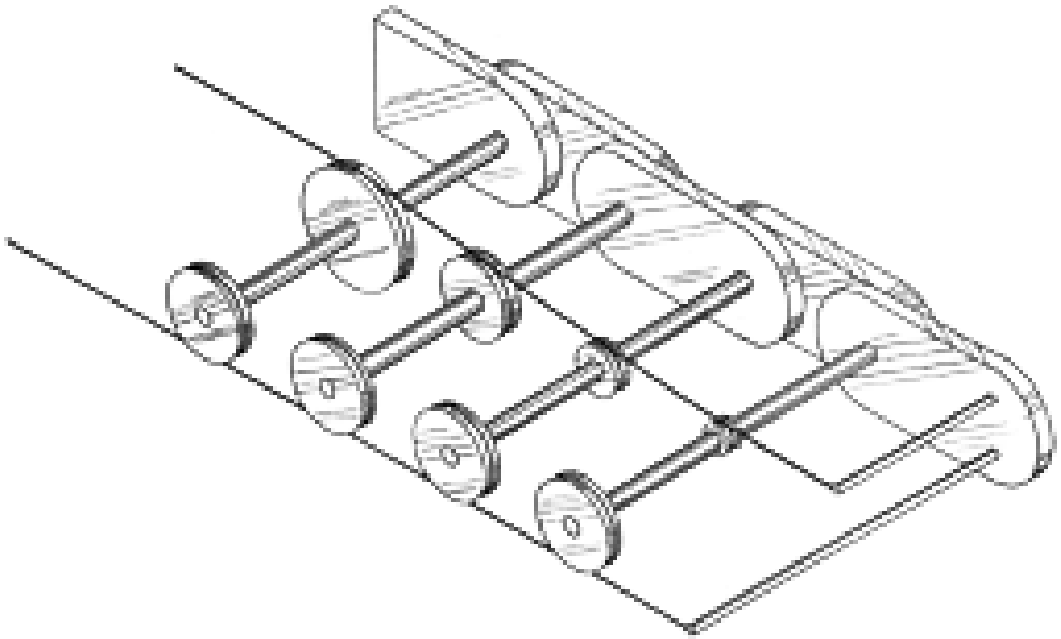
Grasping | Suction | Adhesion

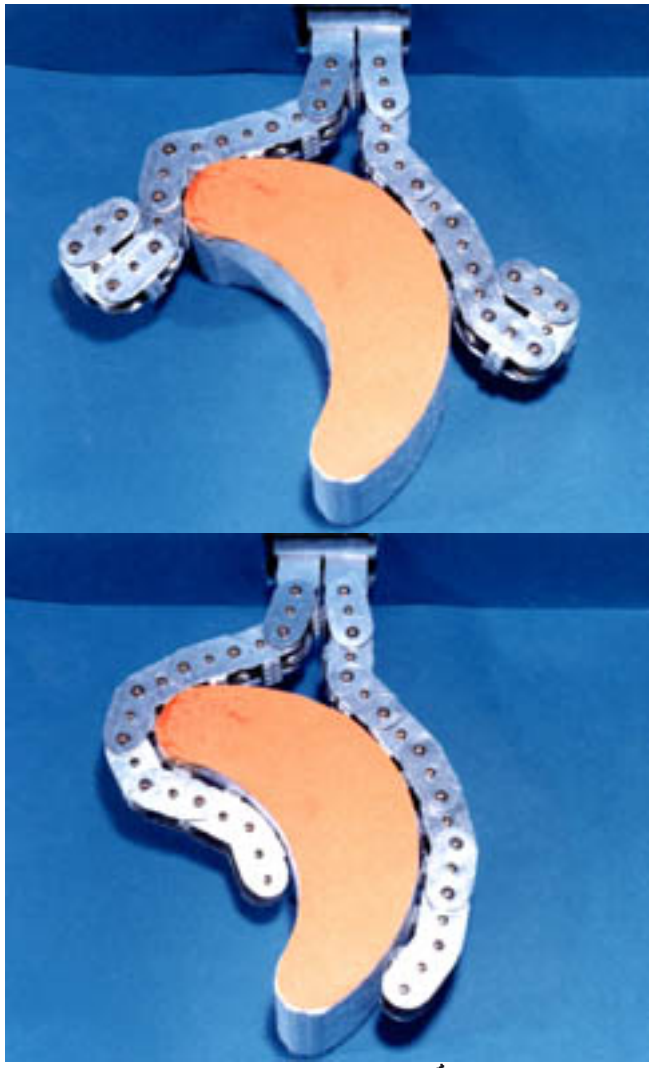


Biological Helical Tension Spring!

Knot

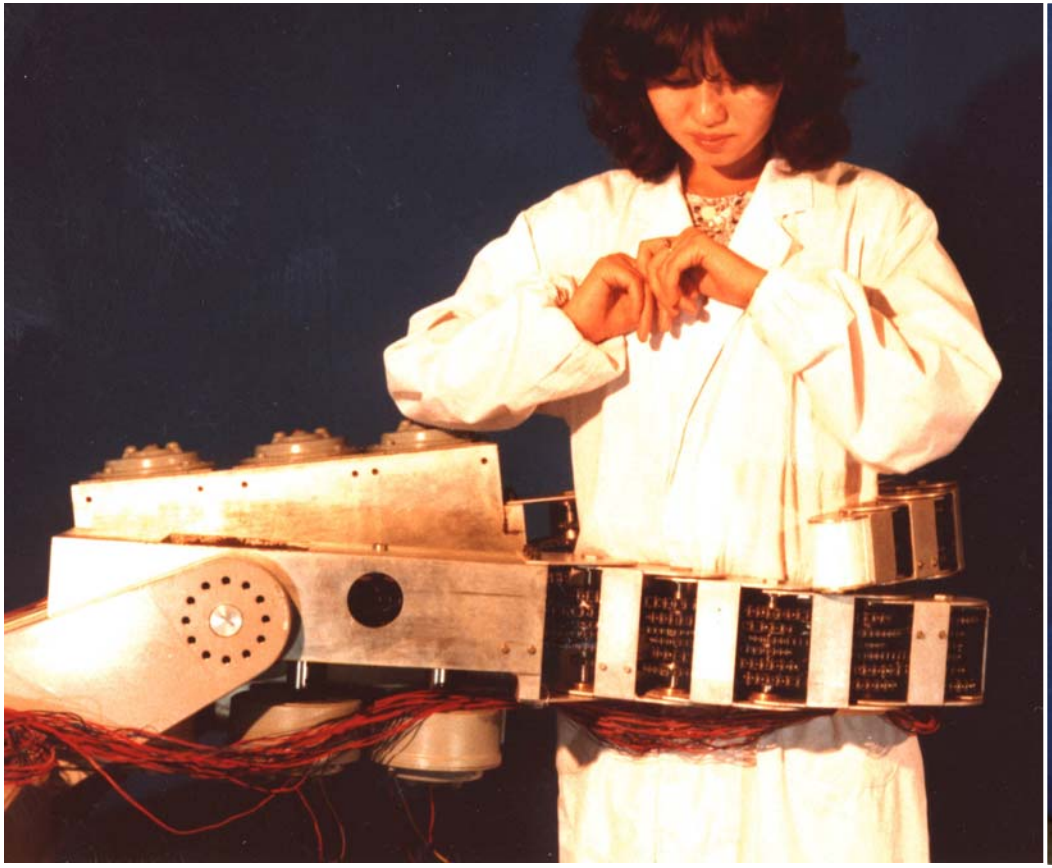
Grasping | Suction | Adhesion





Shape Gripper
Hirose & Fukushima lab.
Tokyo Institute of Technology

Grasping | Suction | Adhesion



Grasping | Suction | Adhesion

SARAH robothand
Robotics Laboratory, Laval University, Canada

Summary: How to increase grip when grasping?

Passive:

- By increasing the friction coefficient (rubber, etc.)
- By varying the direction of normal forces
  (teeth, ripples, spikes, etc.)
  Only in case of deformable contact surface(s)!

Active:

- By shaping around an object

Summary: How to increase grip when grasping?

Passive:

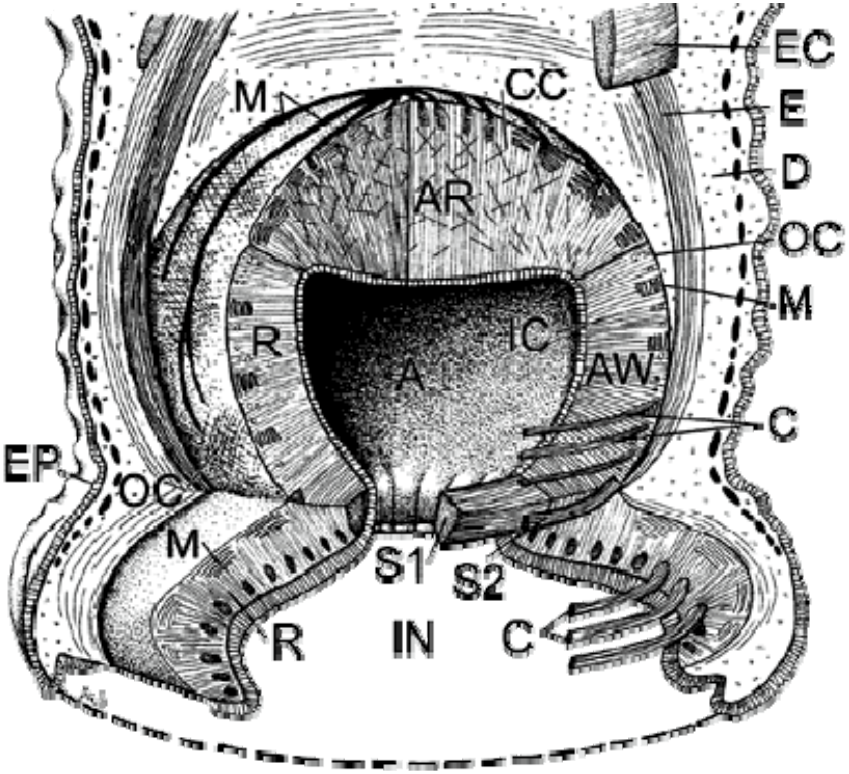
- By increasing the friction coefficient (rubber, etc.)
- By varying the direction of normal forces
  (teeth, ripples, spikes, etc.)
  Only in case of flexible contact surface(s)!

Active:

- By shaping around an object

*Friction can in these case be **zero** while still having sufficient grip*

Grasping | Suction | Adhesion



Sucking Cup

Grasping | Suction | Adhesion

Why many small suckers instead of a few big ones?

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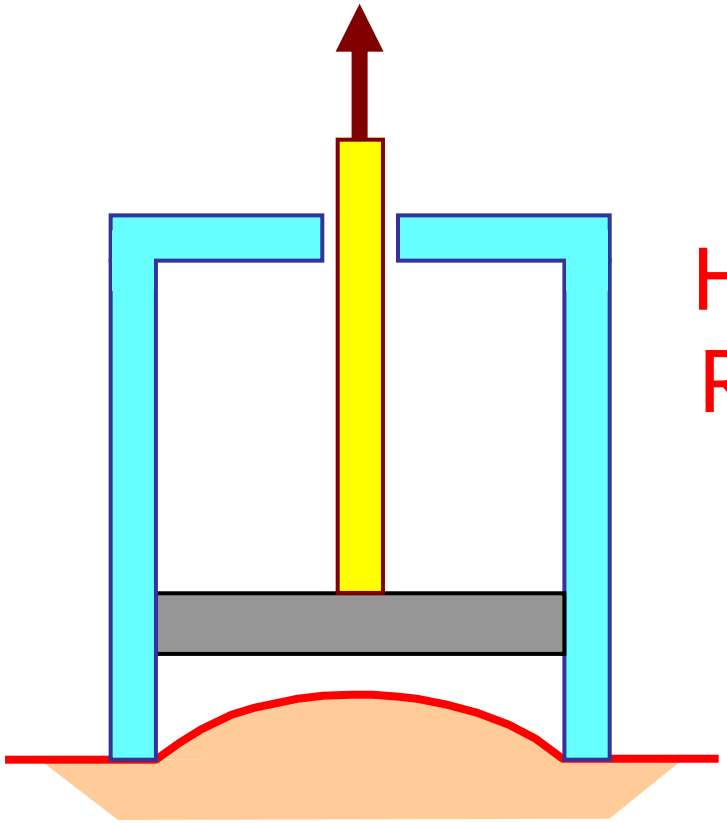
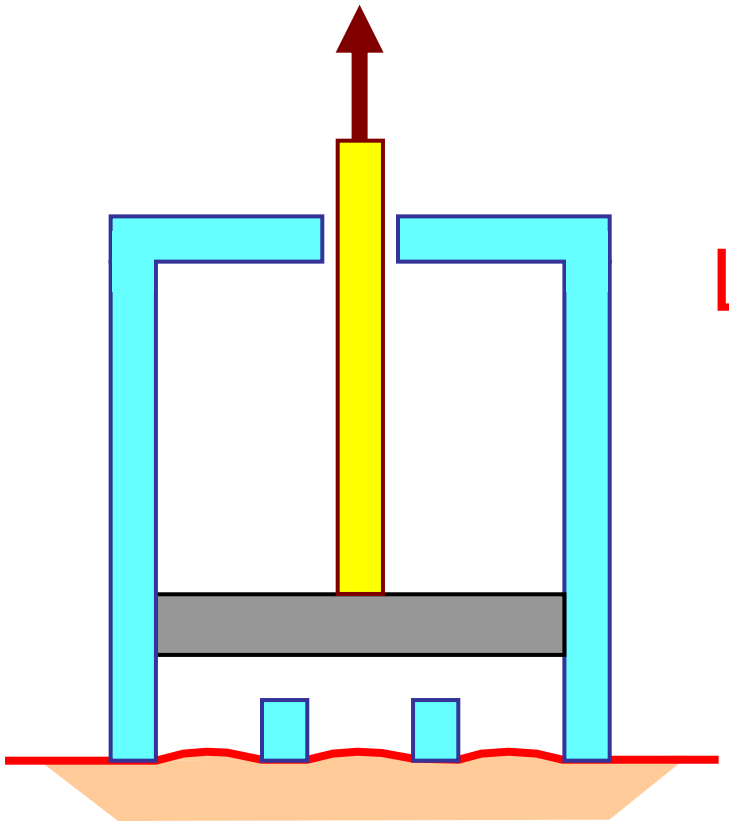
Grasping | Suction | Adhesion



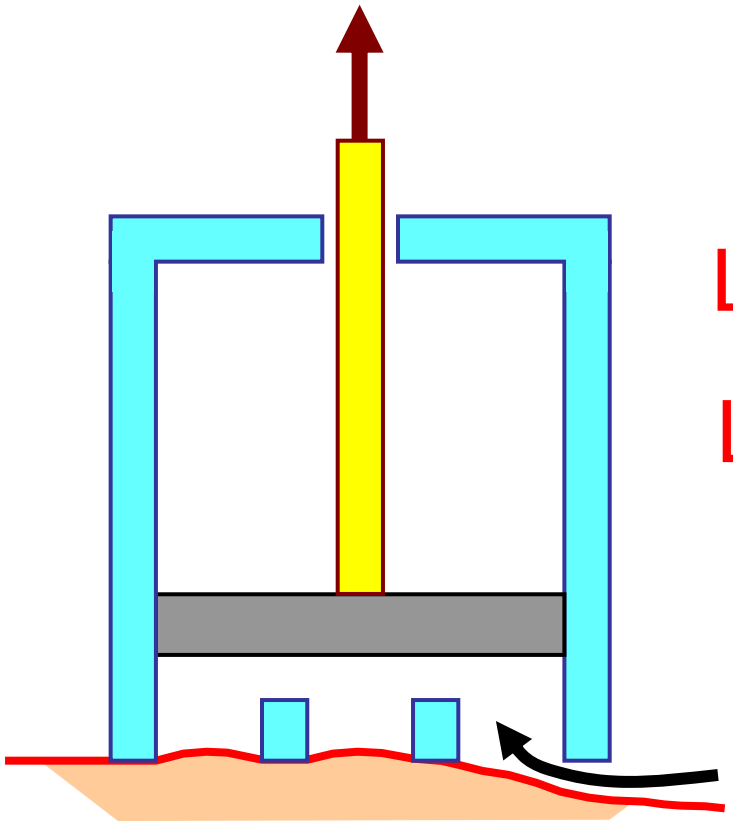
High stresses in tissue
Risk of tissue damage
& losing grip

Grasping | Suction | Adhesion



Low stresses in tissue

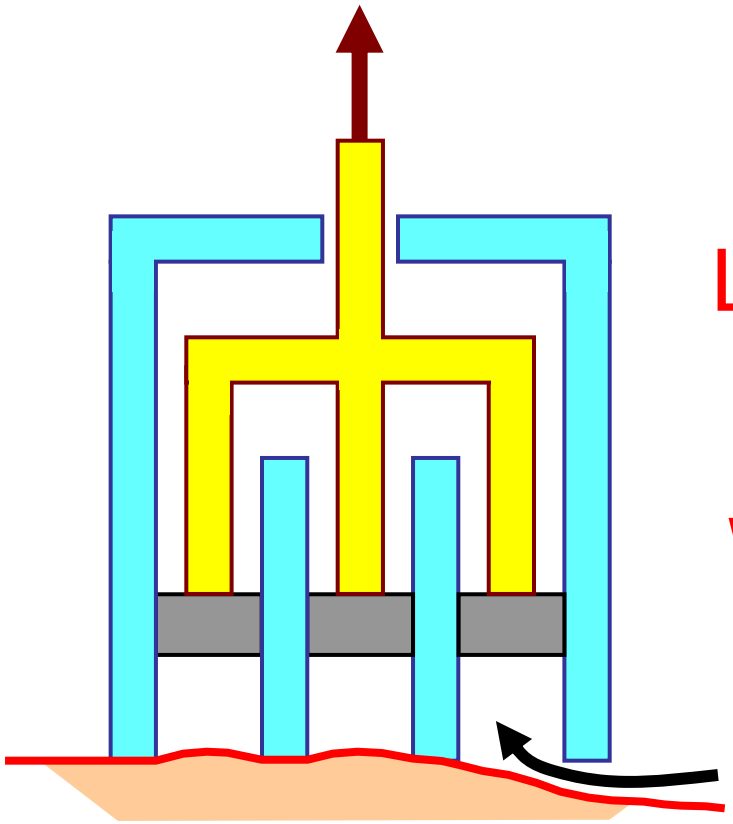
Grasping | Suction | Adhesion



Low stresses in tissue

Leakage stops suction

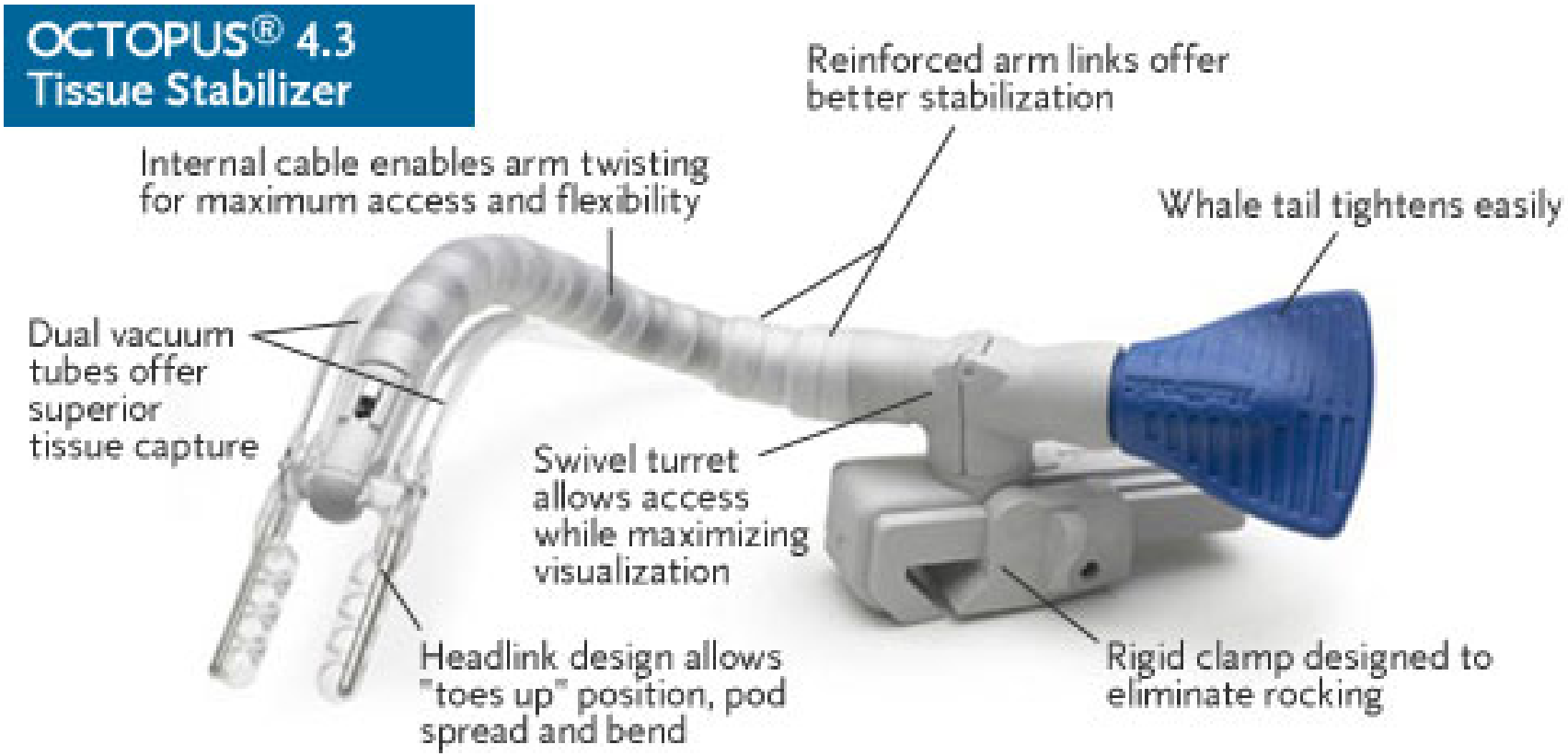
Grasping | Suction | Adhesion



Low stresses in tissue

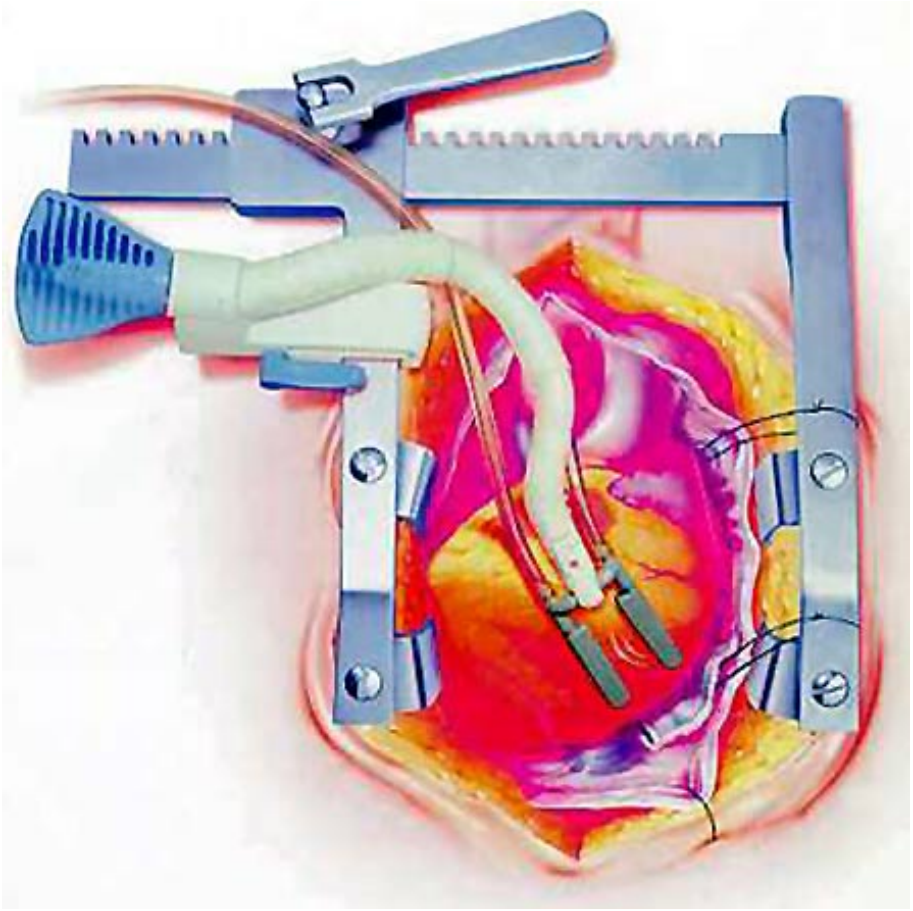
Suction continues with multiple suckers

Grasping | Suction | Adhesion



Octopus heart stabilizer for bypass surgery

Grasping | Suction | Adhesion



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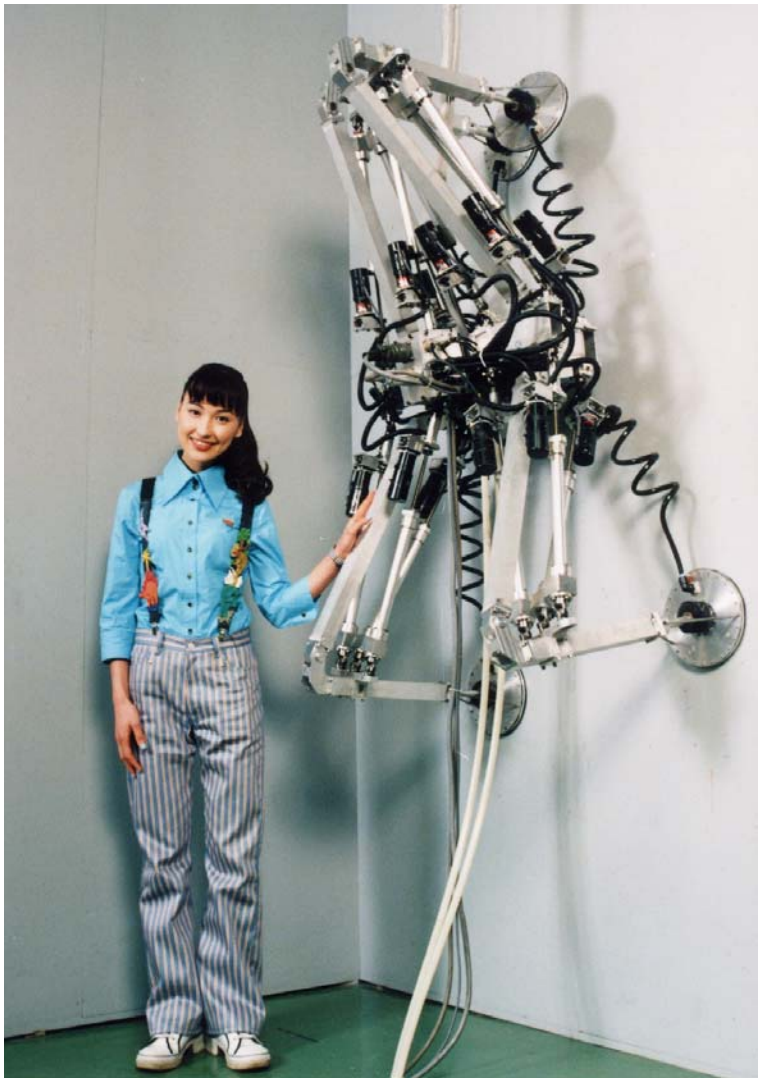

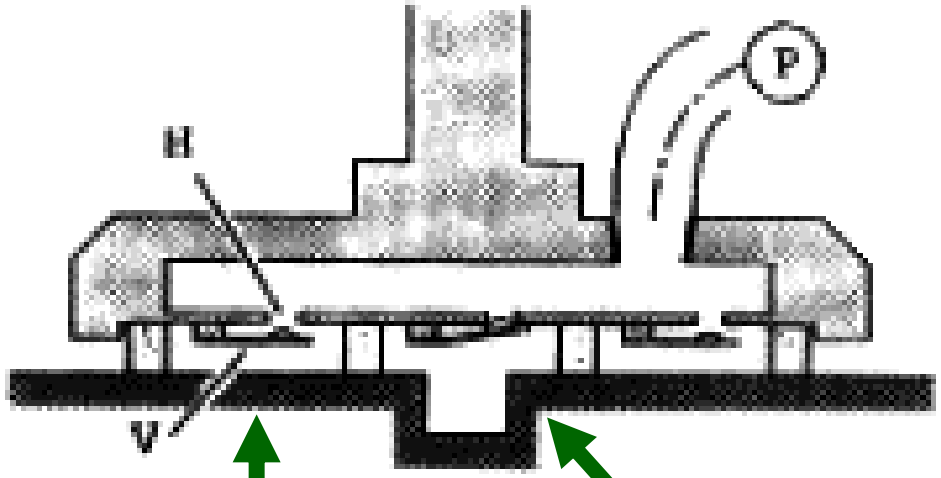

no air flow
valve open

air flow
valve closed

Wall-climbing robot
Shigeo Hirose, Tokyo

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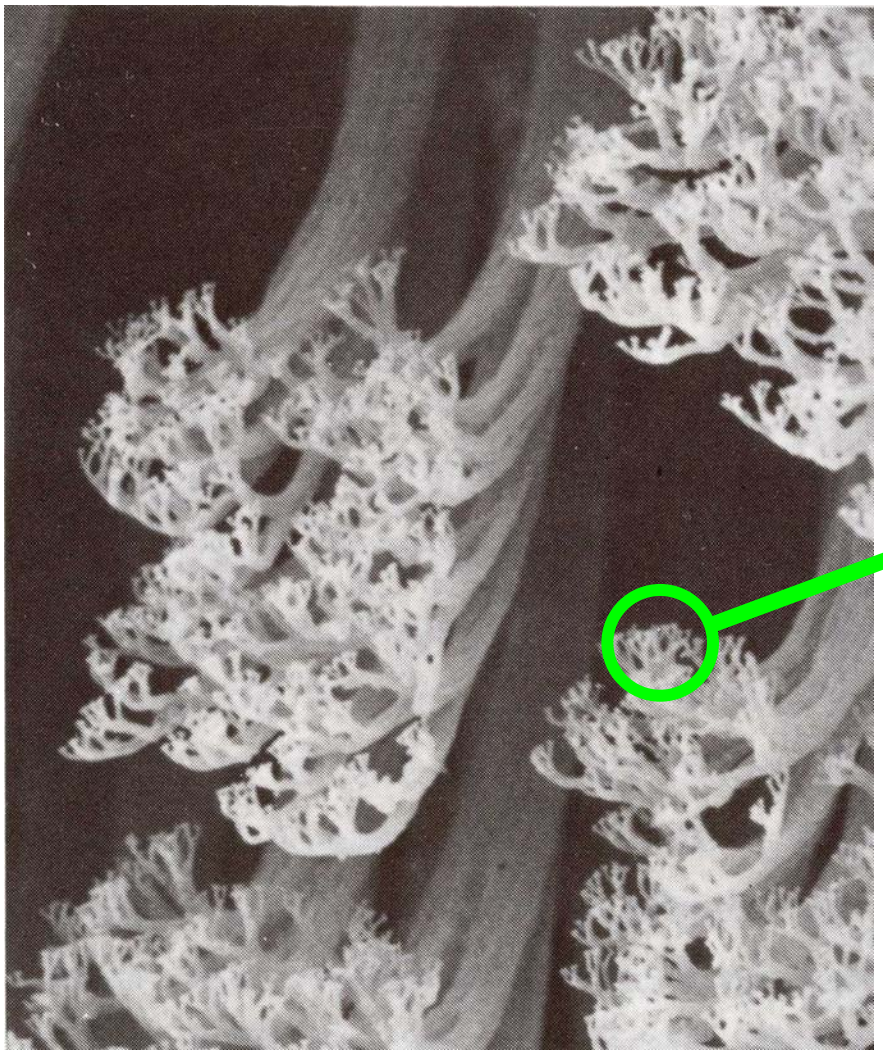
Grasping | Suction | Adhesion

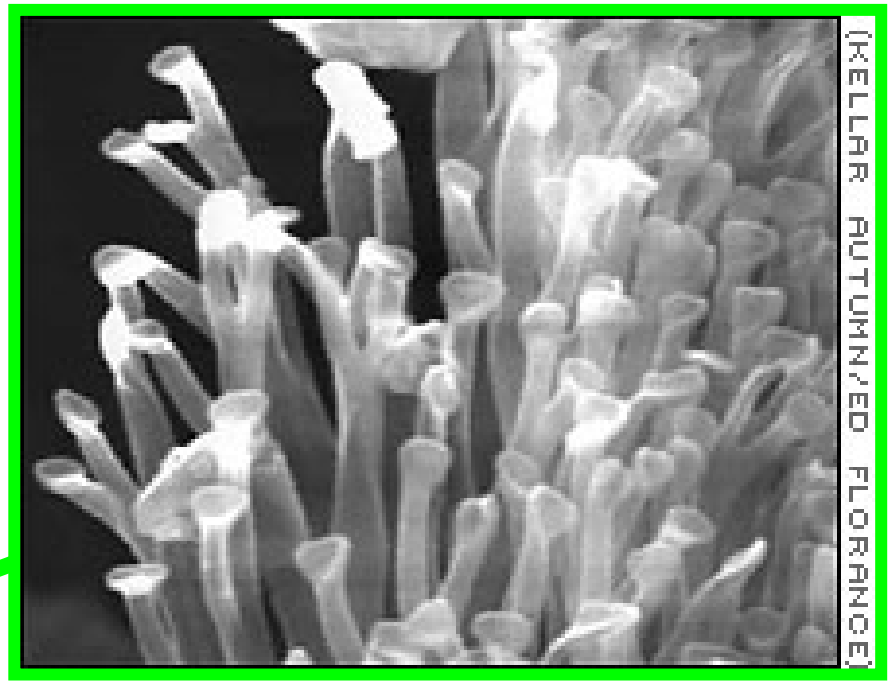
Dry adhesion (Gecko)

Grasping | Suction | Adhesion

Dry adhesion
(Gecko)

Grasping | Suction | Adhesion





Gecko Setae

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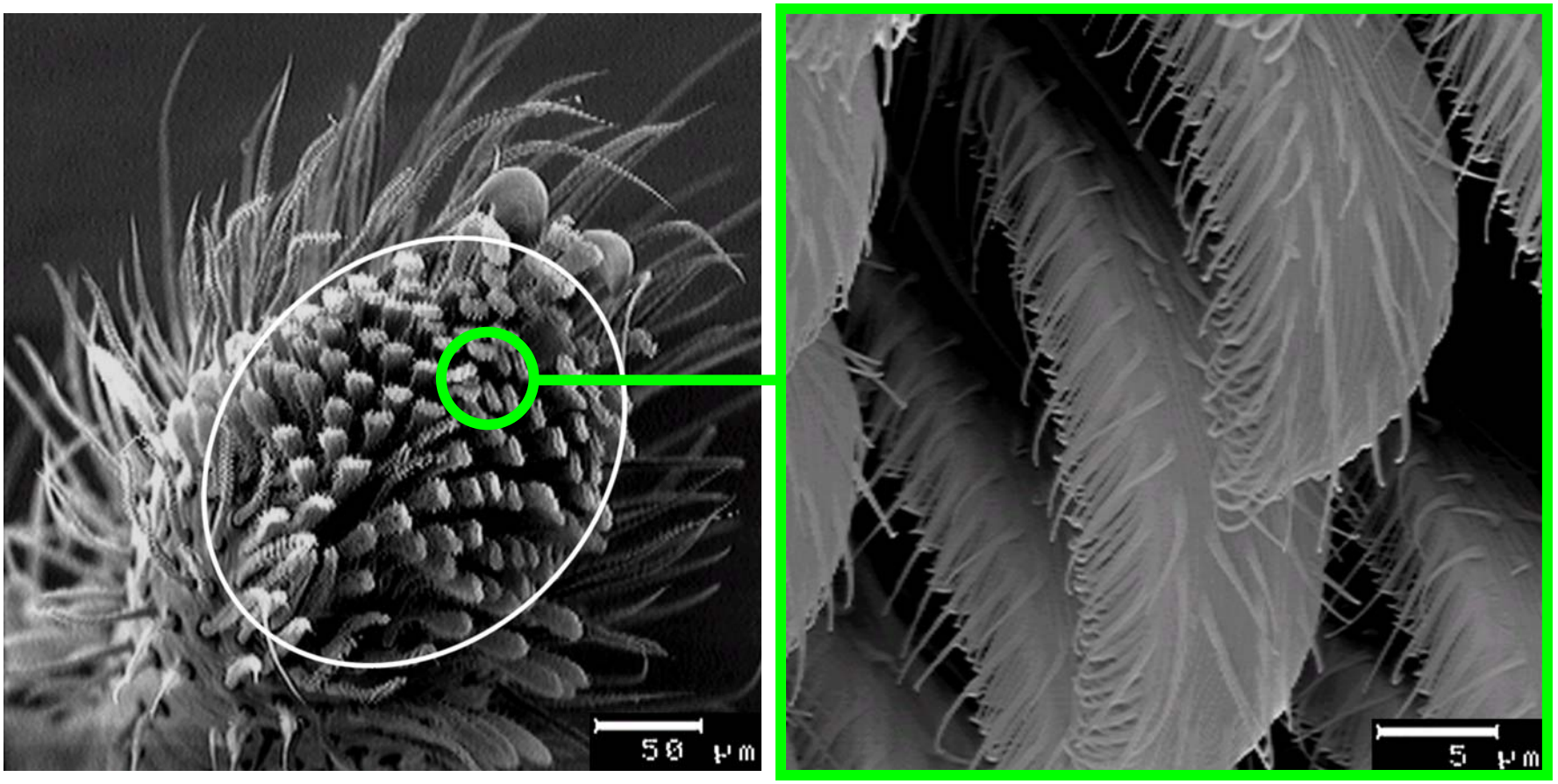
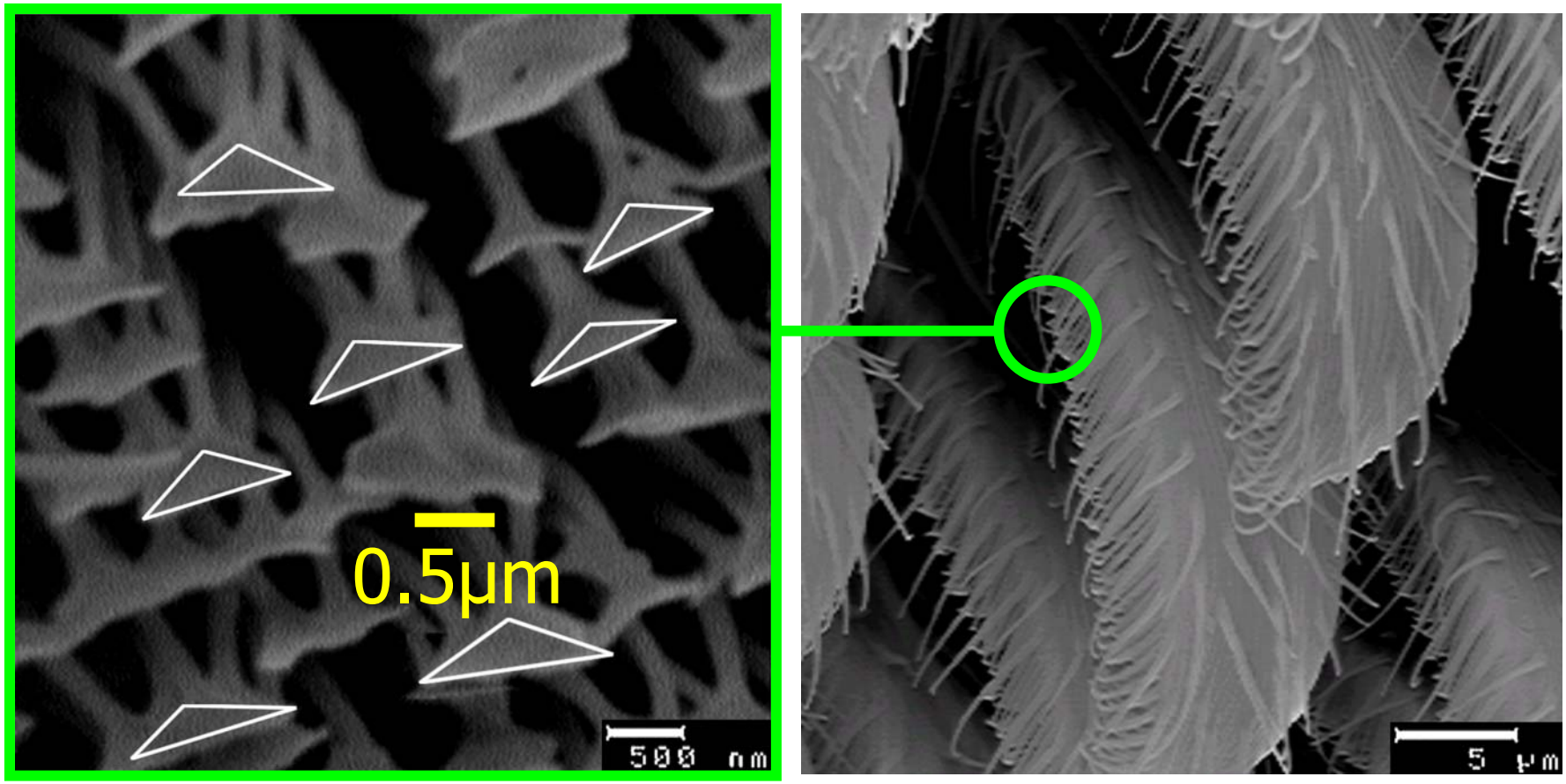
Grasping | Suction | Adhesion



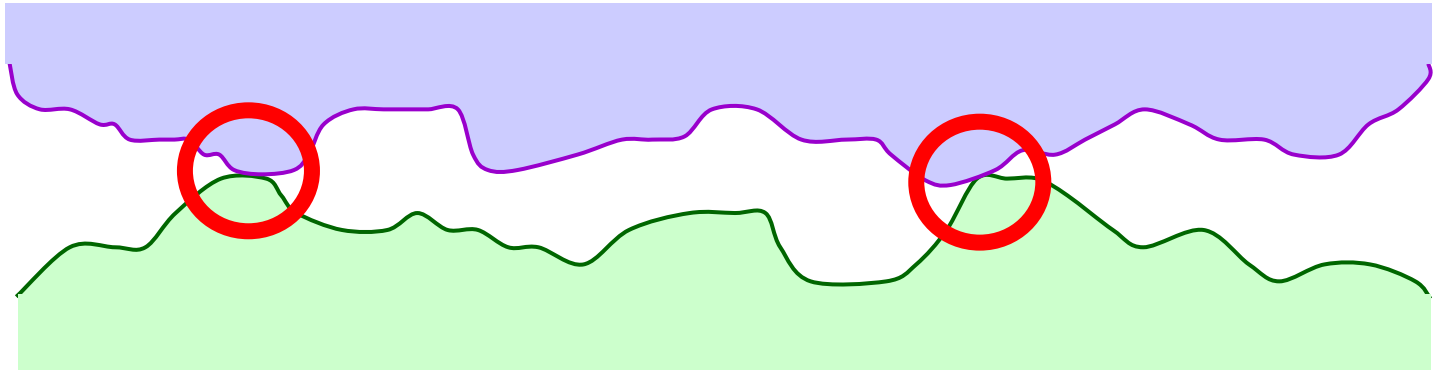
Spider Setae

Grasping | Suction | Adhesion

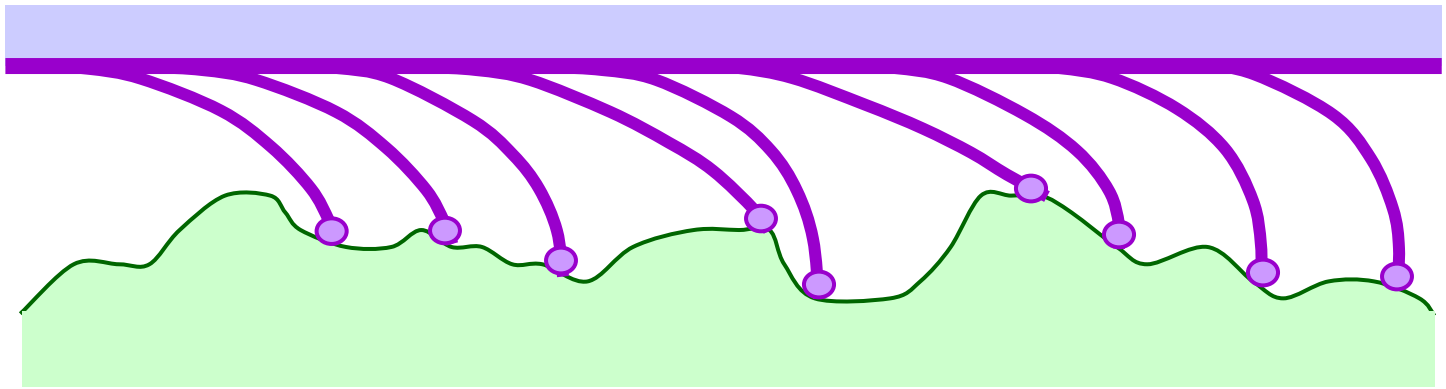


Spider Setae

2 rigid objects:
Only few contact points
Friction independent of contact area



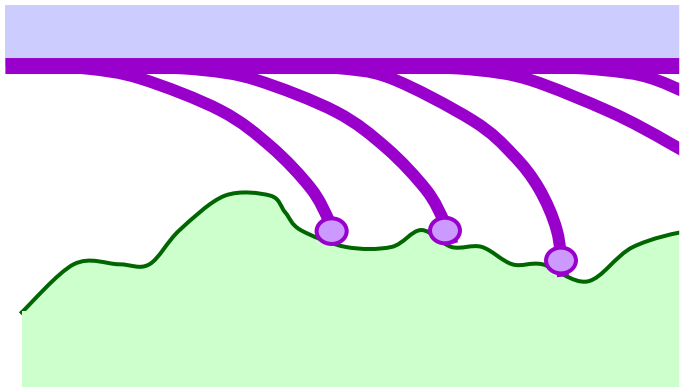
1 (or 2) very flexible objects:
Large number of contact points
Friction strongly depending on contact area



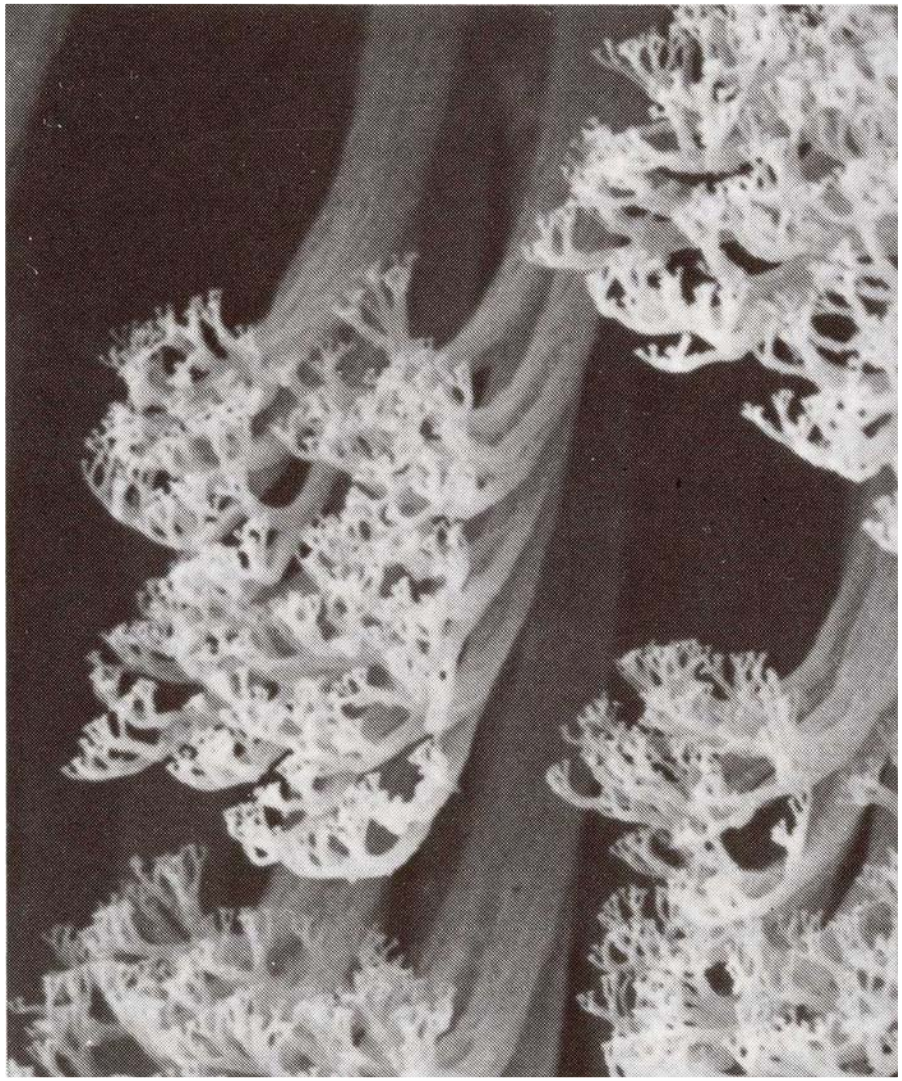
Setae behave like flexible leaf springs
Pads are pushed against the surface
Molecular contact → van der Waals forces

Grasping | Suction | Adhesion

1 (or 2) very
Large number
Friction strongly dep

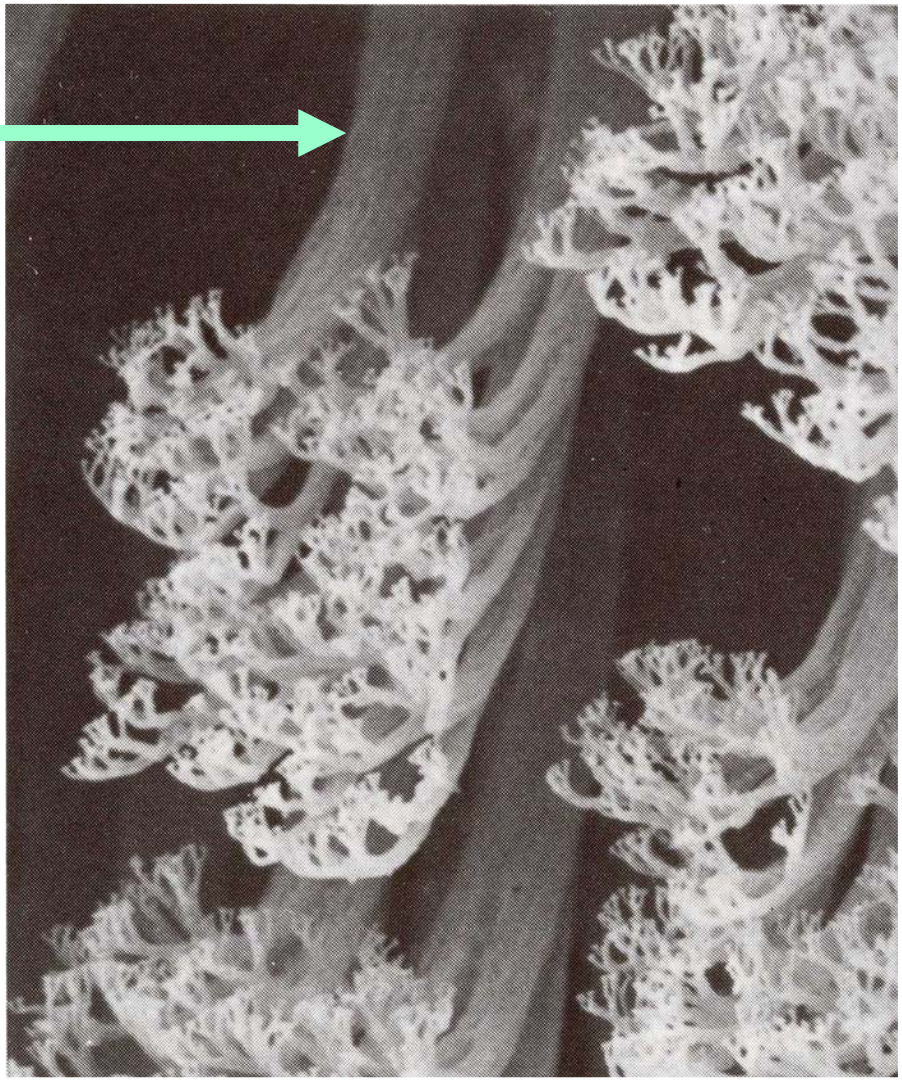


Setae behave like
Pads are pushed
Molecular contact –



Grasping | Suction | Adhesion

Thick supporting "leaf springs" for larger adaptability at more strength

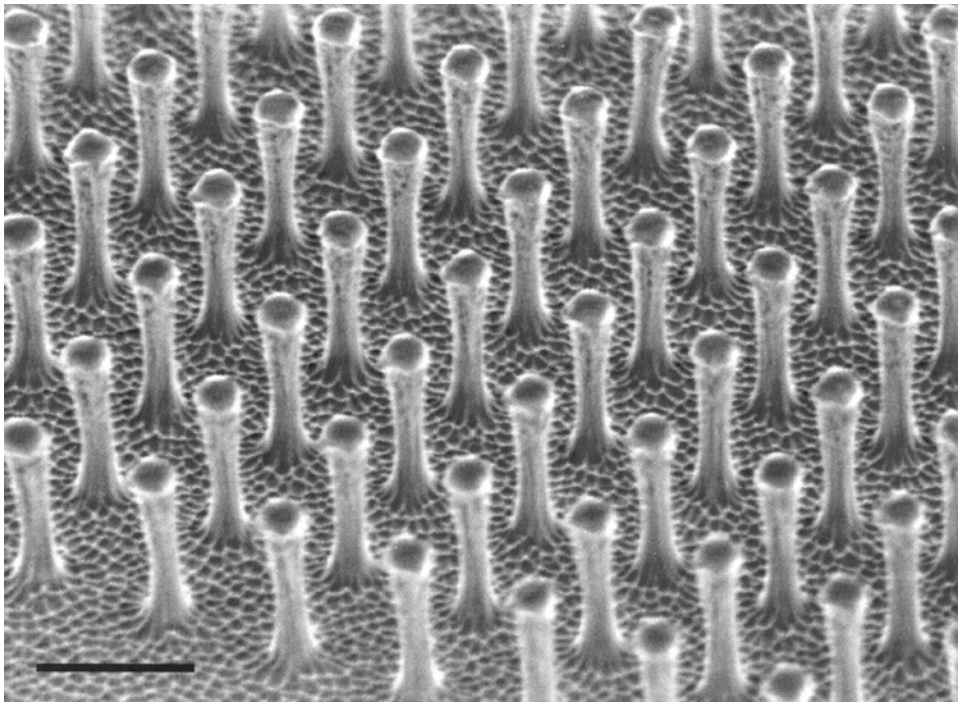


Grasping | Suction | Adhesion

Multiple leaf spring construction in wiper blade (ruitenwisser)

Grasping | Suction | Adhesion

Grasping | Suction | Adhesion



2µm

Artificial Setae
Dry tape?

StickyBot

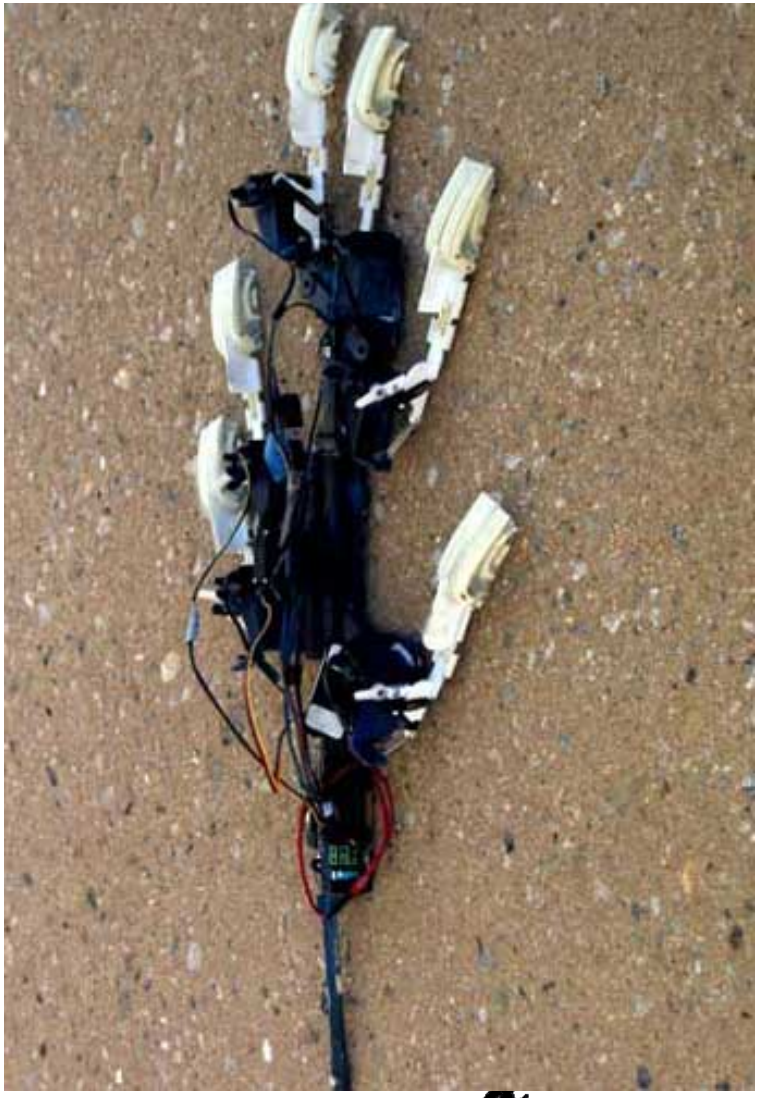
Stanford University
Biomimetics & Dexterous
Manipulation Laboratory

Gecko-like
Glass climbing robot

- No setae, no v/d Waals
- Toes covered with flexible, flat, sticky surface

SpinyBot

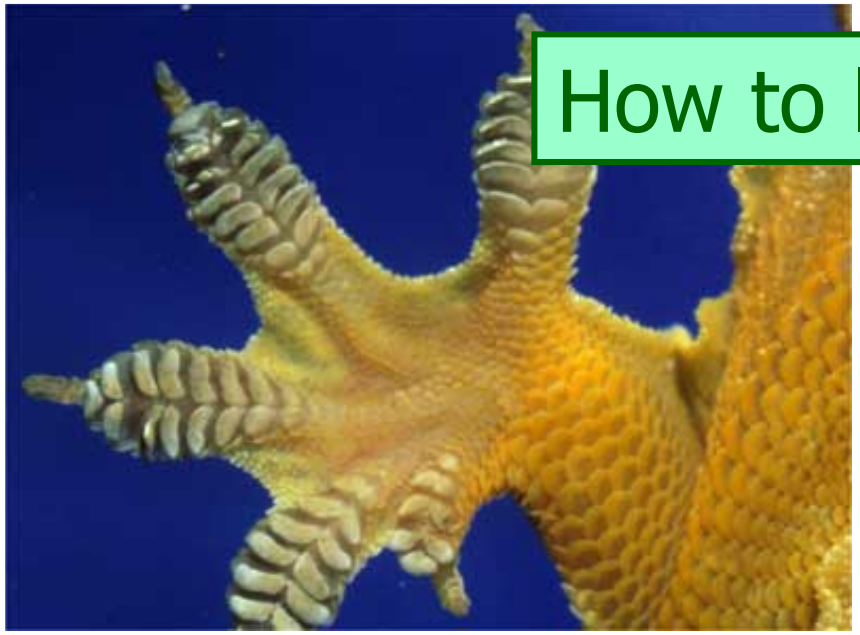
Stanford University
Biomimetics & Dexterous
Manipulation Laboratory



Gecko-like
Concrete climbing robot

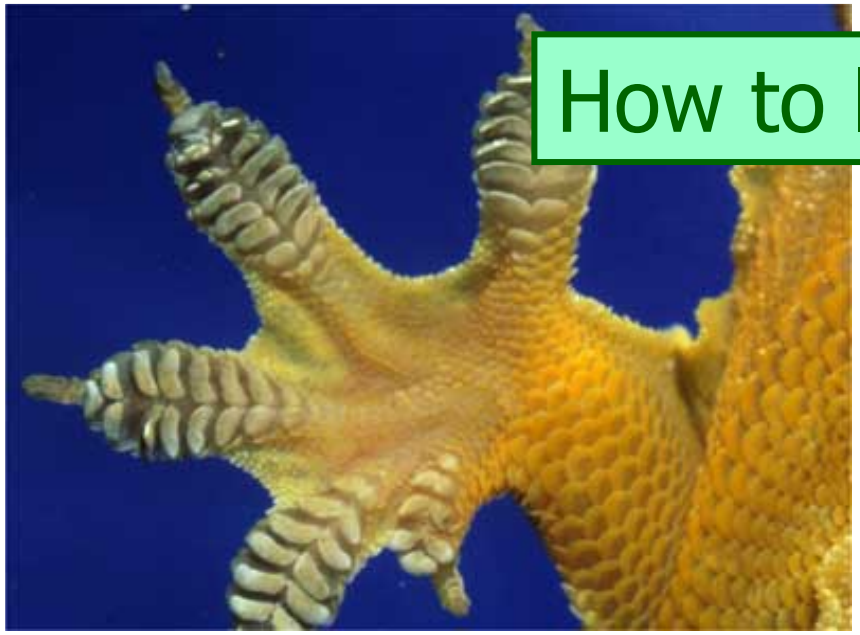
- No setae, no v/d Waals
- Toes covered with many leaf-springs ending in sharp curved hooks

Grasping | Suction | Adhesion



How to lift a foot that sticks?

Grasping | Suction | Adhesion



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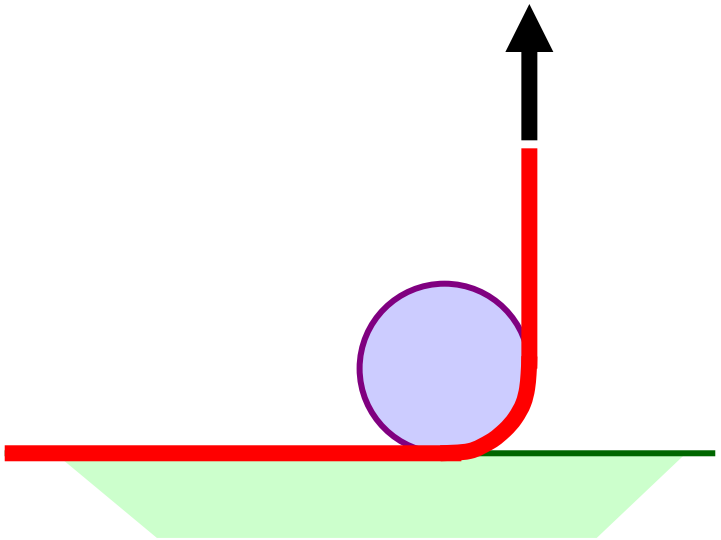

Unrolling!

Lifting the 2-D surface impossible

Lifting the 1-D borderline easy

Grasping | Suction | Adhesion