# 动植物的“取水有术”

## -------特殊浸润性界面上的流体输运过程

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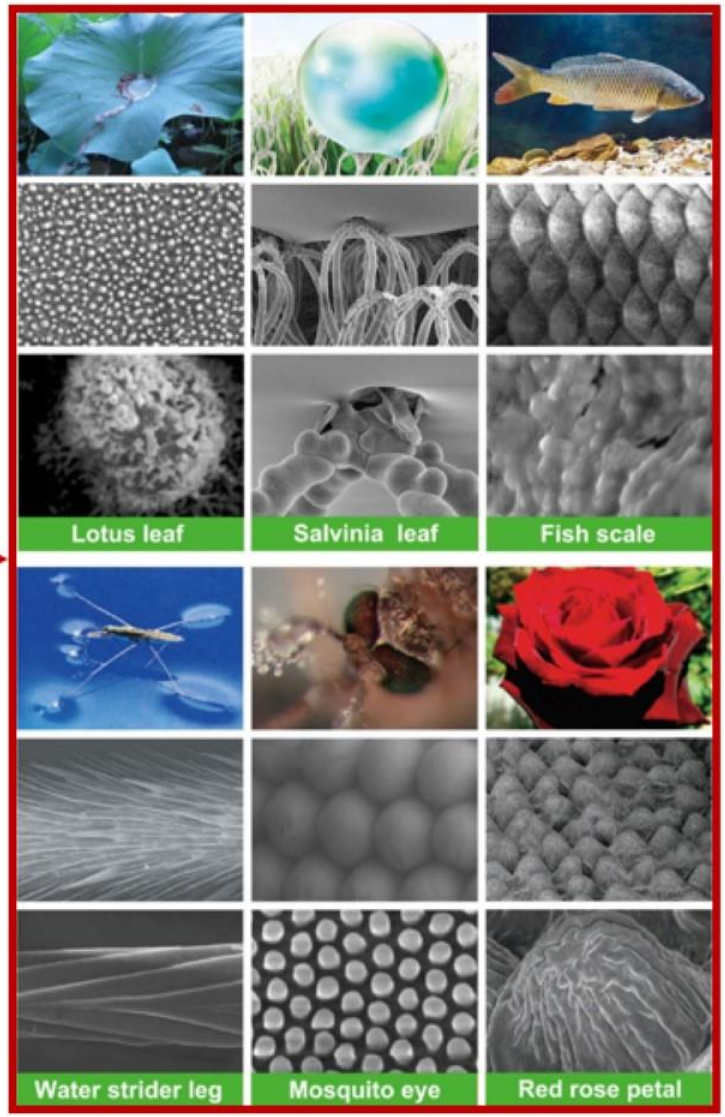
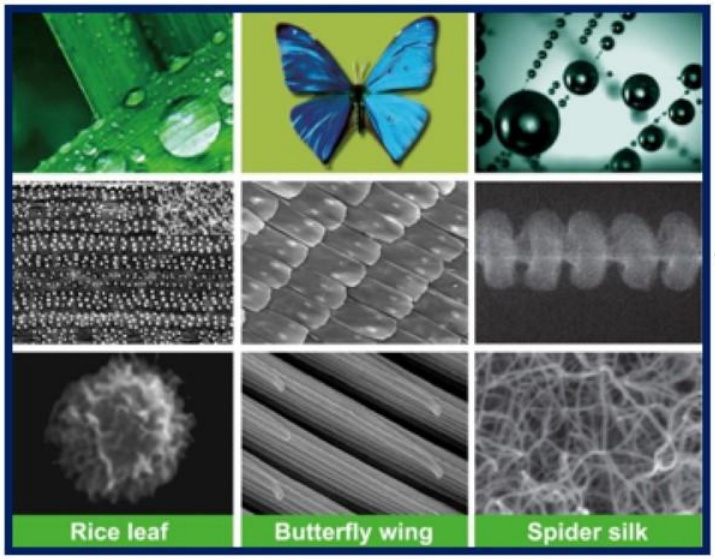
2019-4-26

# 仿生构筑功能材料：大自然的鬼斧神工

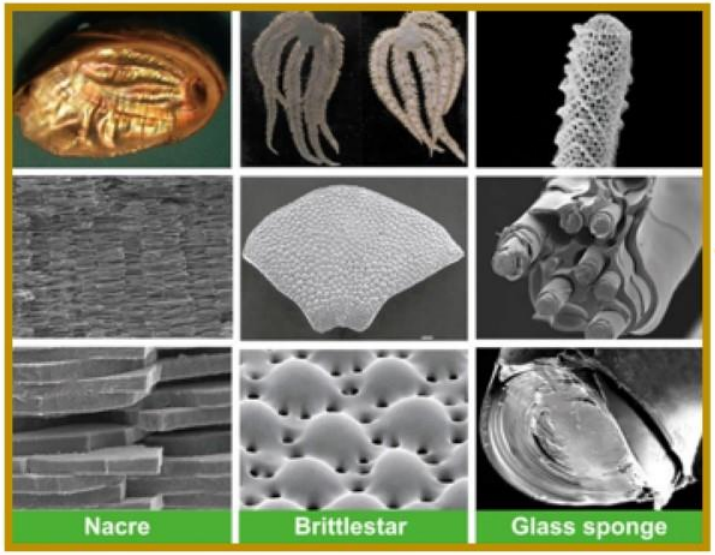
超浸润性功能界面




各向异性功能界面



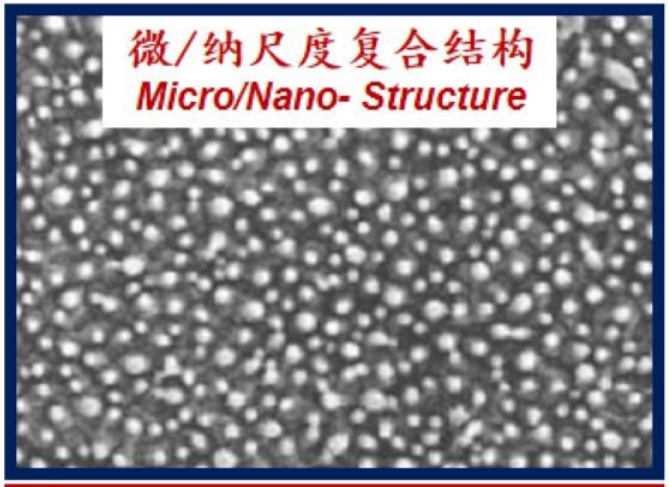

其他功能材料

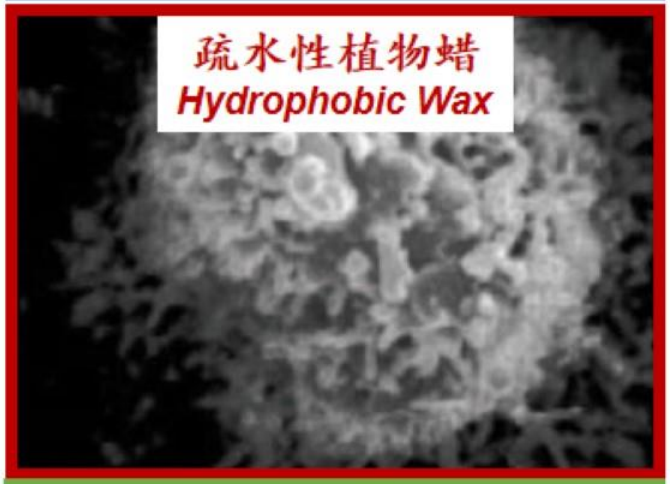



*Nano Today, 2011, 6, 155*

# 引言

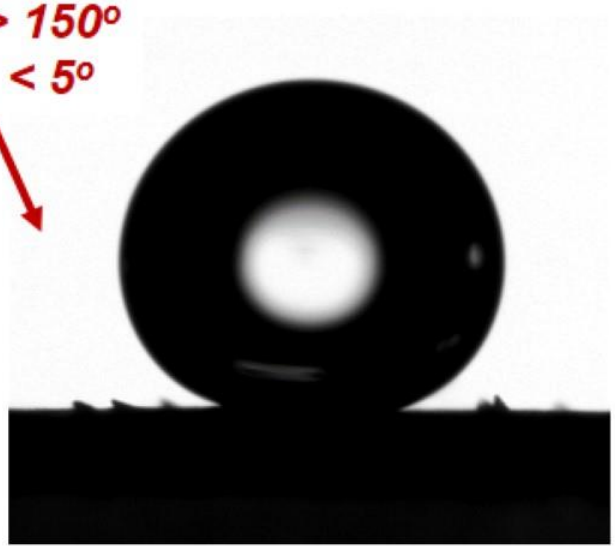
## 超疏水材料的杰出代表——荷叶




Lotus Leaf

水滴接触角 > 150°
水滴滚动角 < 5°



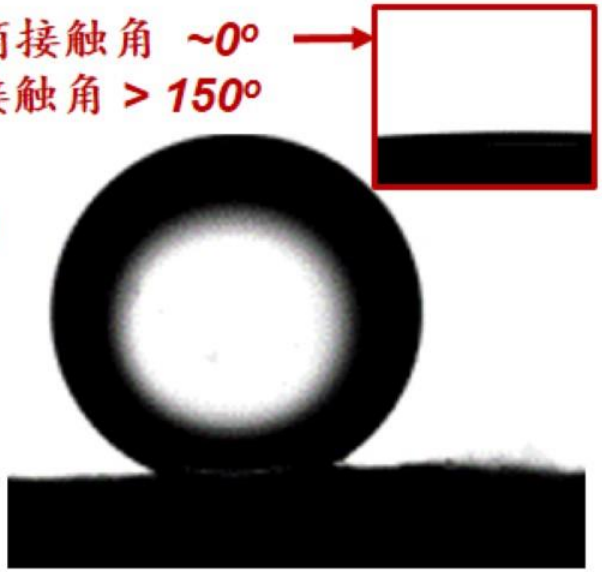
出淤泥而不染，濯清涟而不妖

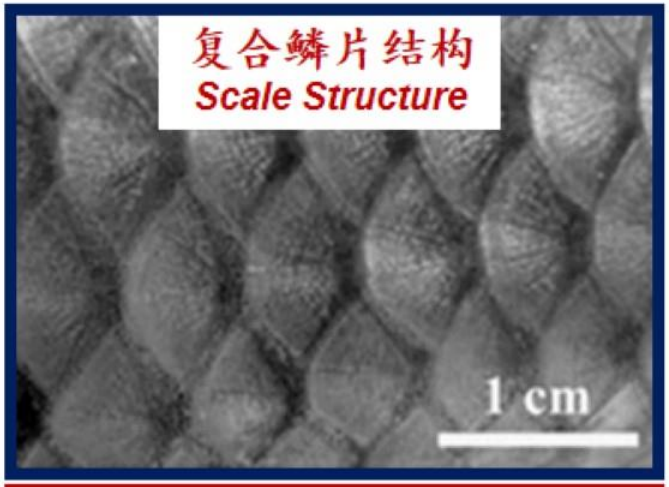
*Advanced Materials, 2002, 14, 1857.*

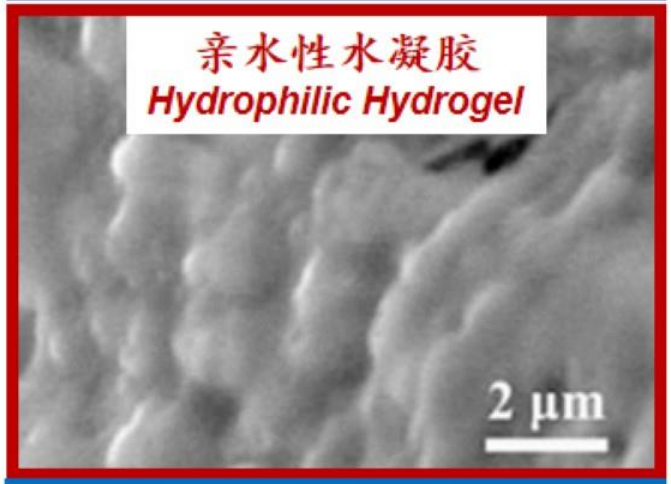
# 引言

## 超亲水材料的杰出代表——鱼鳞片

空气中水滴接触角 ~0°
水下油滴接触角 > 150°





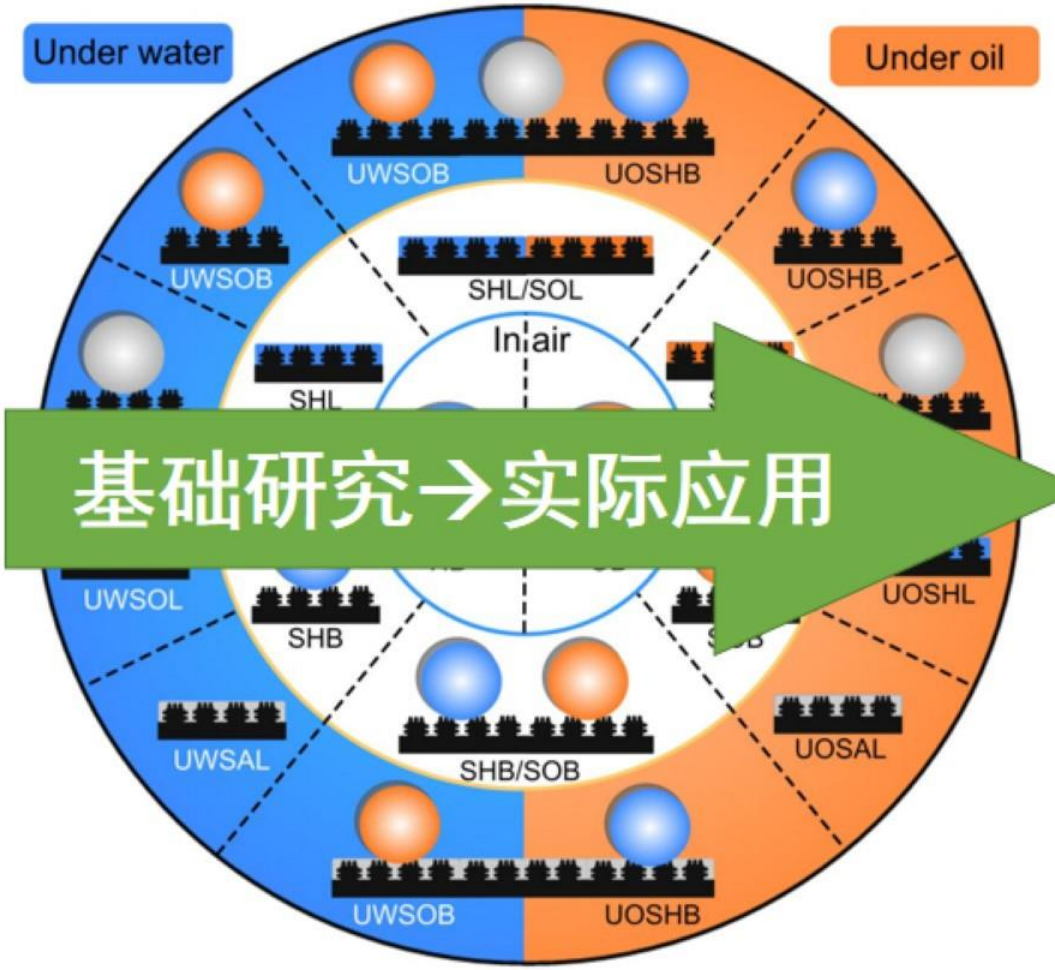

**Fish Scale**

*Advanced Materials, 2009, 21, 665*

# 引言

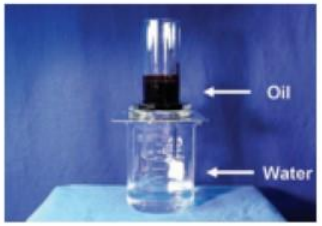
## 超浸润性界面系统总览

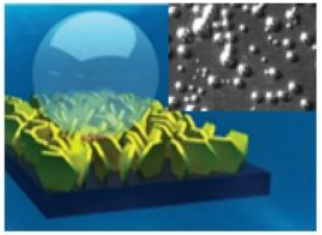
自然揭秘




基础研究→实际应用

实际应用



固/液/气
各向同性
2维平面

拓展 →

固/水/油/气
单/双向各向异性
1维孔道/3维结构

*Advanced Materials, 2014, 26, 6872*
*Advanced Materials, 2014, 26, 2683*
*Advanced Materials, 2011, 23, 4270*

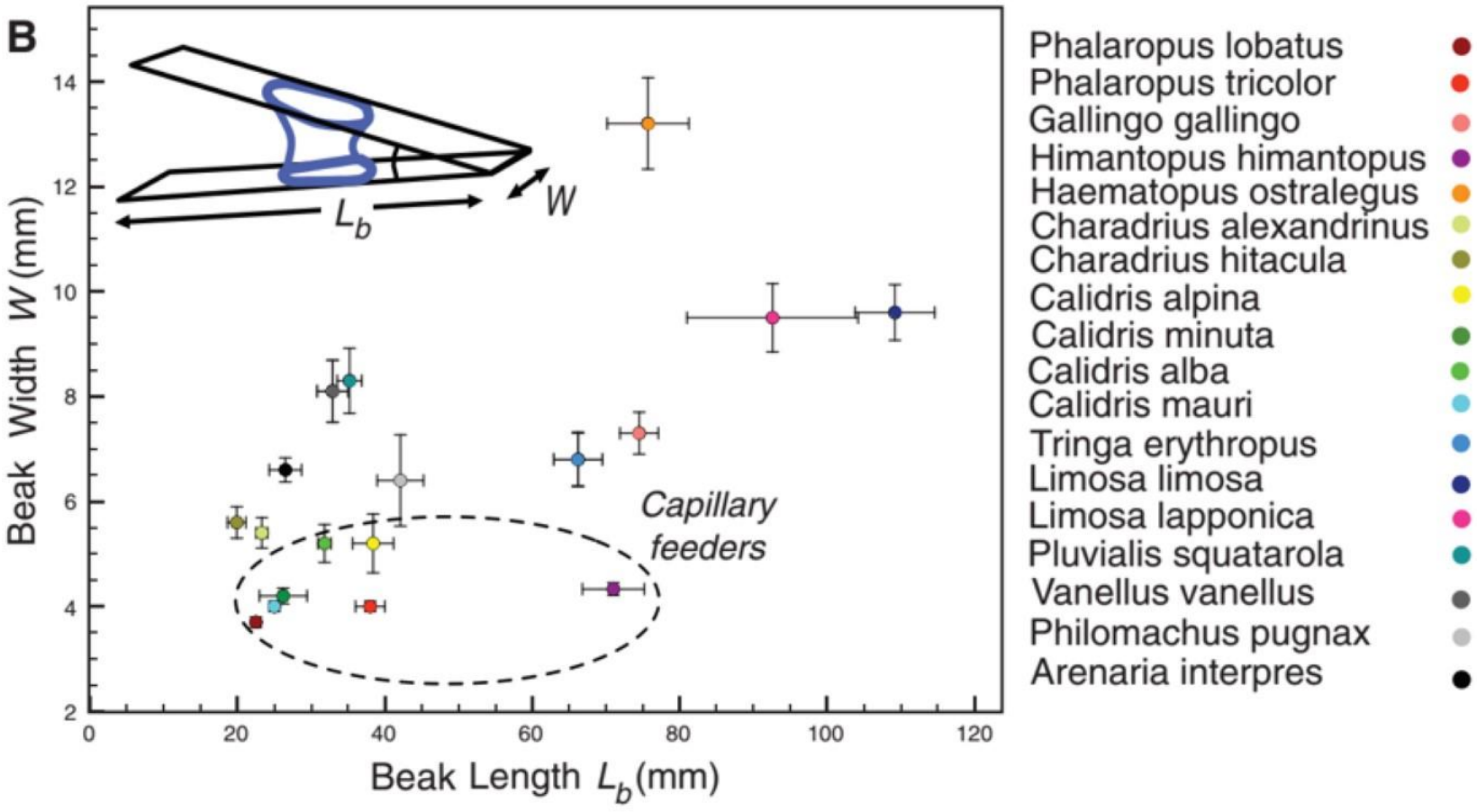
# 神奇动植物如何利用特殊浸润性界面饮水？

# 硬嘴水鸟如何喝水？

*Science 2008, 320, 931*

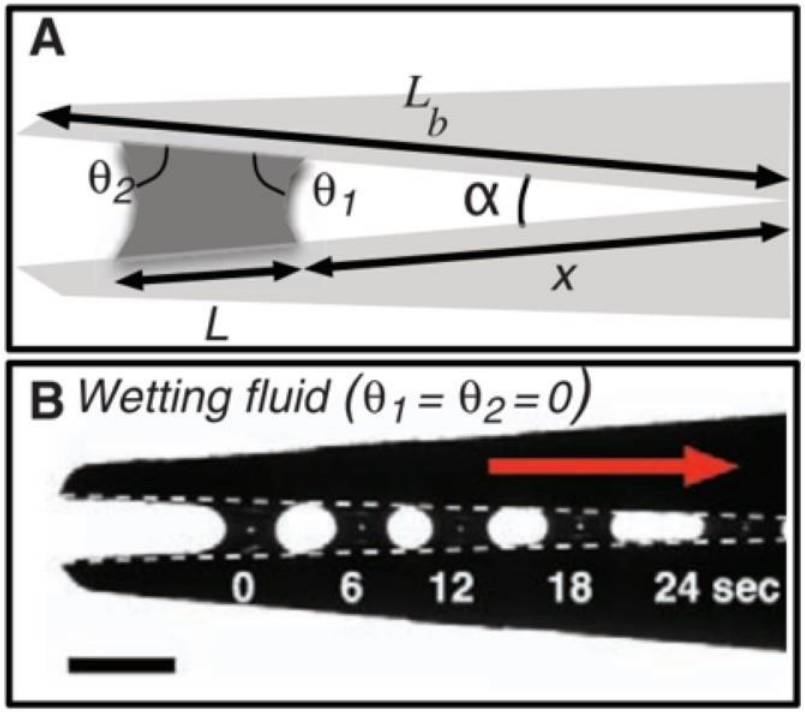
# 硬嘴水鸟如何喝水？

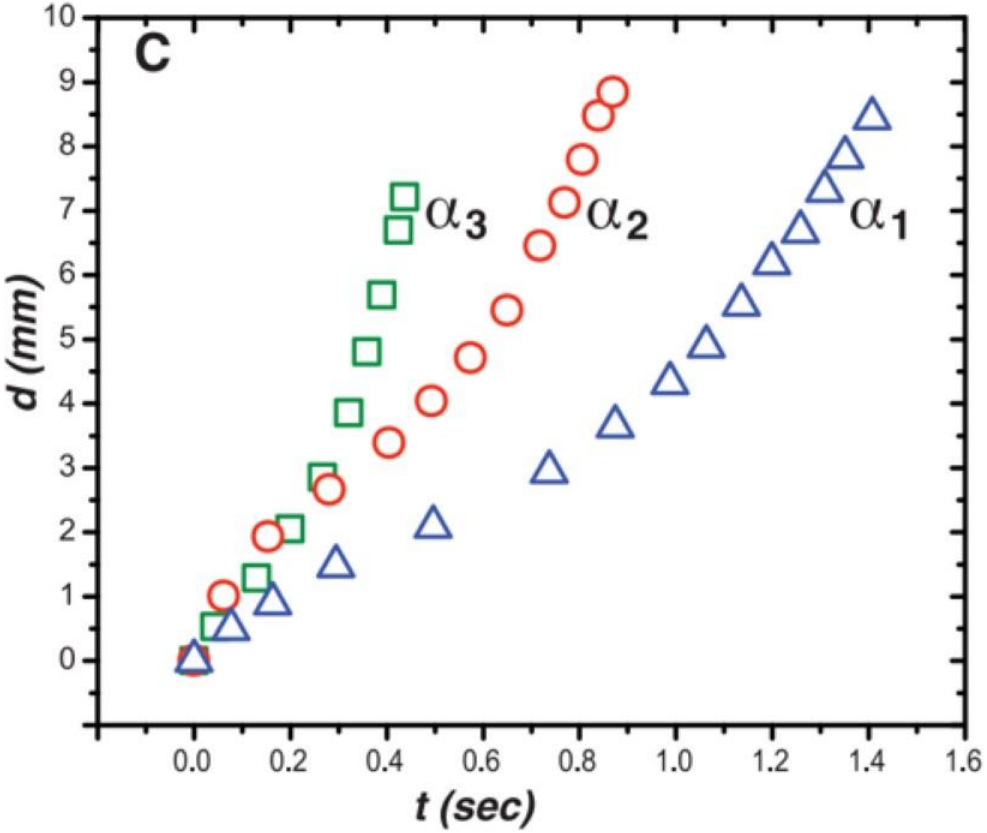
## 长窄嘴的水鸟利用毛细作用喝水



# 硬嘴水鸟如何喝水？

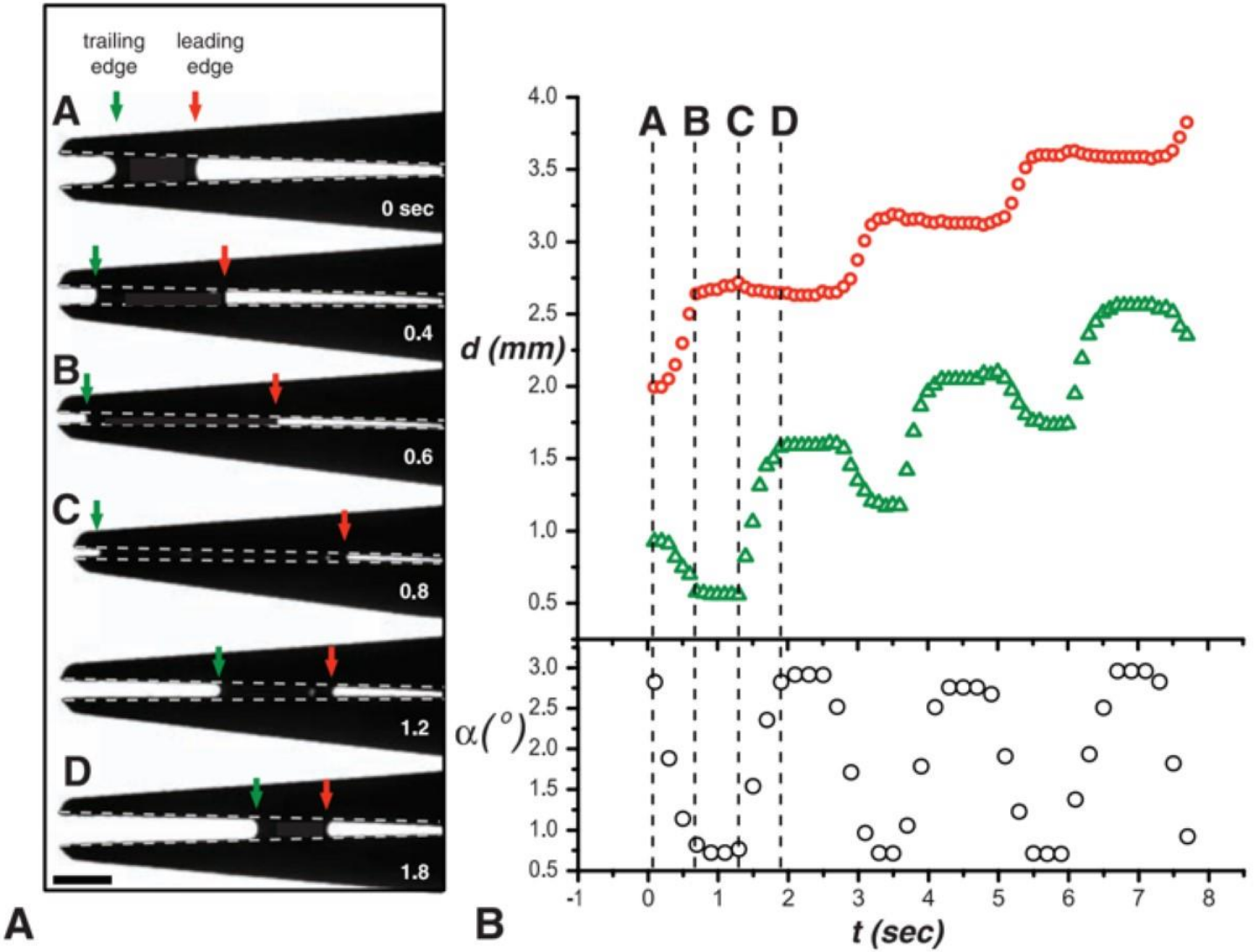
## 锥形通道诱导的不对称Laplace压



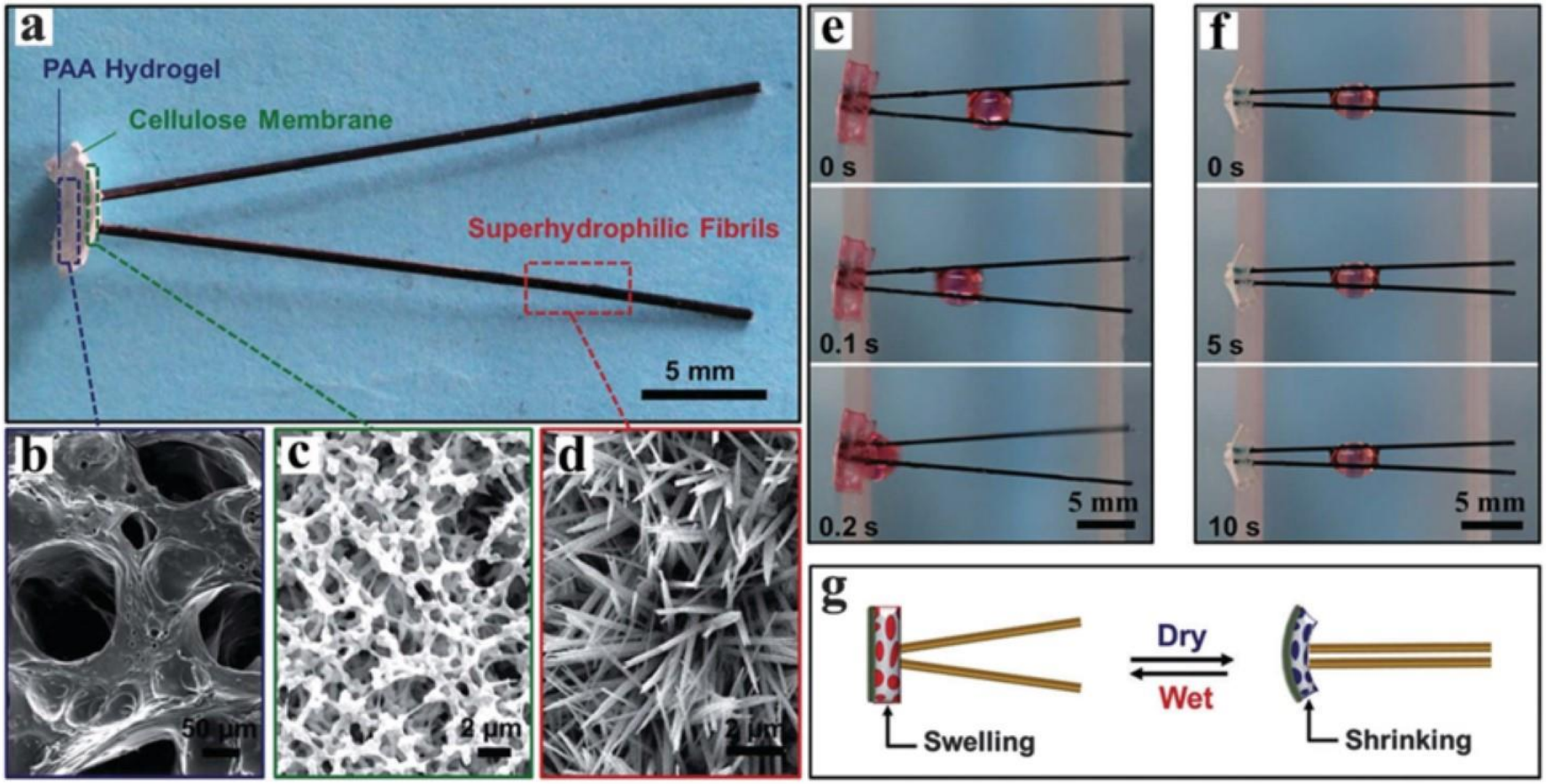
# 硬嘴水鸟如何喝水？

## 一开一合：棘尺结构+不对称Laplace压-驱水



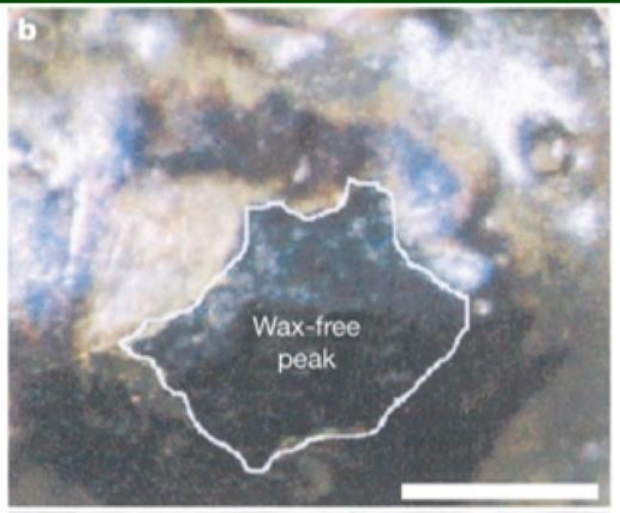
# 仿造水鸟嘴结构实现液滴定向输运

## 人造锥形结构用于液滴输运




*J. Mater. Chem. A 2015, 3, 15540*

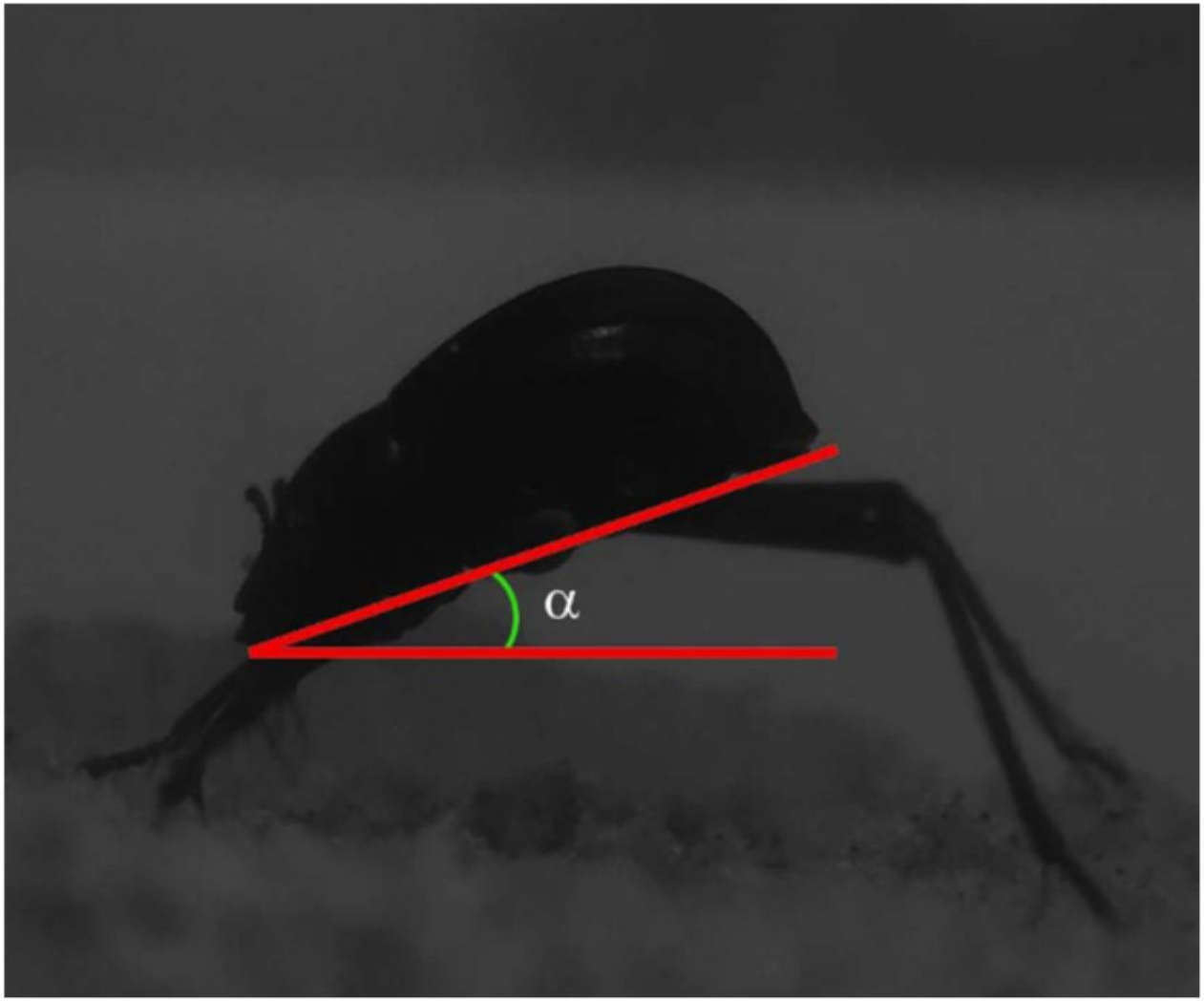
# 沙漠甲虫集雾成水


*Nature 2001, 414, 33*

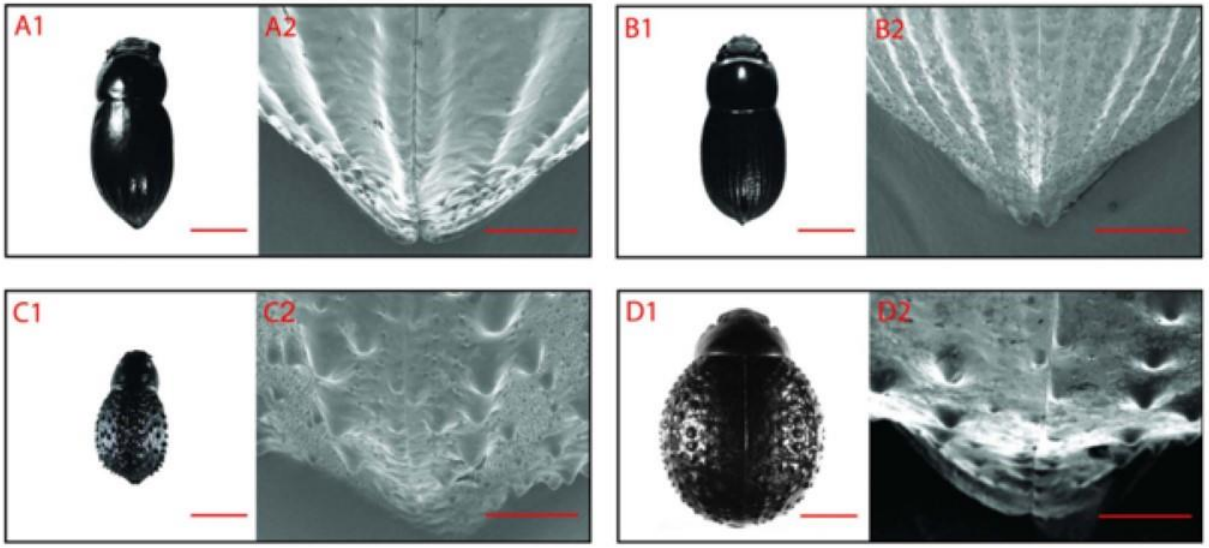
# 沙漠甲虫集雾成水

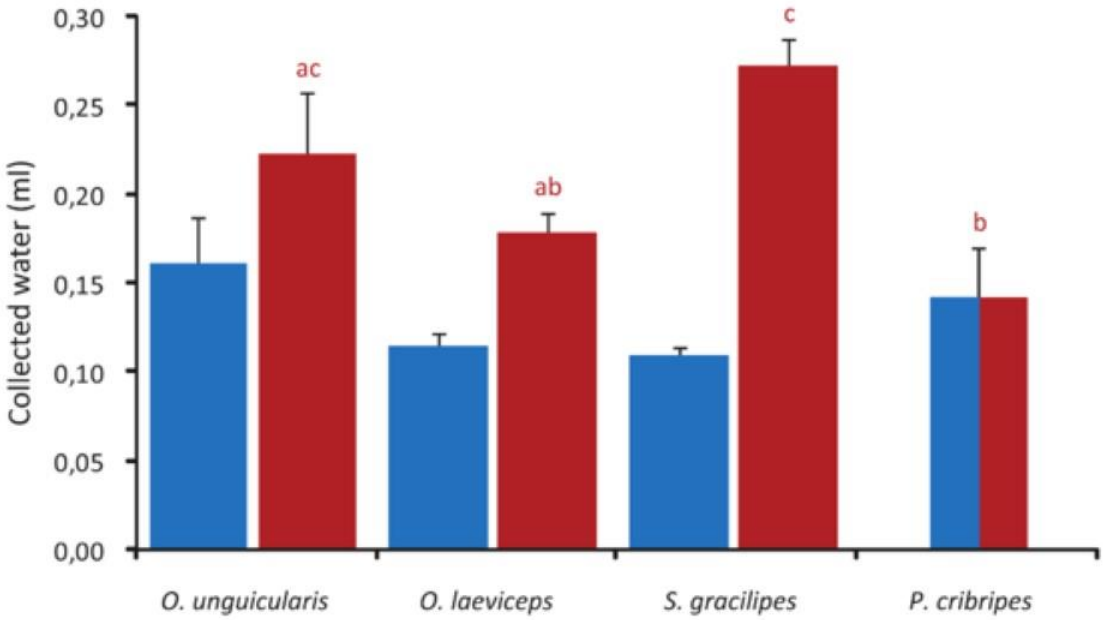
## 重力诱导的水收集




*Frontiers in Zoology 2010, 7, 23*

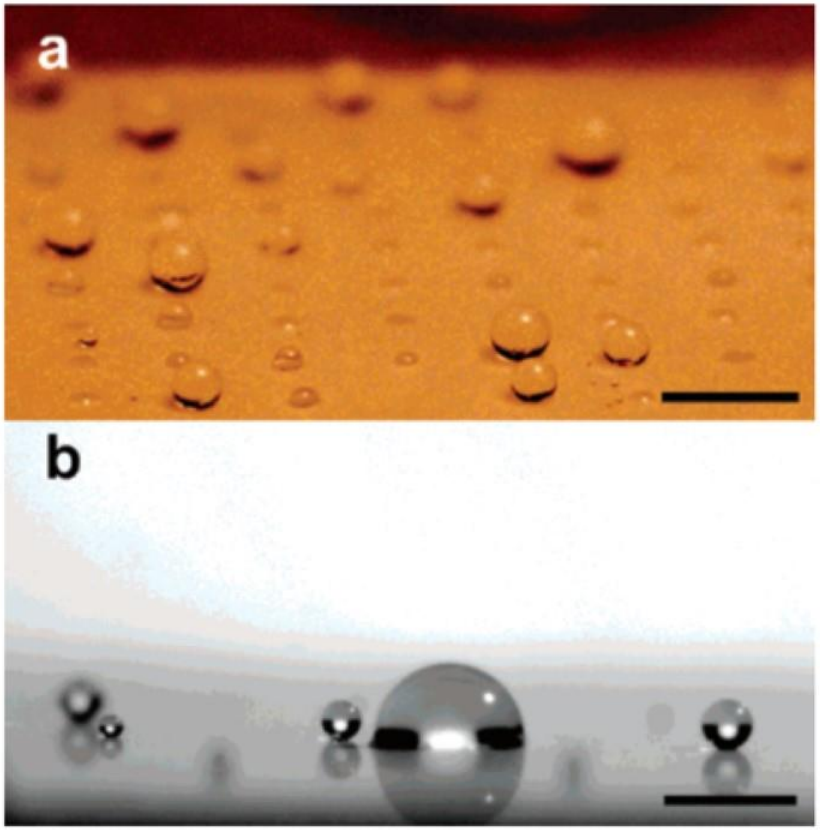
# 沙漠甲虫集雾成水

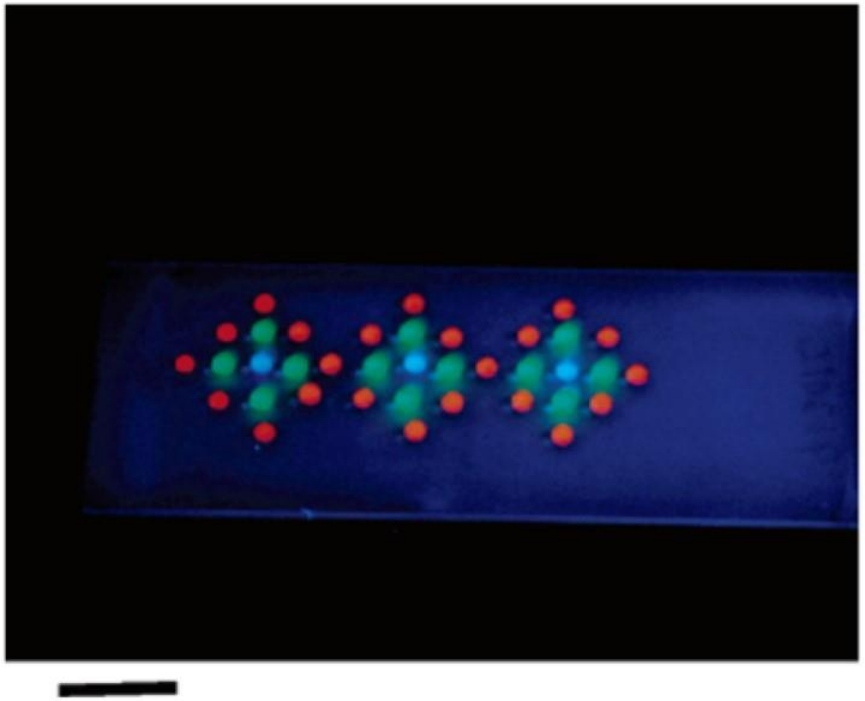

A1
A2
B1
B2
C1
C2
D1
D2


Collected water (ml)
0,30
0,25
0,20
0,15
0,10
0,05
0,00
ac
ab
c
b
O. unguicularis
O. laeviceps
S. gracilipes
P. cribripes

# 模仿沙漠甲虫后背结构

## 图案化亲疏水界面用于微检测

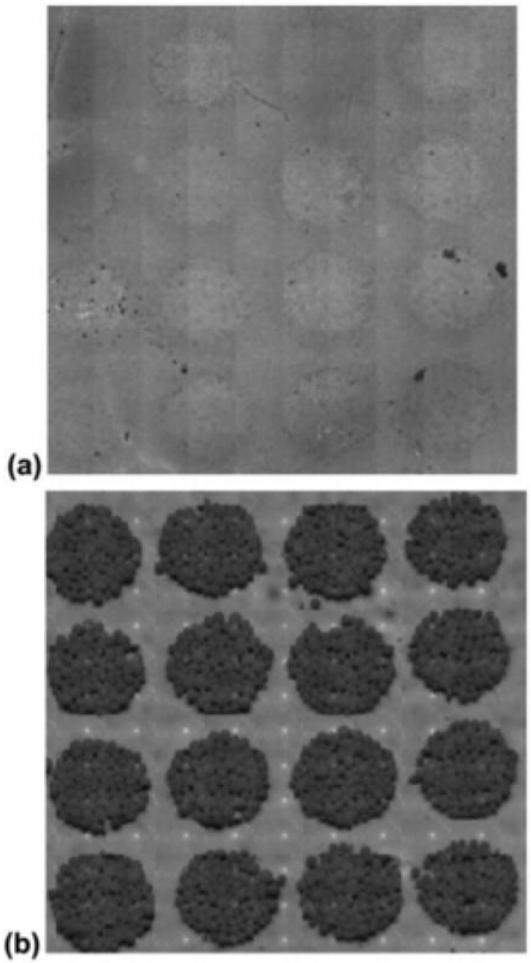


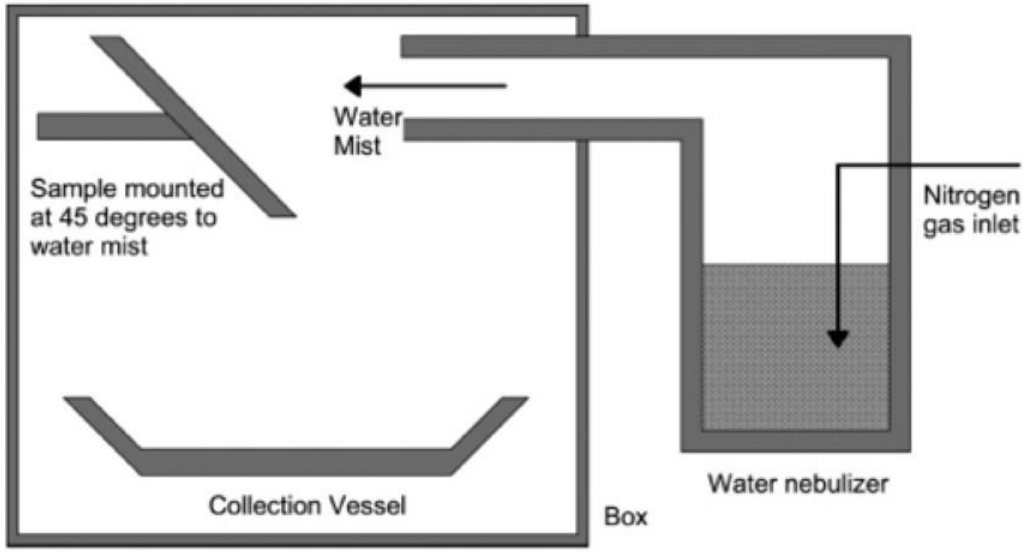



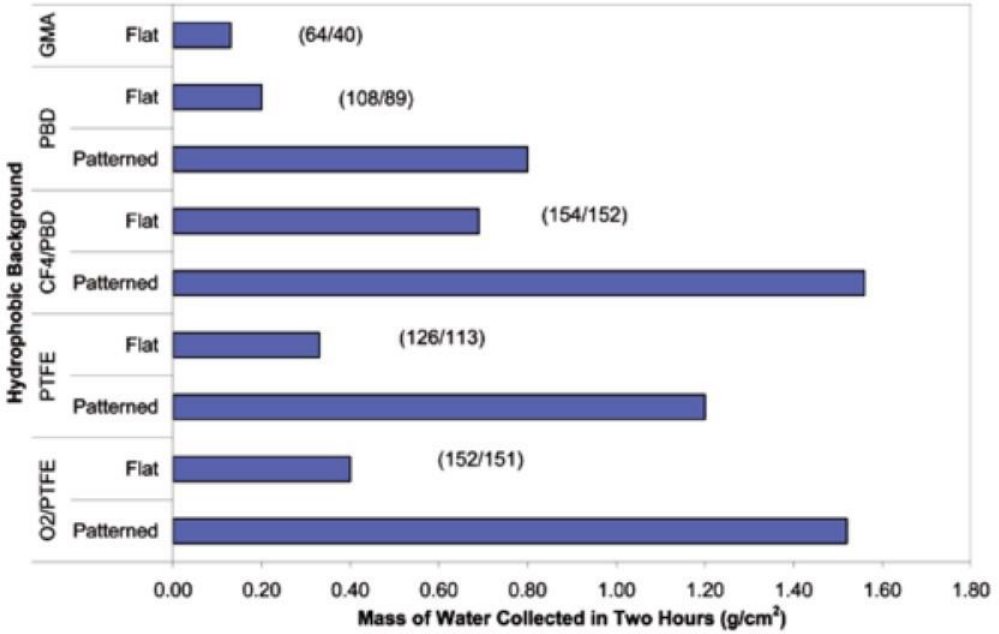
*Nano Lett. 2006, 6, 1213*

# 模仿沙漠甲虫后背结构

## 图案化界面用于蒸汽收集




*Langmuir, 2007, 23, 689*

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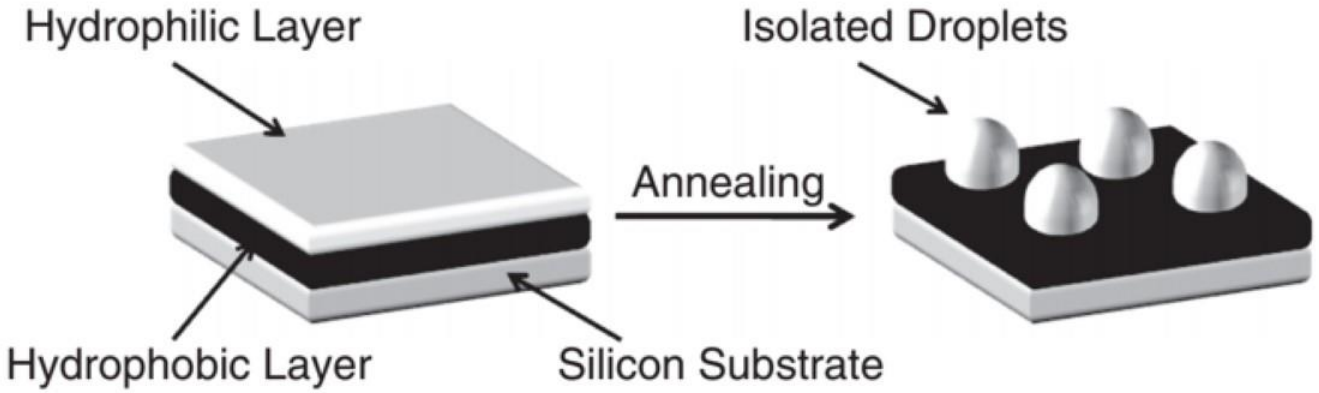
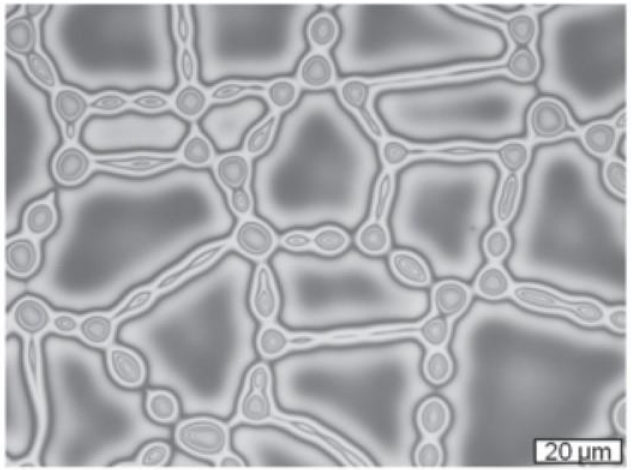
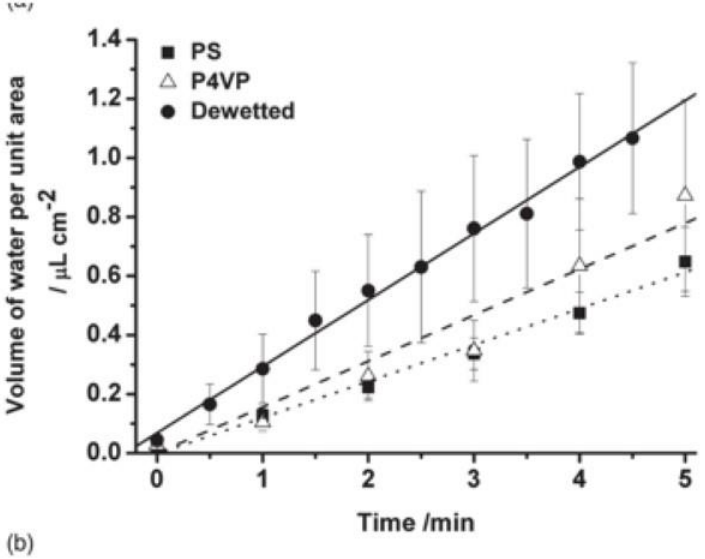


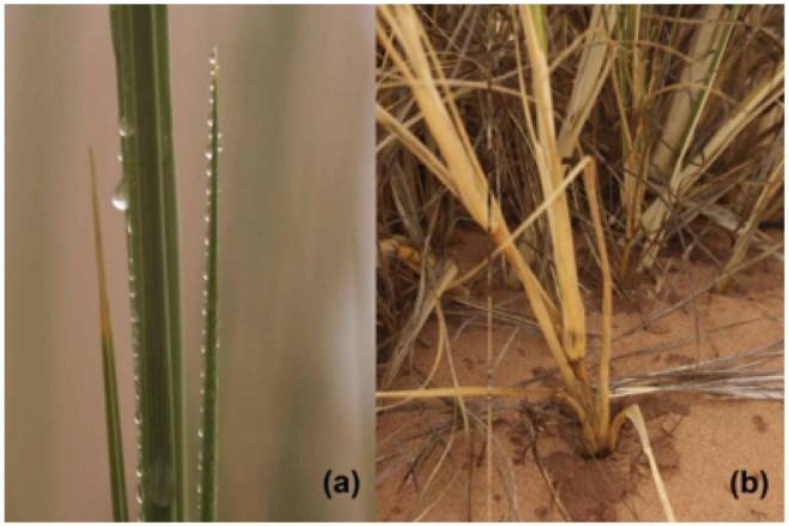



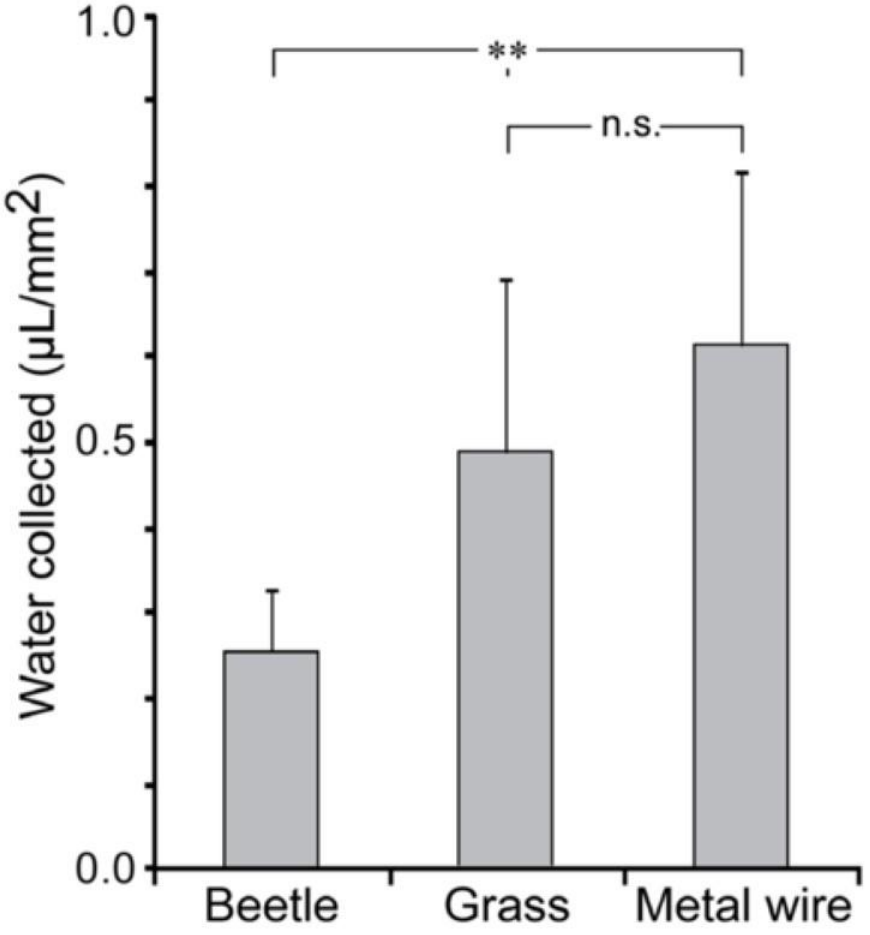




*Adv. Mater. 2011, 23, 3718*

# 沙漠“杂草”集雾成水

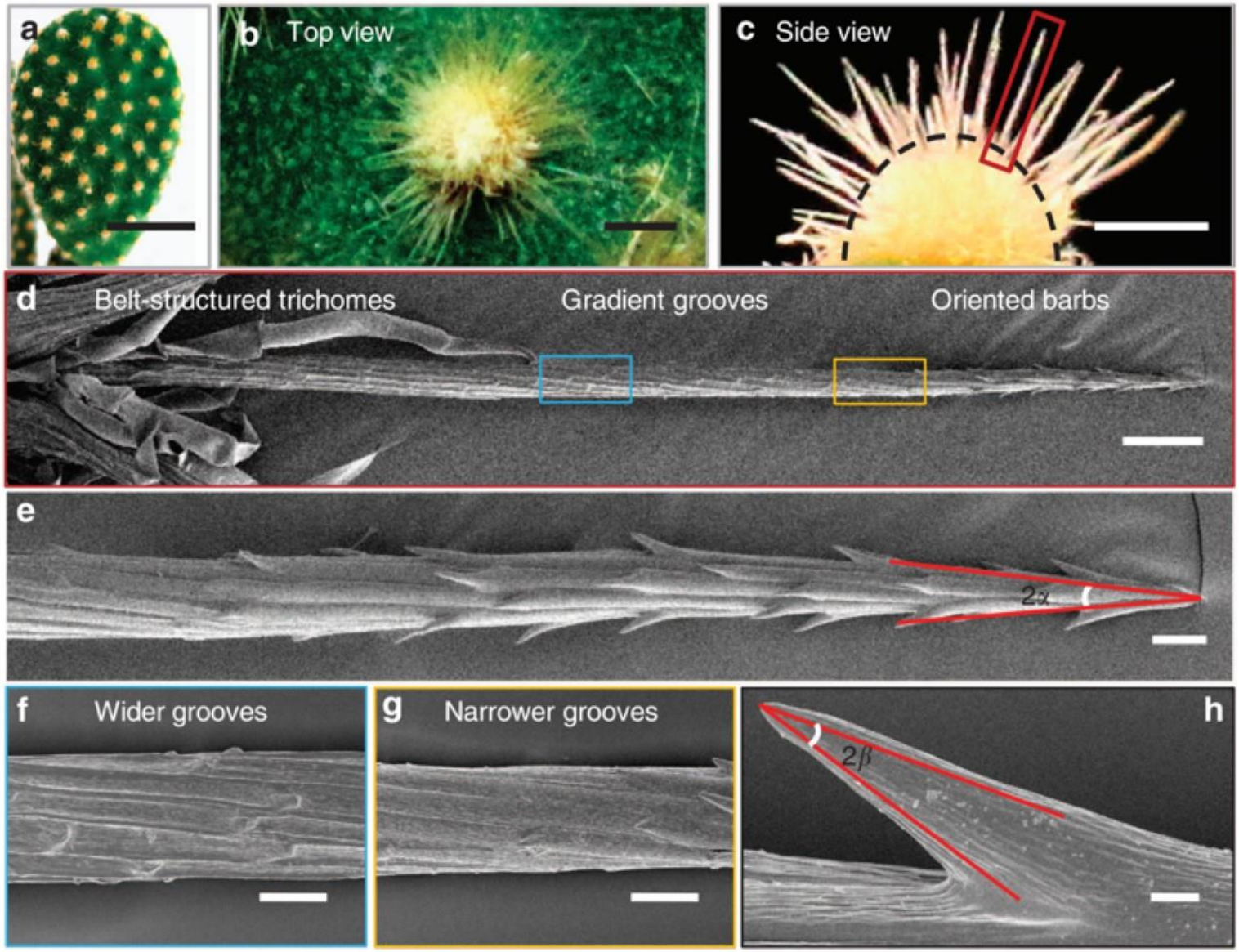
## Bushman grass



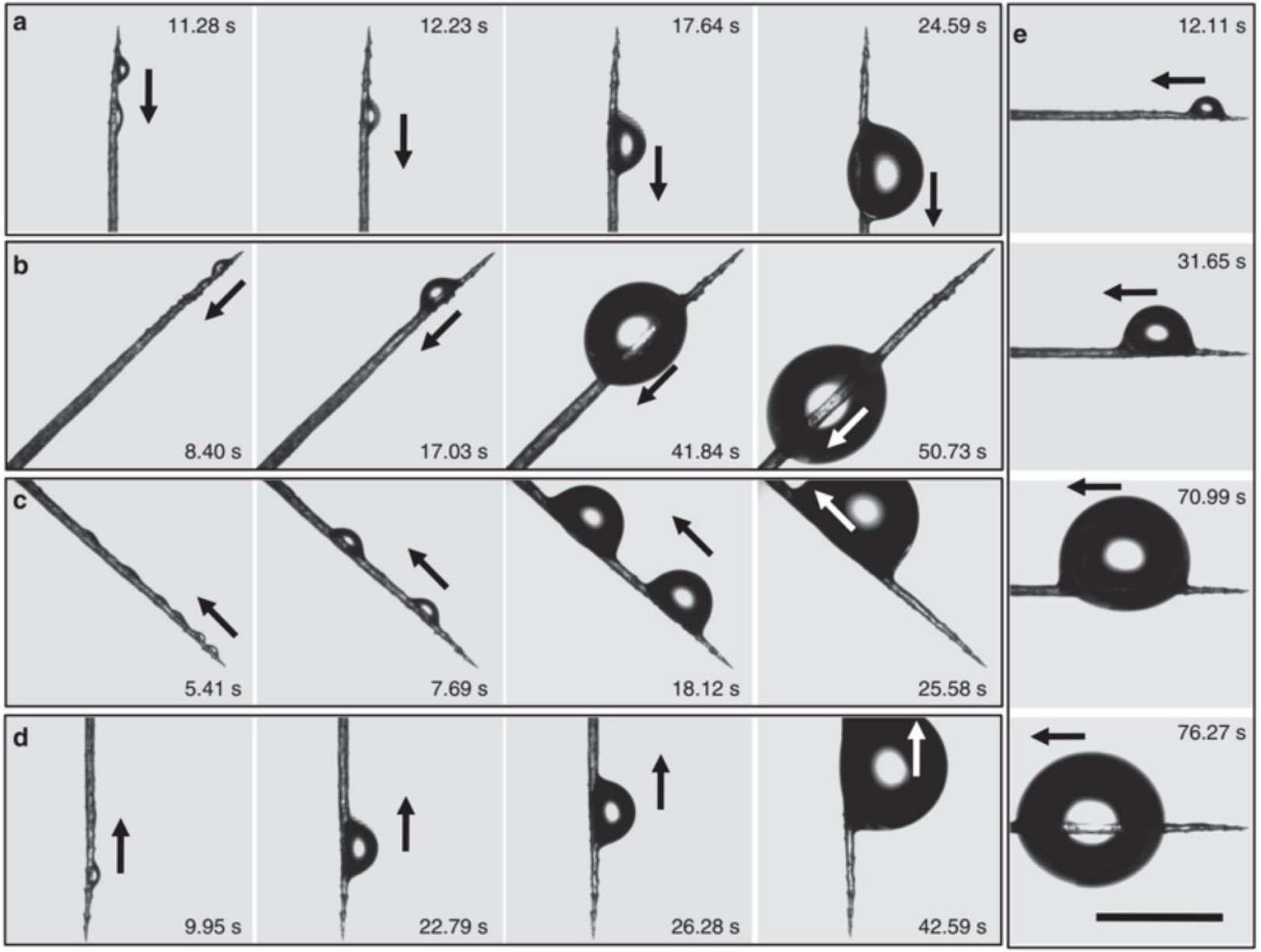

*PloS One, 2012, 7, e34603*

# 沙漠仙人掌集雾成水

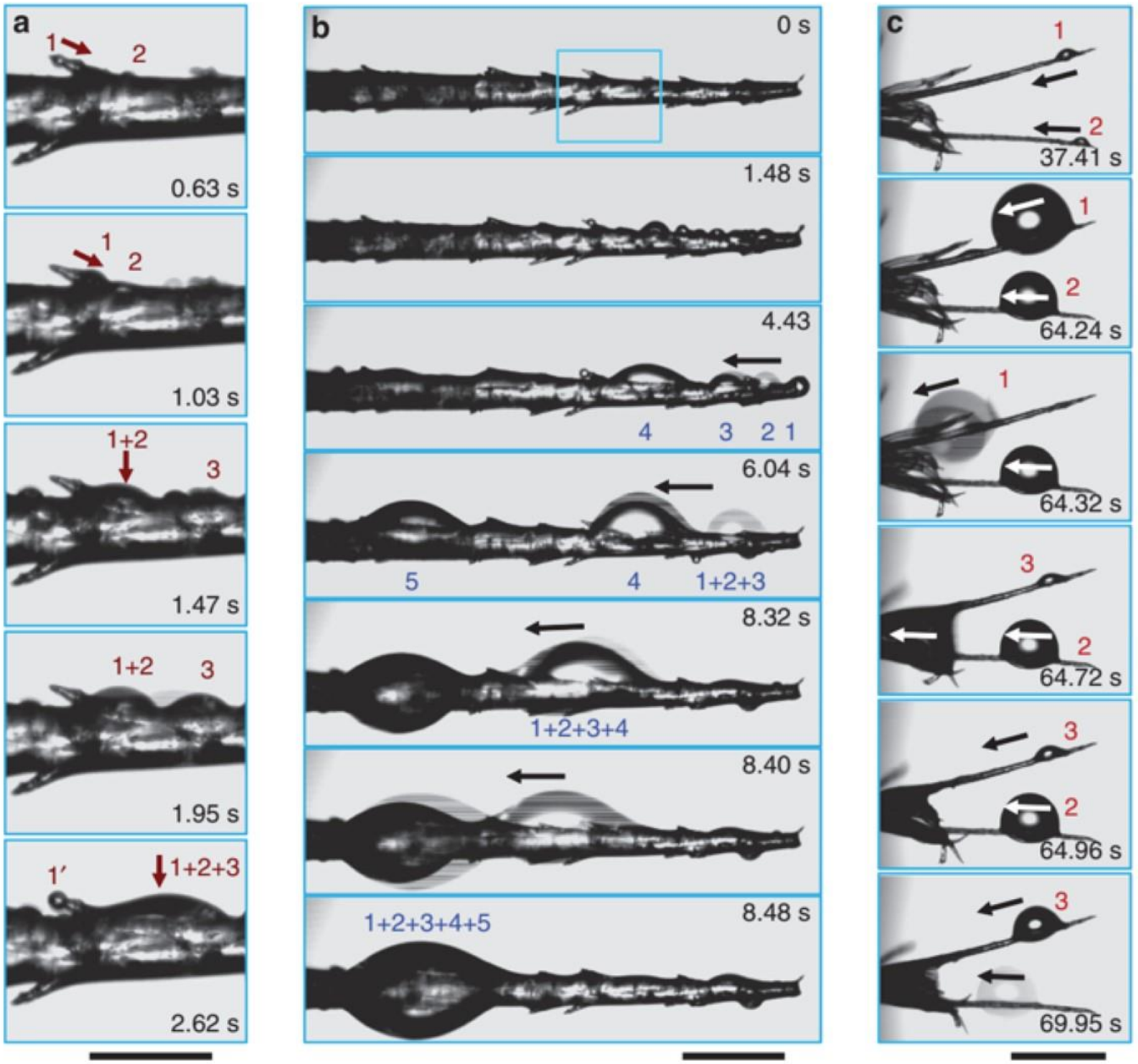



*Nat. Commun. 2012, 3, 1247*

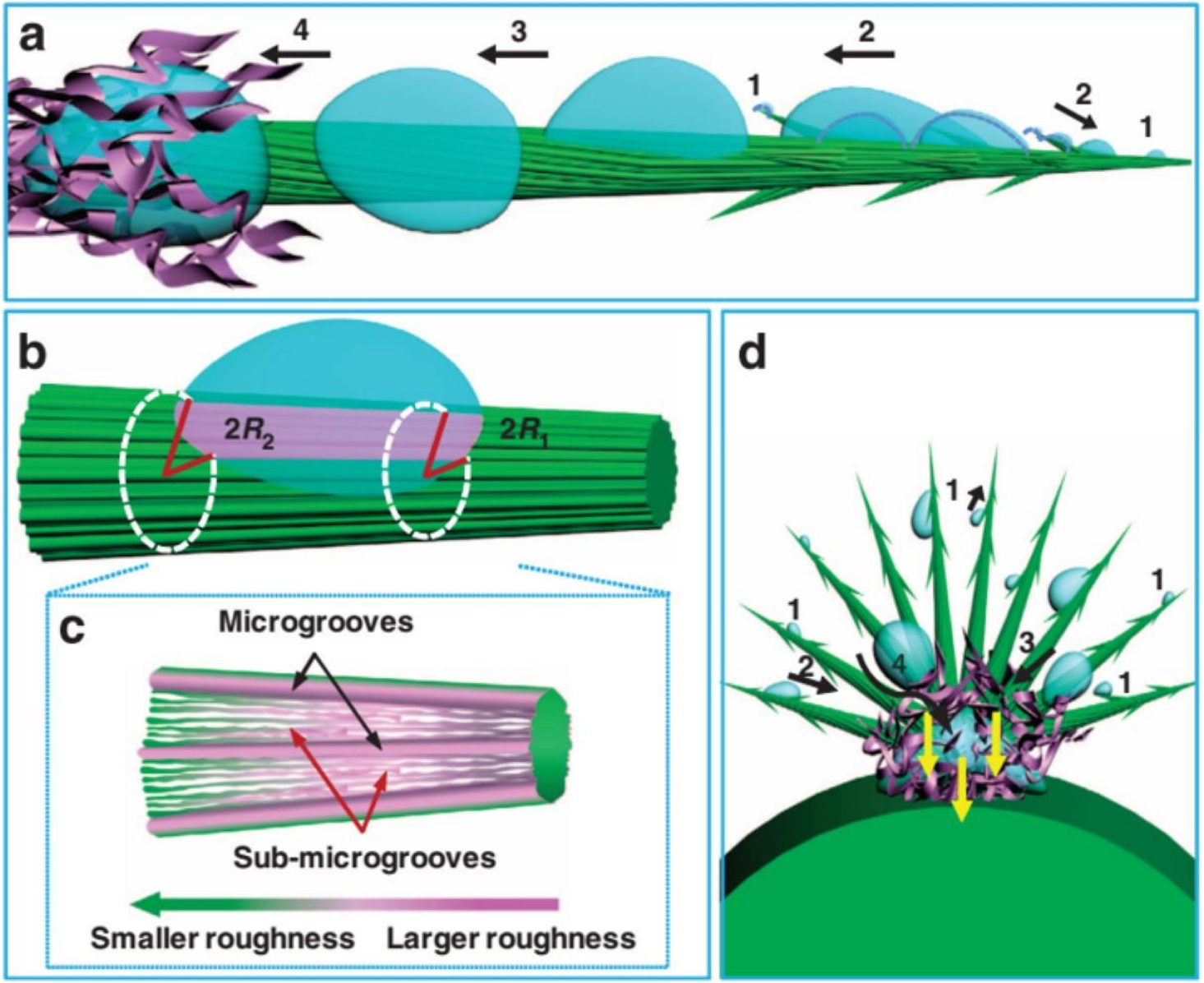
# 沙漠仙人掌集雾成水


a
11.28 s
12.23 s
17.64 s
24.59 s
b
8.40 s
17.03 s
41.84 s
50.73 s
c
5.41 s
7.69 s
18.12 s
25.58 s
d
9.95 s
22.79 s
26.28 s
42.59 s
e
12.11 s
31.65 s
70.99 s
76.27 s

# 沙漠仙人掌集雾成水


a
1
2
0.63 s
1
2
1.03 s
1+2
3
1.47 s
1+2
3
1.95 s
1′
1+2+3
2.62 s
b
0 s
1.48 s
4.43
4
3
2 1
6.04 s
5
4
1+2+3
8.32 s
1+2+3+4
8.40 s
8.48 s
1+2+3+4+5
c
1
2
37.41 s
1
2
64.24 s
1
64.32 s
3
2
64.72 s
3
2
64.96 s
3
69.95 s

# 沙漠仙人掌集雾成水

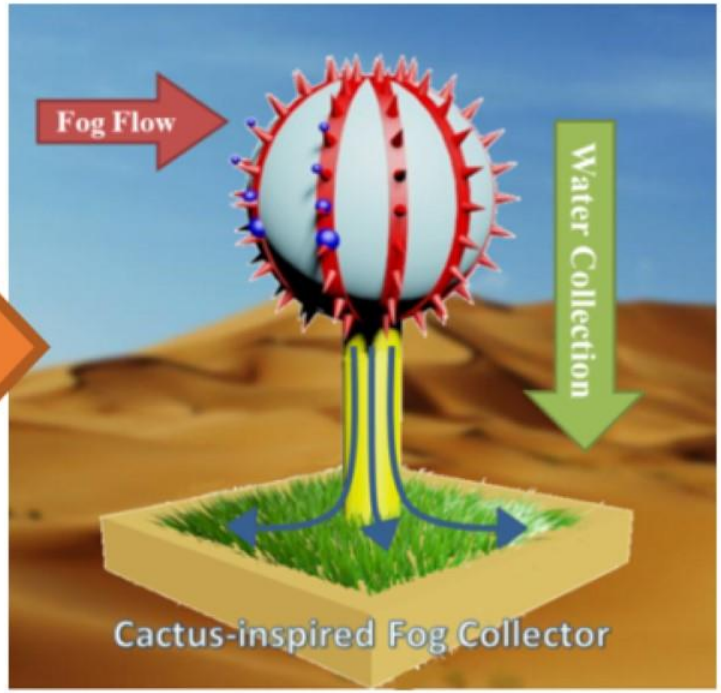

a
4
3
2
1
2
1
b
$2R_2$
$2R_1$
c
Microgrooves
Sub-microgrooves
Smaller roughness
Larger roughness
d
1
1
1
2
3
4
1

# 仿造沙漠仙人掌实现集雾成水

## 仿仙人掌雾水收集器用于缓解干旱多雾地区的淡水危机

高效雾滴收集、定向雾水输送、快速水分贮存“一体化过程”

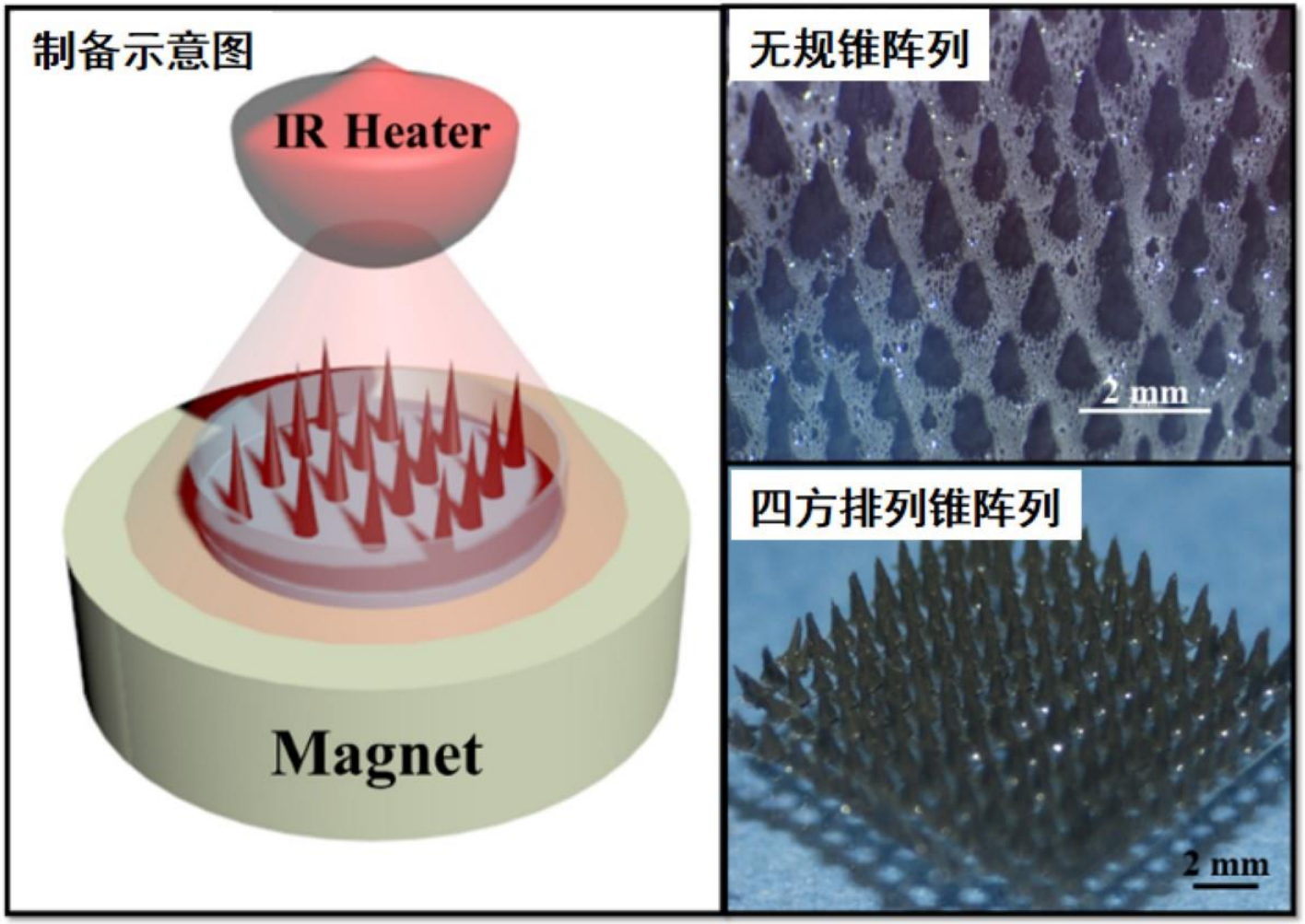
仿生




疏水（PDMS）/超亲水（棉絮纤维）协同+锥形几何梯度

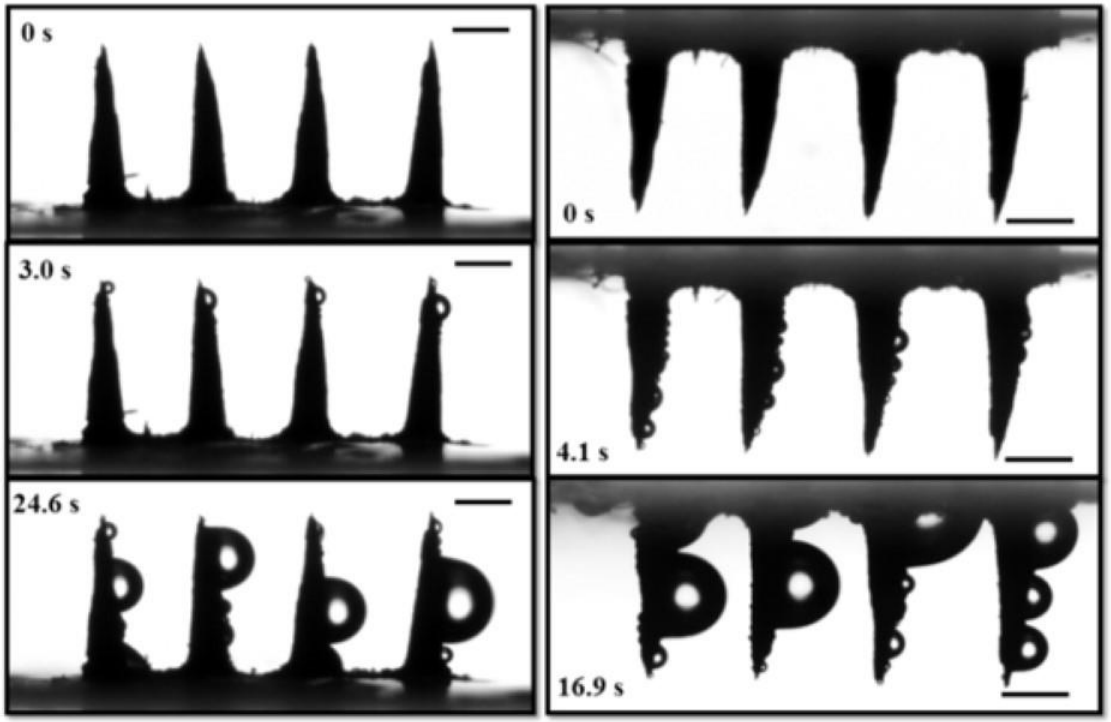
# 仿造沙漠仙人掌实现集雾成水

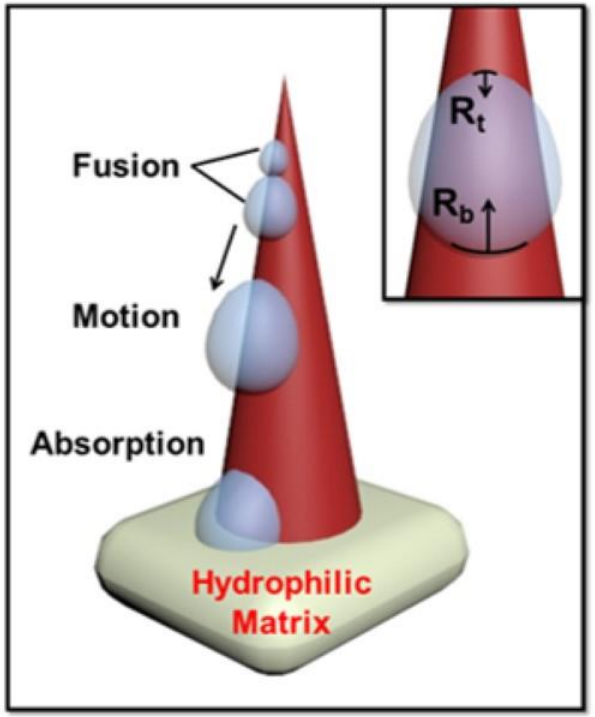
## 磁性粒子辅助成型制备仿仙人掌刺阵列——无模板、快速、经济



# 仿造沙漠仙人掌实现集雾成水

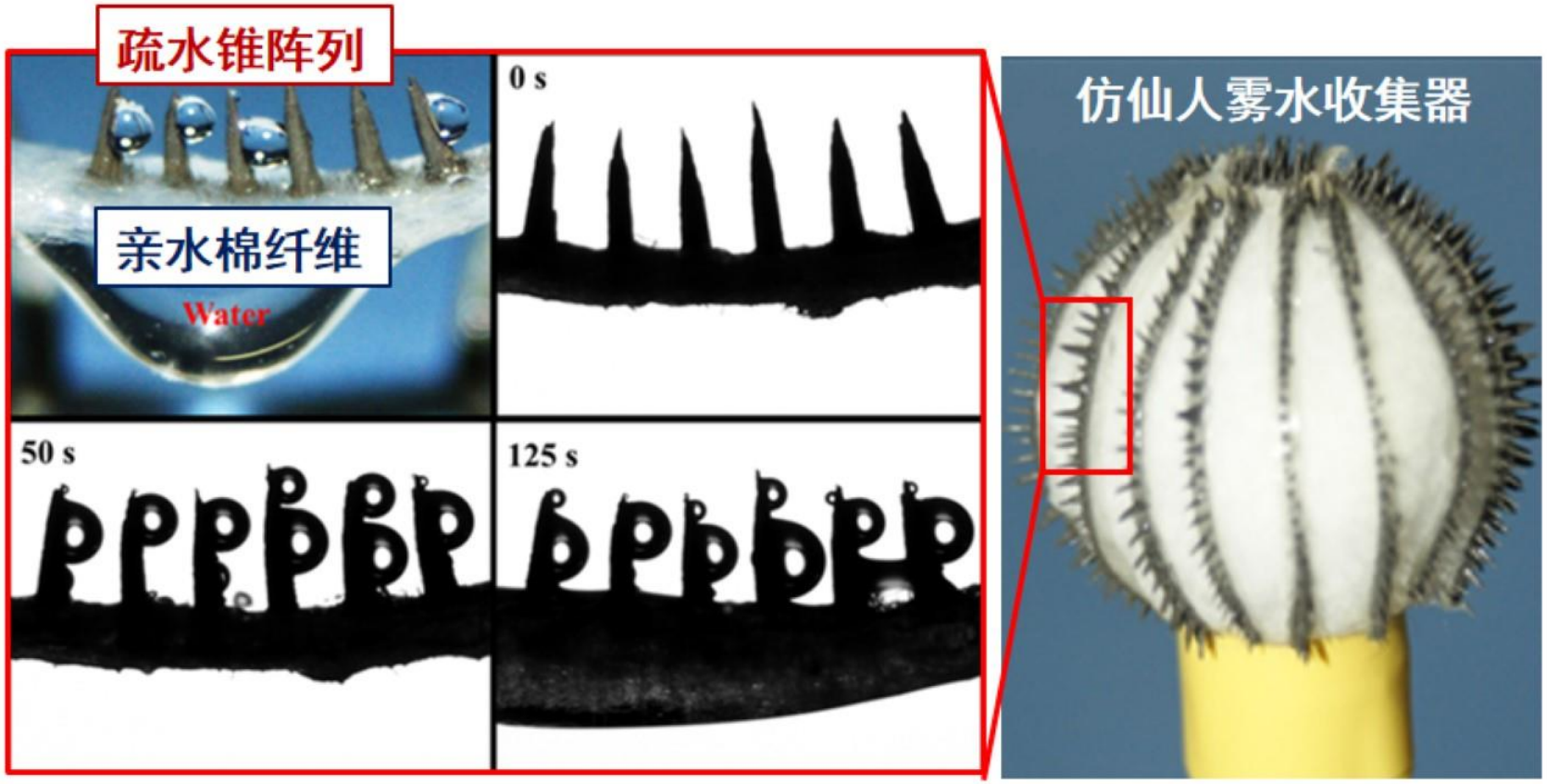
## 定向的雾水收集及输送 ——Laplace压差驱动的液滴运动



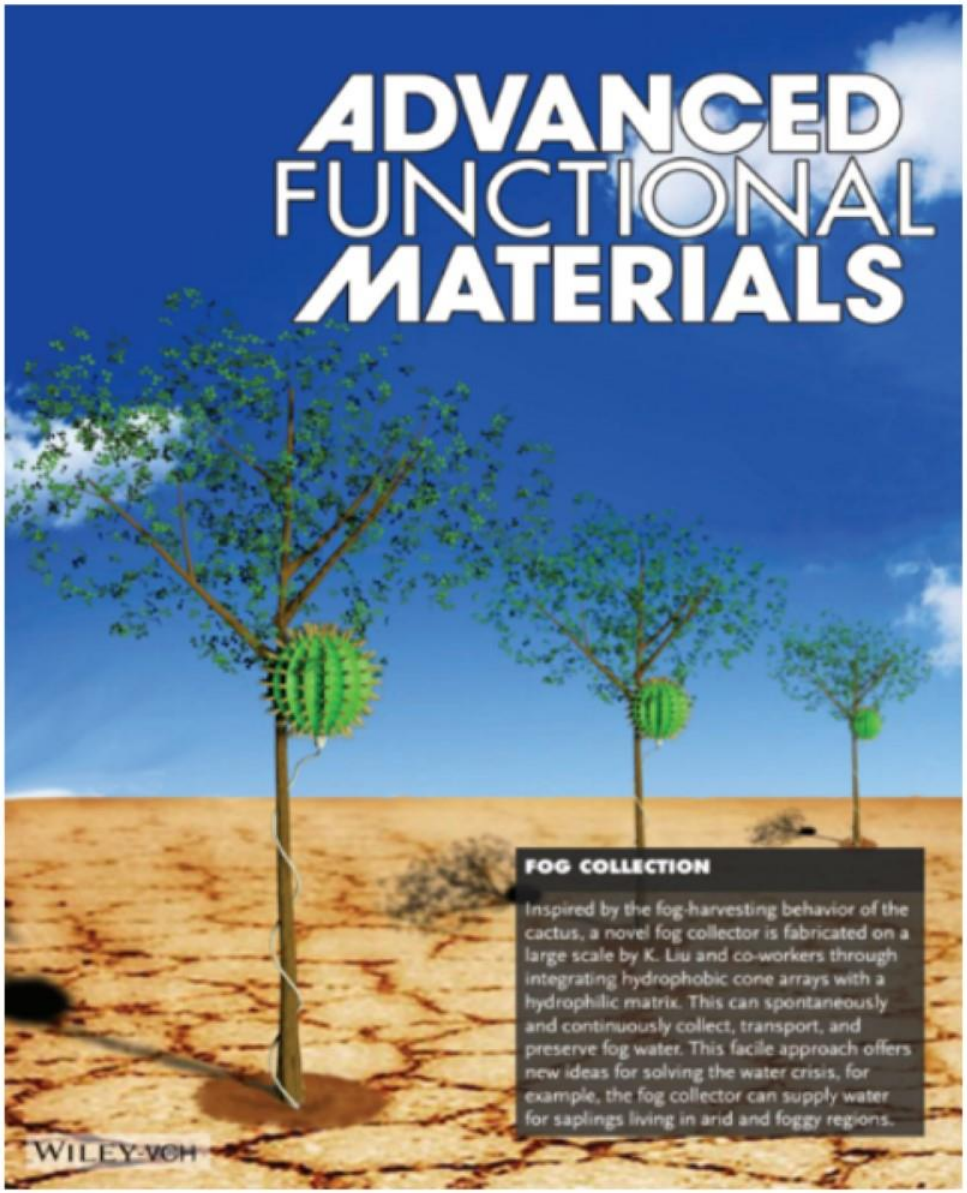



# 仿造沙漠仙人掌实现集雾成水

## 收集雾水的快速转移、贮存——亲/疏水协同作用下的液滴运动



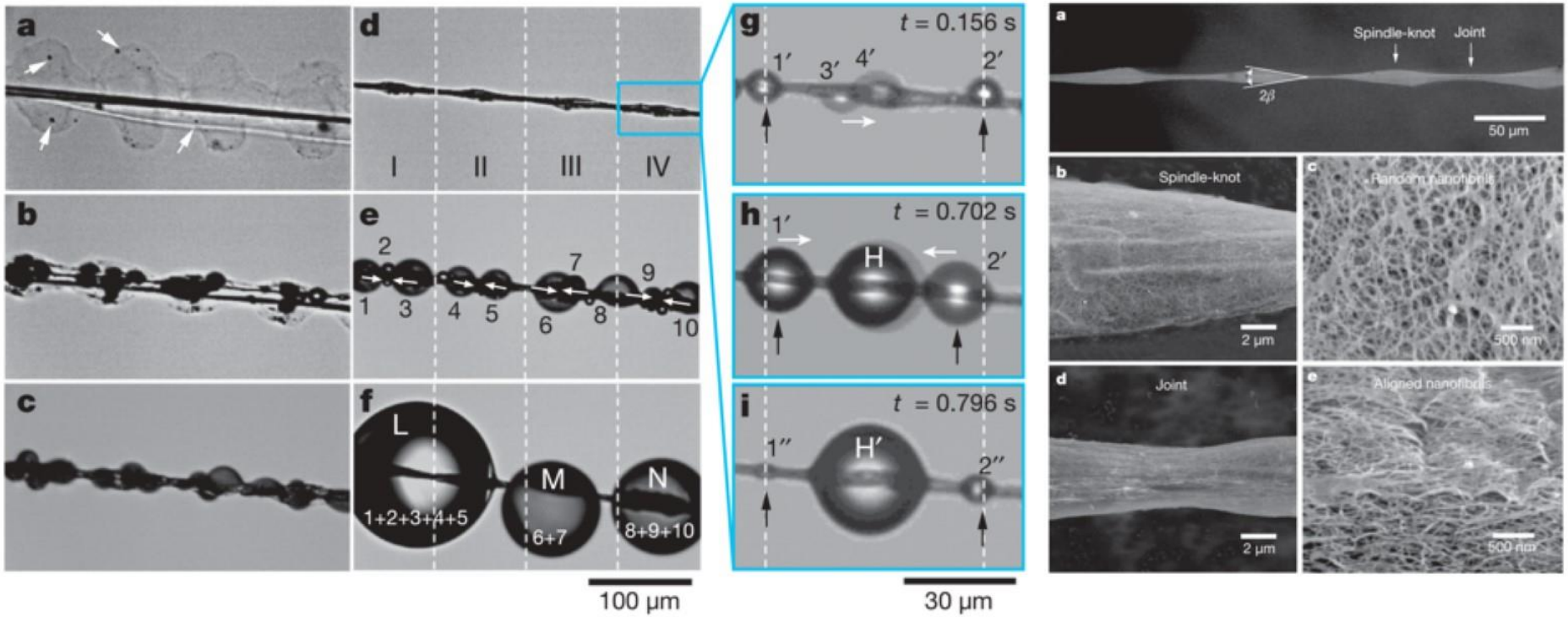
# 仿造沙漠仙人掌实现集雾成水




*Advanced Functional Materials 2014, 24, 3235. (Times Citation > 100)*

# 蜘蛛丝集雾成水

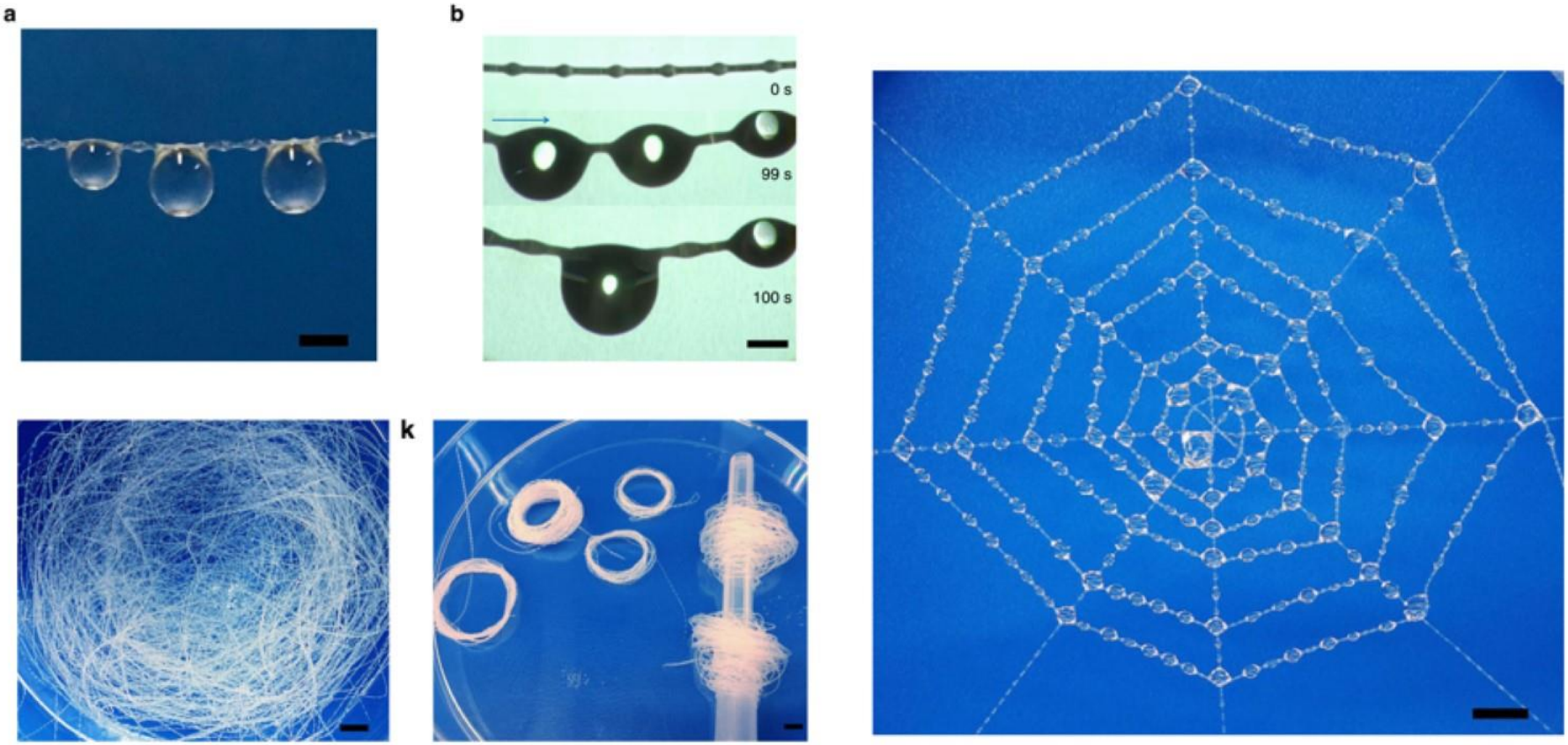
## 蜘蛛怎么喝水？




*Nature, 2010, 463, 640*

# 仿造蜘蛛丝实现集雾成水

## 规模化制备用于实际场景下的雾水收集

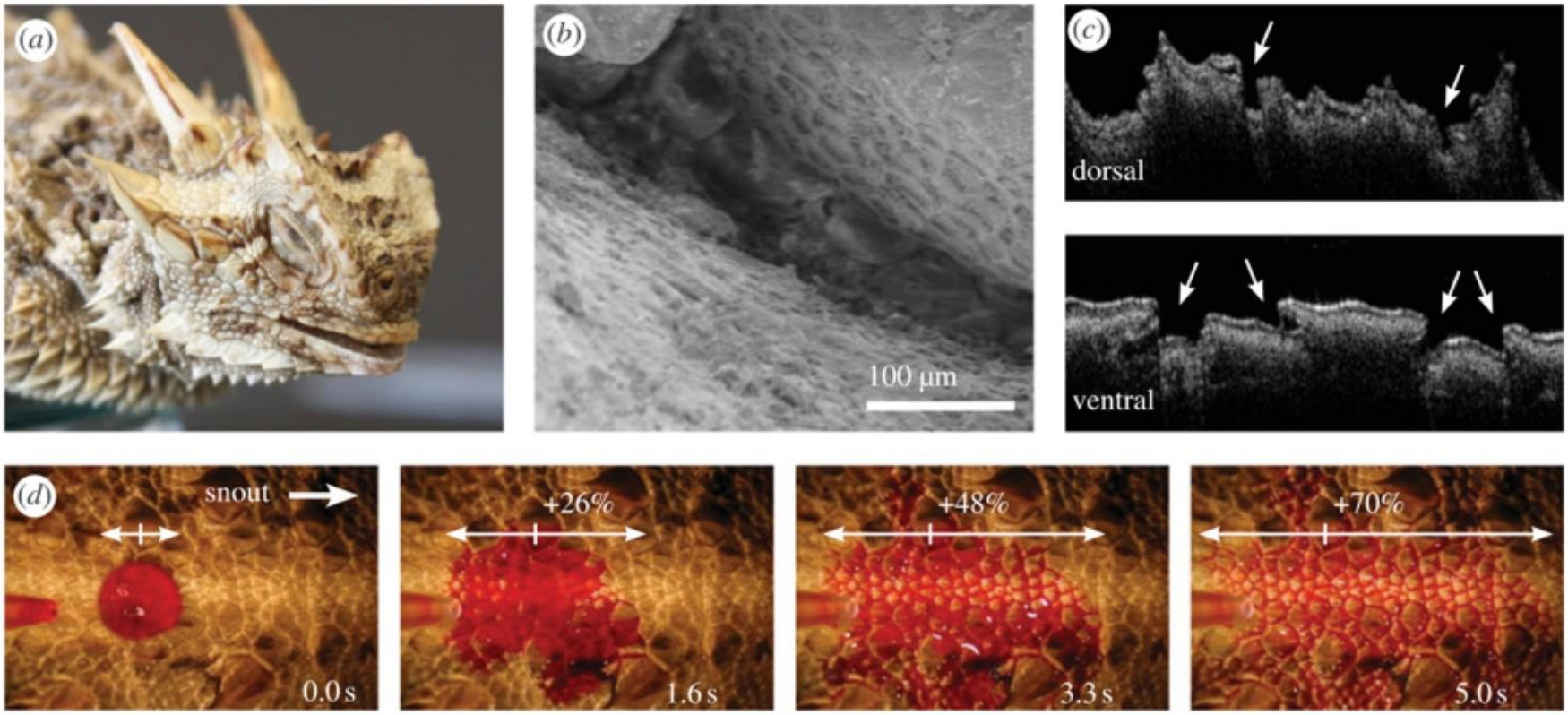



*Nat. Commun. 2017, 8, 1080*

# 沙漠蜥蜴如何饮水？

# 沙漠蜥蜴如何饮水？

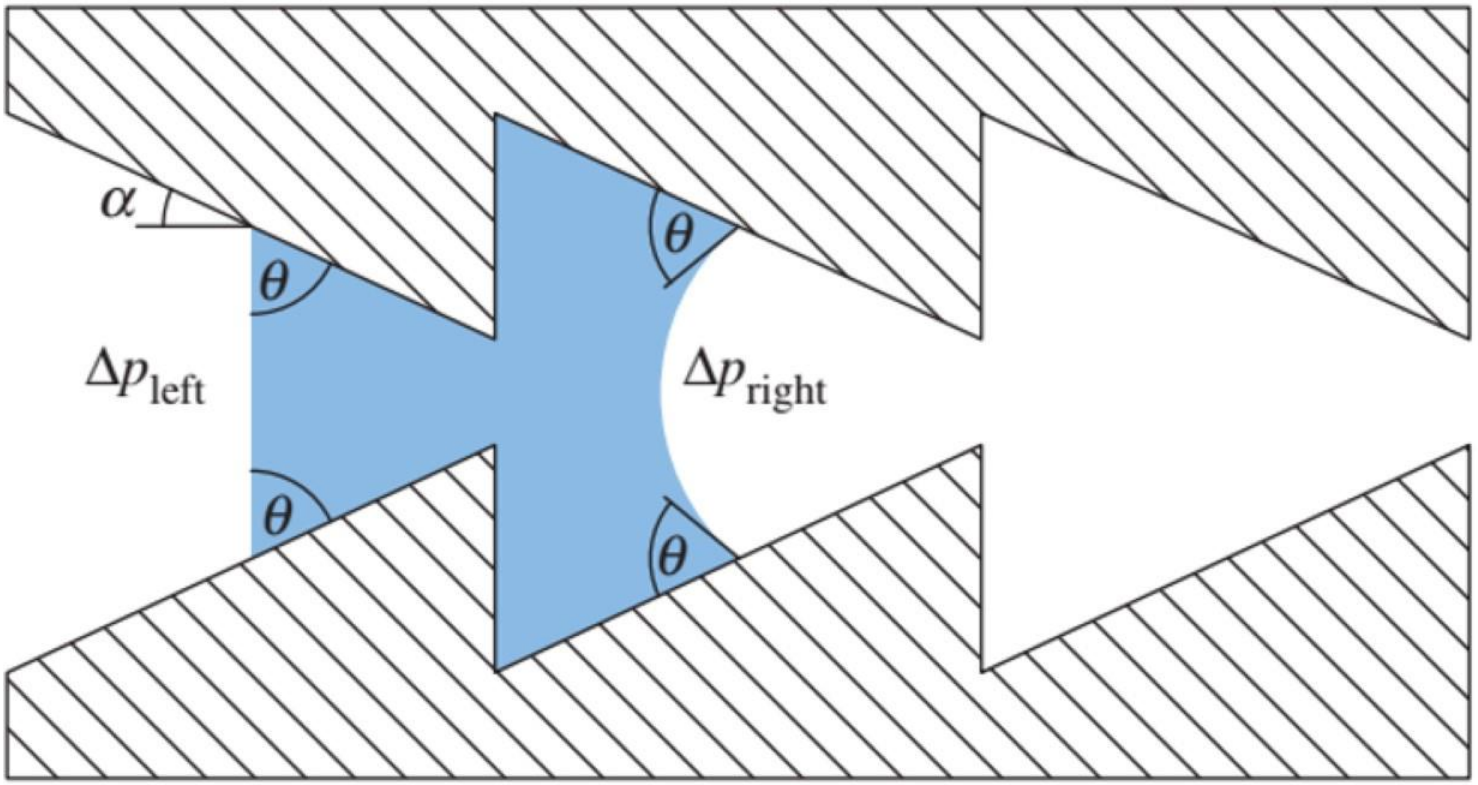
## 定向水传递界面



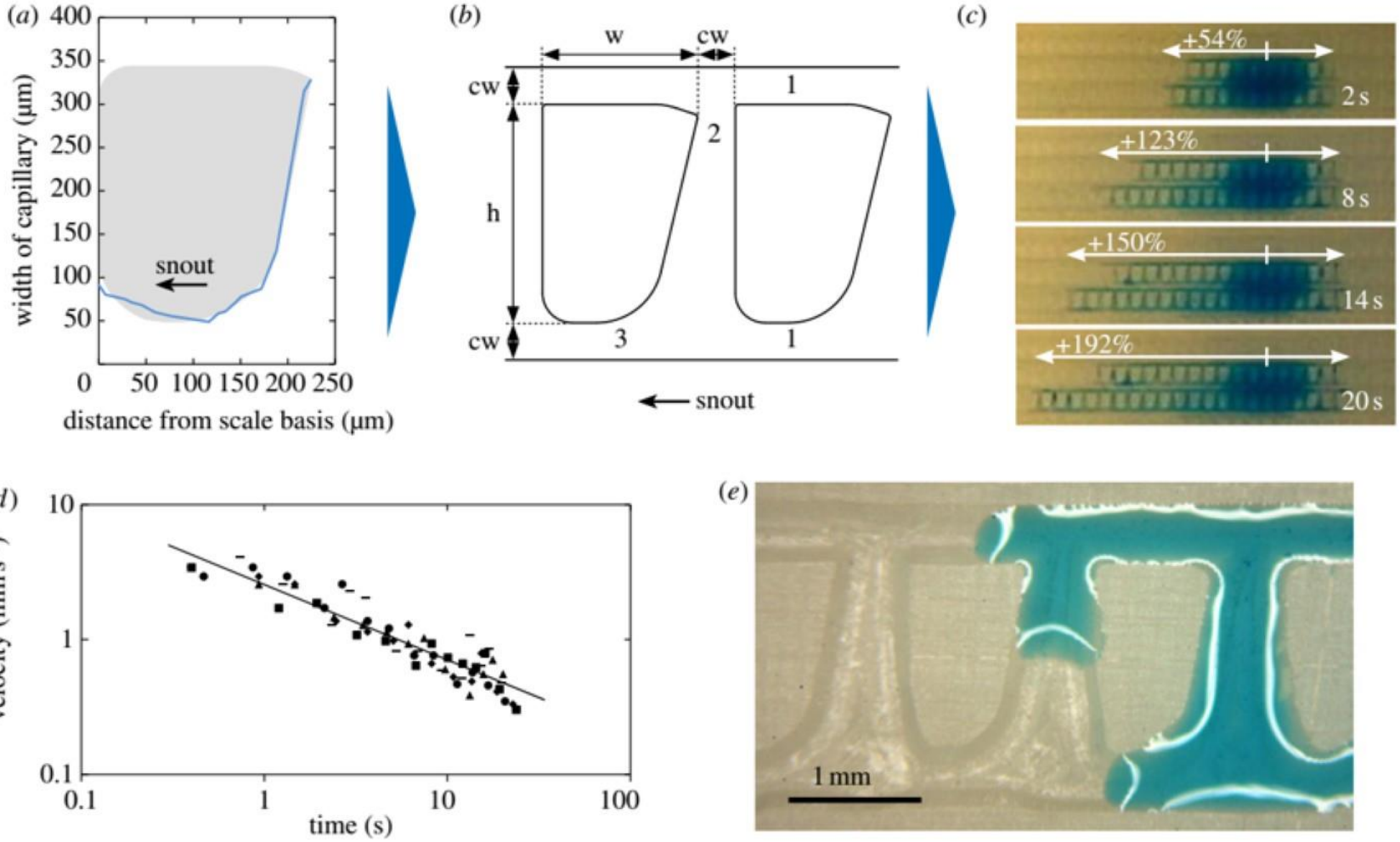

*J. R. Soc. Interface 2015, 12, 20150415*

# 沙漠蜥蜴如何饮水？

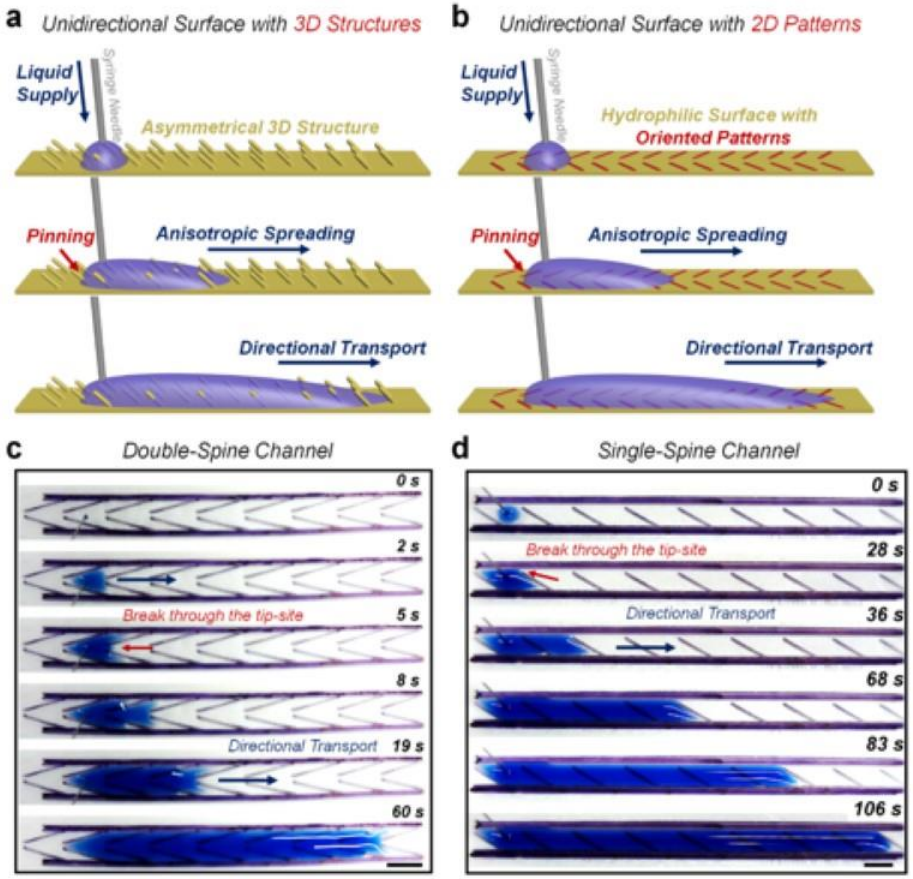
## 不对称鳞片结构诱导的不对称Laplace压



# 仿造沙漠蜥蜴鳞片实现定向水输运



# 仿造沙漠蜥蜴鳞片实现定向水输运





*Materials Horizons 2018, 5, 303*

# Materials Horizons Outstanding Paper Runner-up 2018

## Unidirectional water delivery on a superhydrophilic surface with two-dimensional asymmetrical wettability barriers

Hui Geng, Haoyu Bai, Yangyang Fan, Shaoyu Wang, Teer Ba, Cunming Yu, Moyuan Cao* and Lei Jiang

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# 总结

自然界将解答我们无数的疑问，给予我们不尽的灵感。

所谓自然科学，就是观察自然现象，解释自然问题，获得自然启发，进而实现人类自己小目标的过程。

“人类一思考，上帝就发笑”和自然相比，人类的智慧着实有限，敬畏自然，学习自然，是提高人类自身知识水平的快速路。

仿生思想，已经且必将在科学研究以及生产应用领域获得巨大成功，是多学科交叉的灵感宝库。

# 谢谢大家！