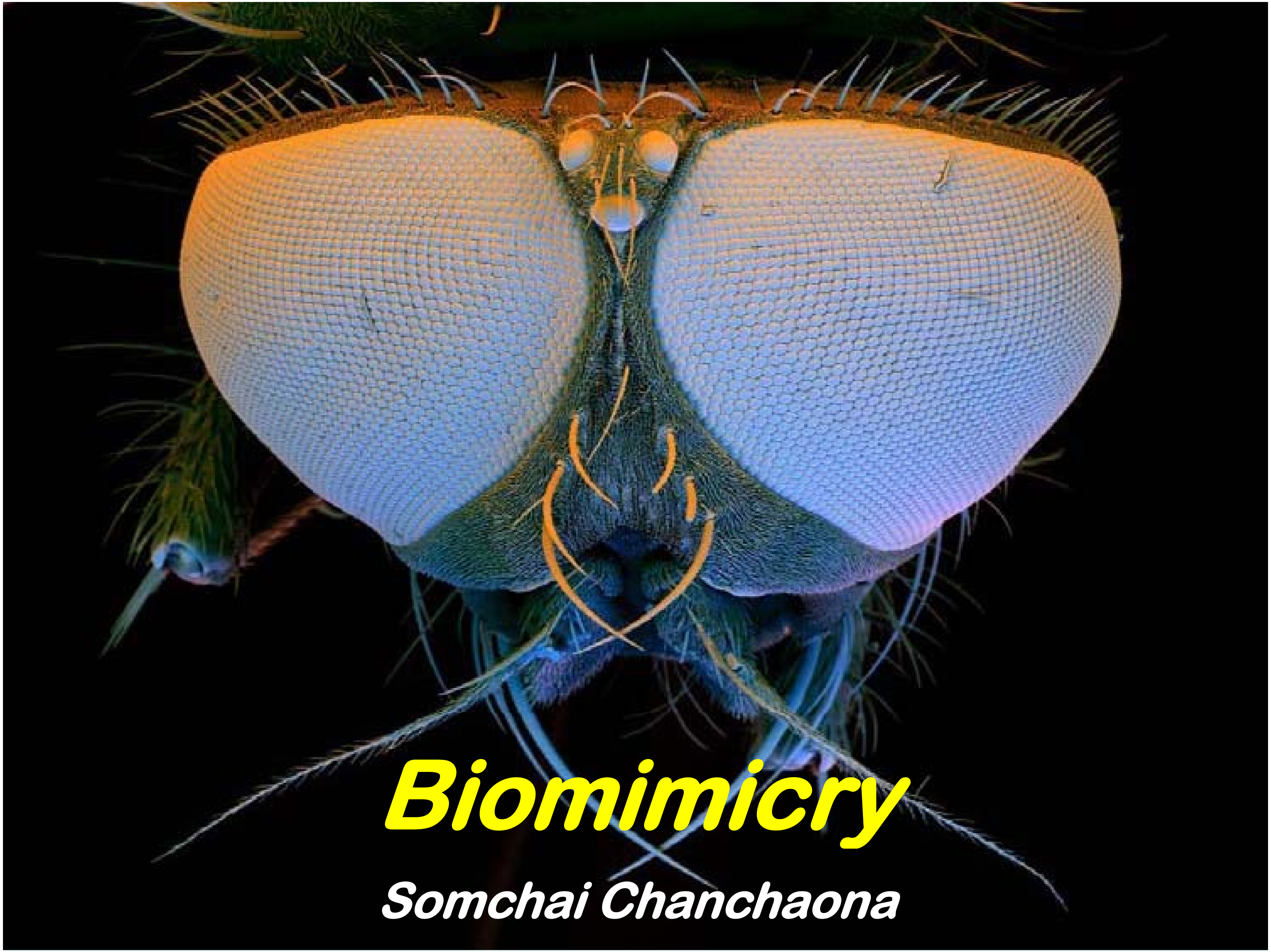


# Biomimicry

*Somchai Chanchaona*

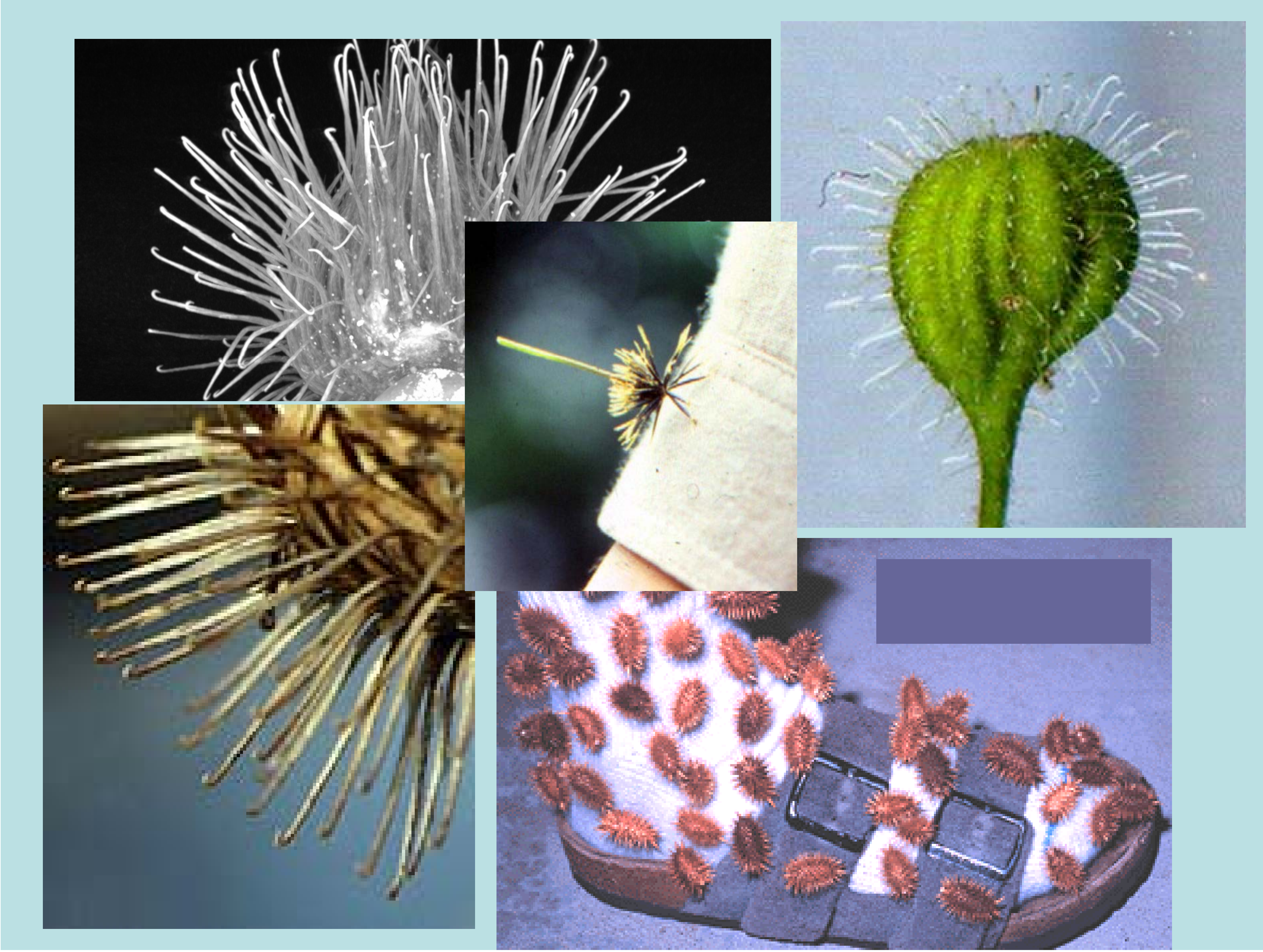
Biomimetics

Biomimicry

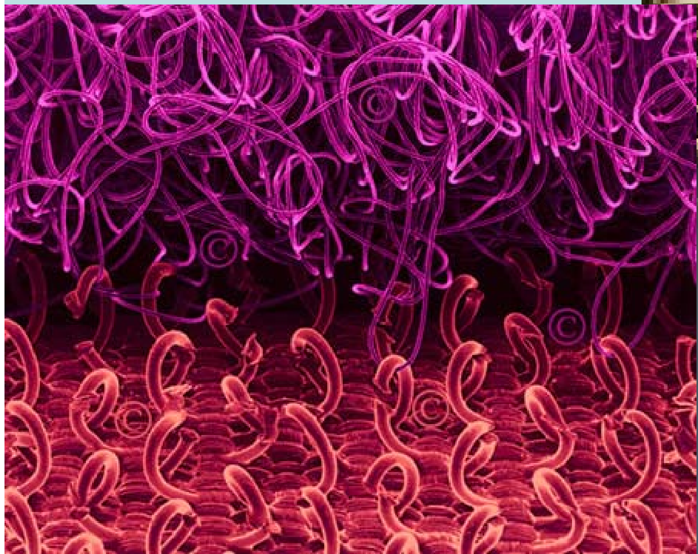
Bio-inspired

Bionics

One day in 1948, the Swiss engineer George de Mestral was cleaning his dog of burrs picked up on a walk when he realized how the hooks of the burrs clung to the fur. His realization led to the invention of Velcro -- and a multimillion-dollar industry.



# *Burdock →Velcro*



# *Thorn to Wire Fence*

**1868, Michael Kelly, Patent**

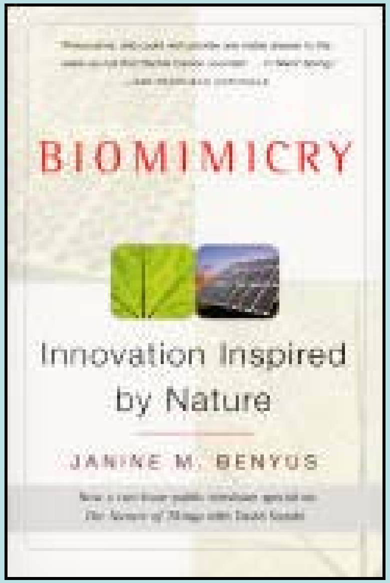
# What is Biomimetics/Biomimicry?

# Biomimetics:

**The study of the structure and function of biological systems as models for the design and engineering of materials.**

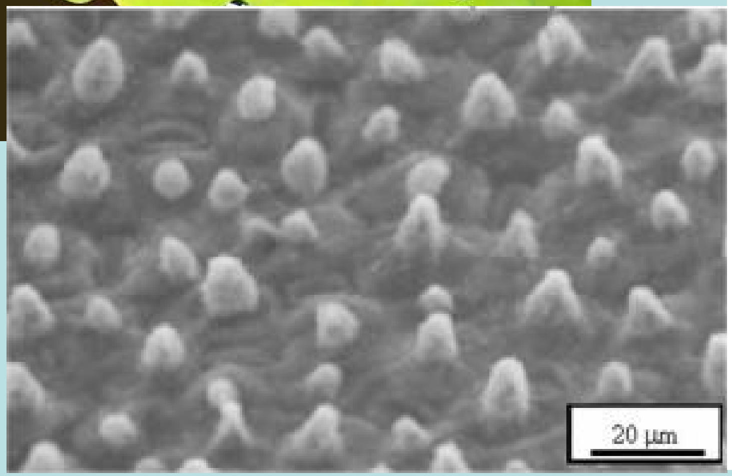
# Biomimicry: Innovation Inspired by Nature
## --Janine Benyus

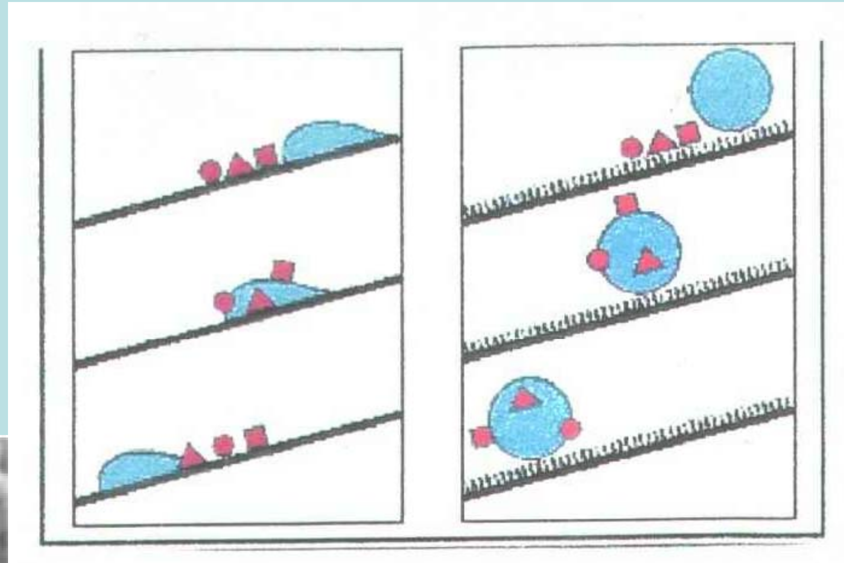
- Using natural processes as the model for agriculture and business.
- Advances in materials and medicine based on research into natural processes.



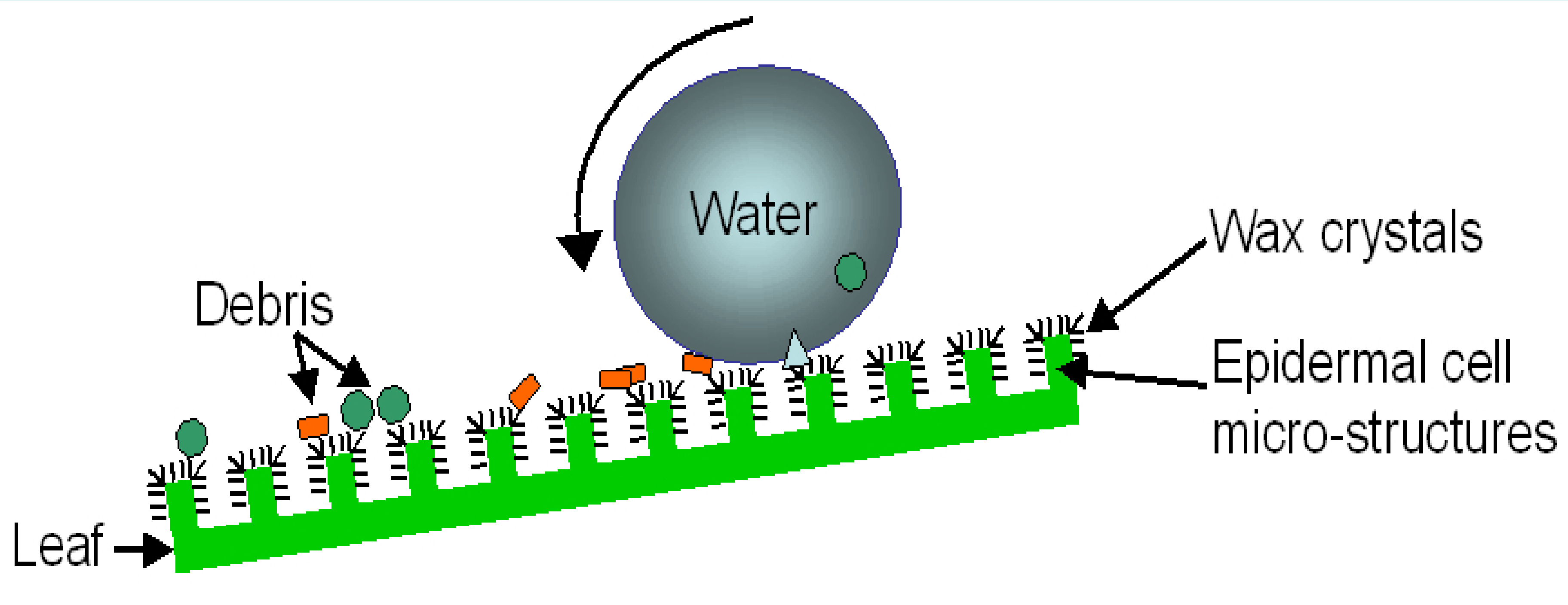
# *Lotus Effect*

## Hydrophobicity and self-clean

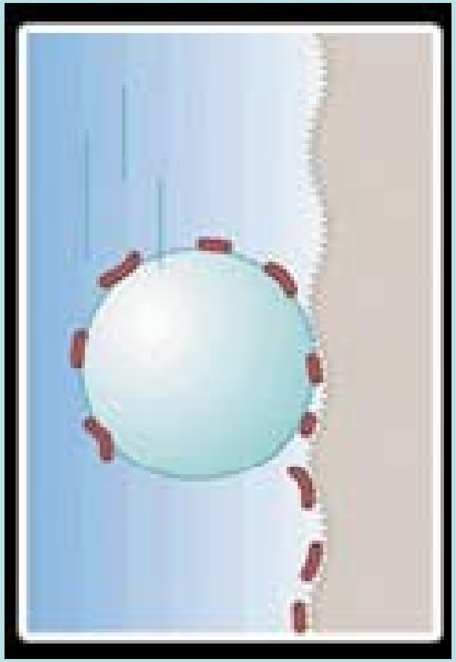


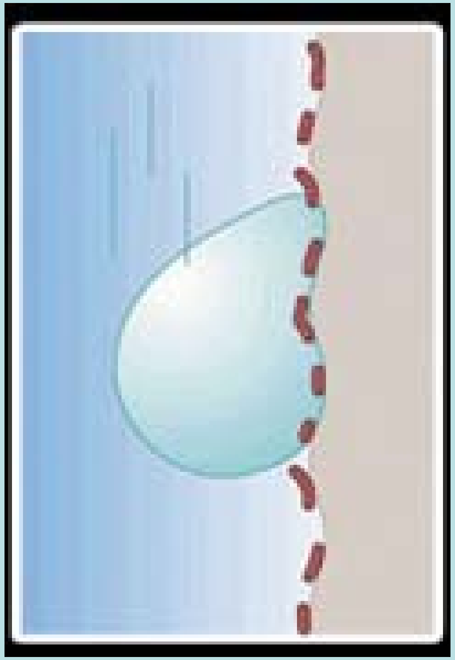
Comprehensive diagram illustrating the connection between roughness and self-cleaning: While on a smooth surface (left) dirt particles are only moved by the water droplet, on a rough surface (right) they adhere to the water droplet and are carried and washed away by the droplet while rolling down the surface.



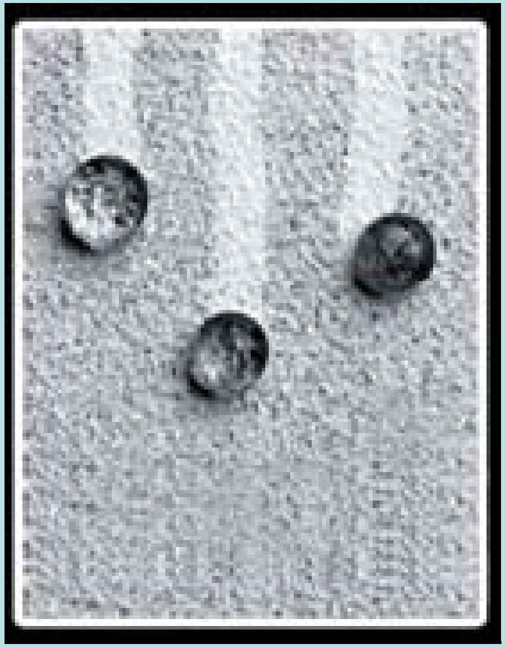

**The Lotus Effect. Water forms droplets on the tips of the epidermal protrusions and collects pollutants, dirt and small insects as it rolls off the leaf.**



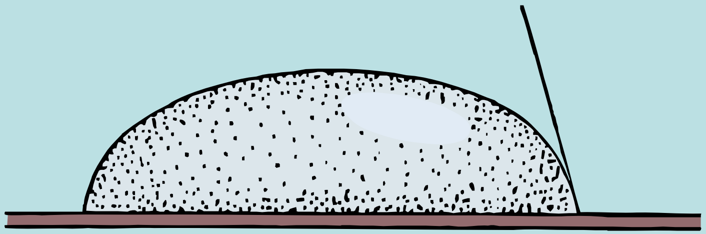
How a raindrop cleans a lotus leaf



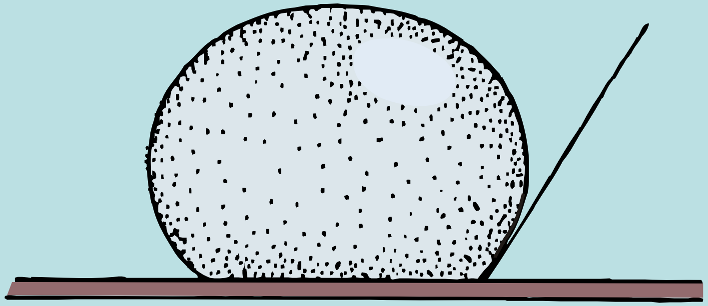
The effect of a raindrop on a normal surface



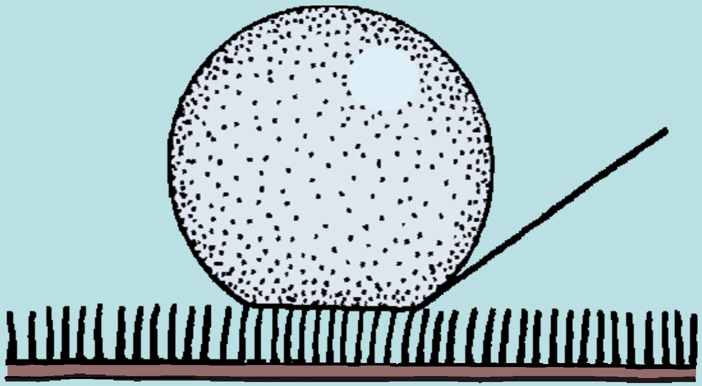
The effect of raindrops on a building exterior covered with Lotusan.



Adhesion > Cohesion

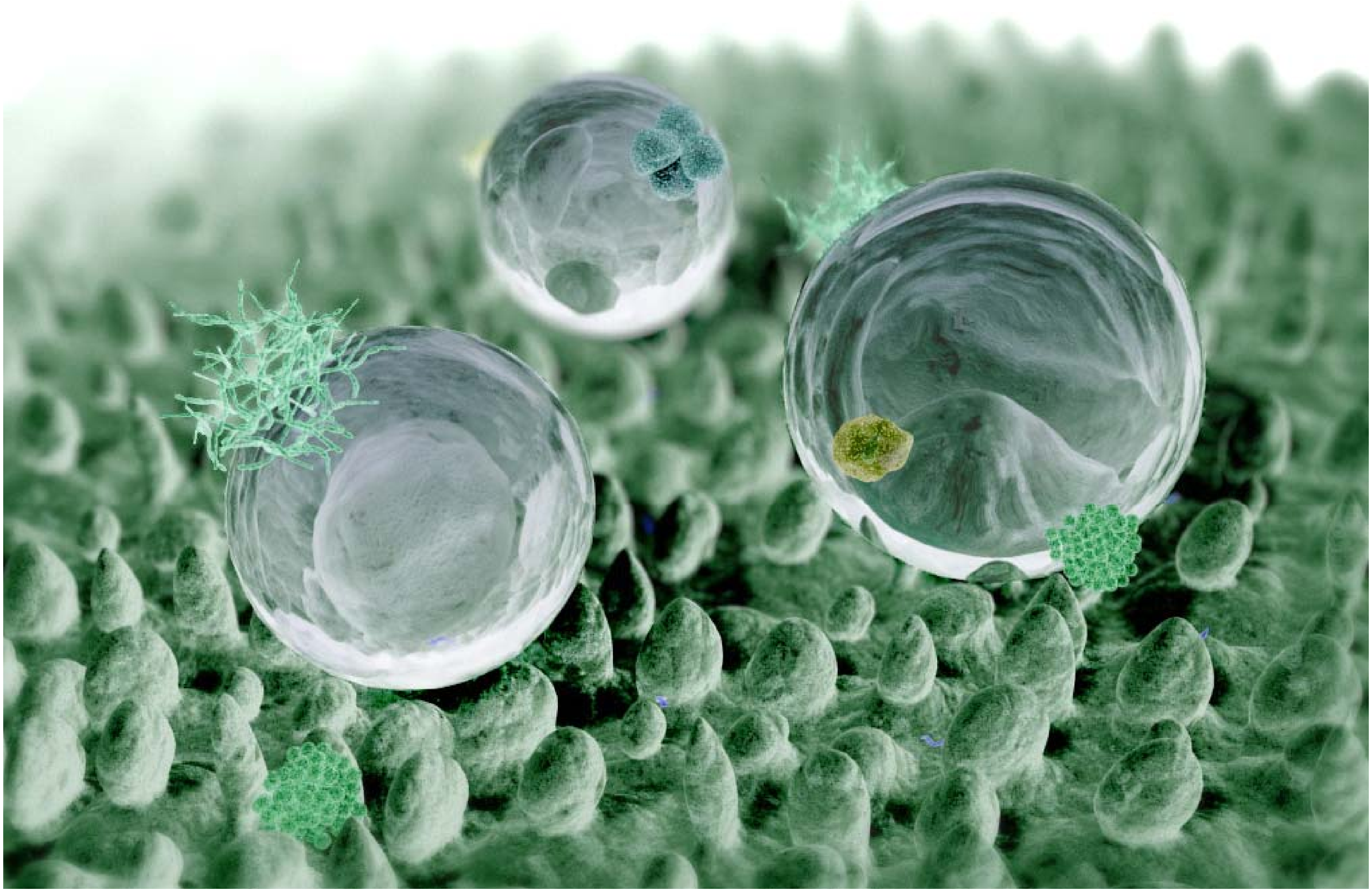


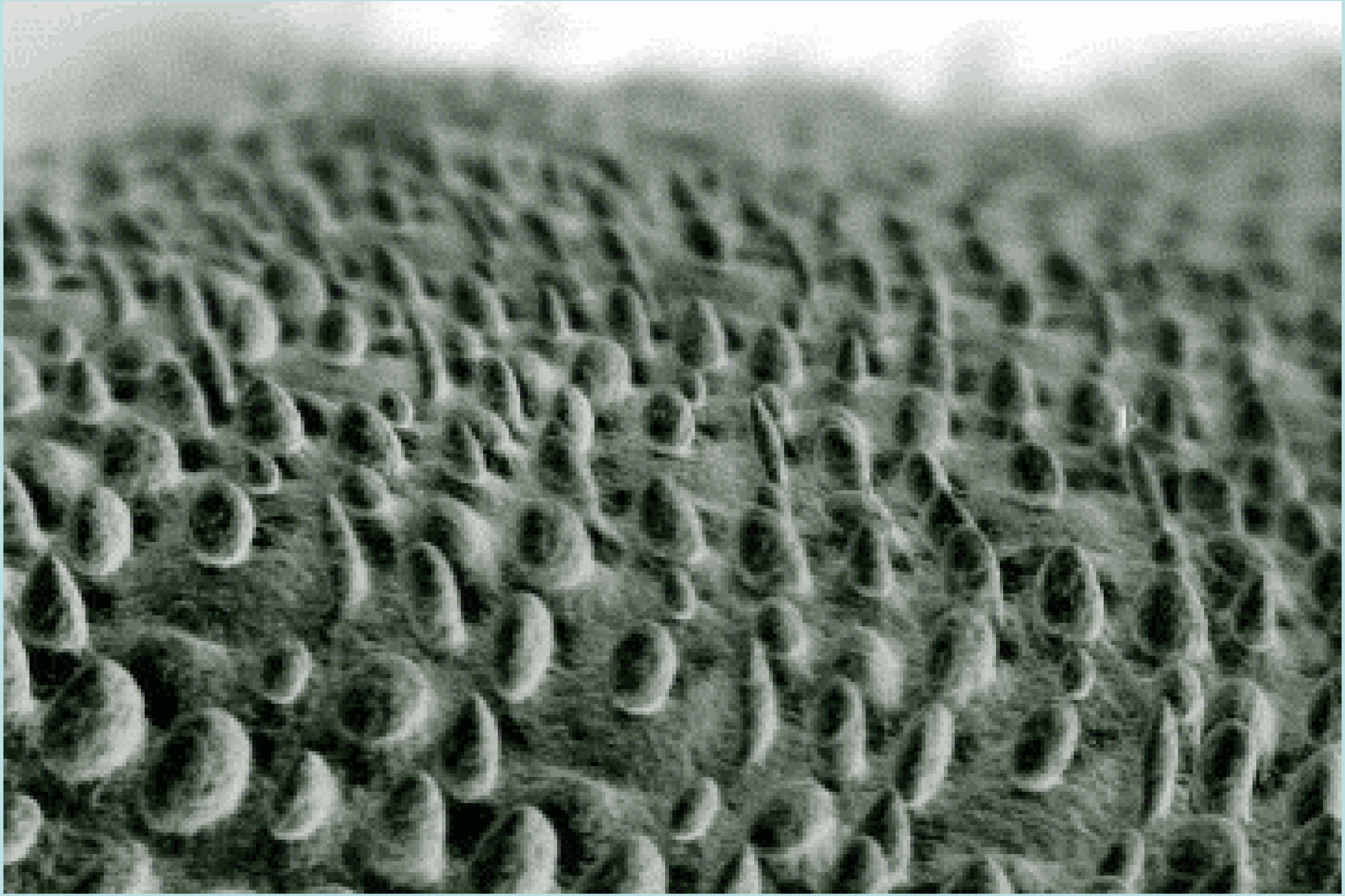
Adhesion < Cohesion



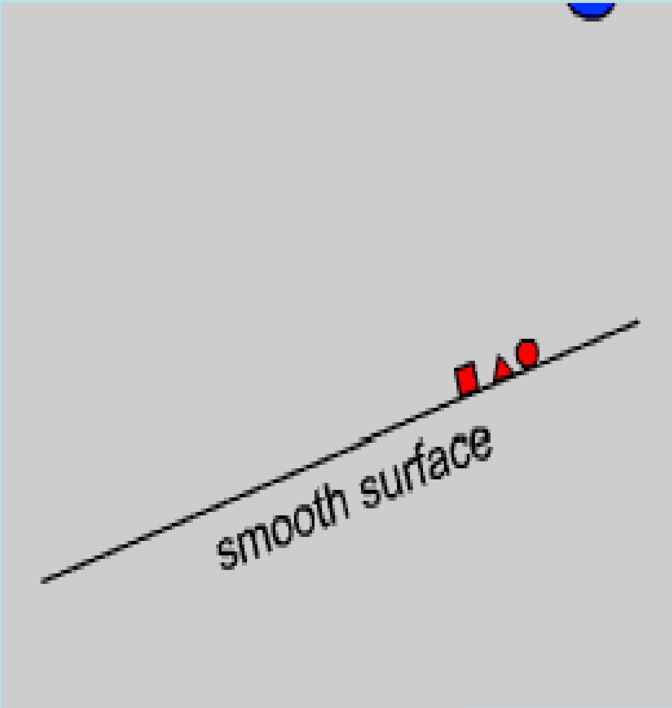
Adhesion << Cohesion

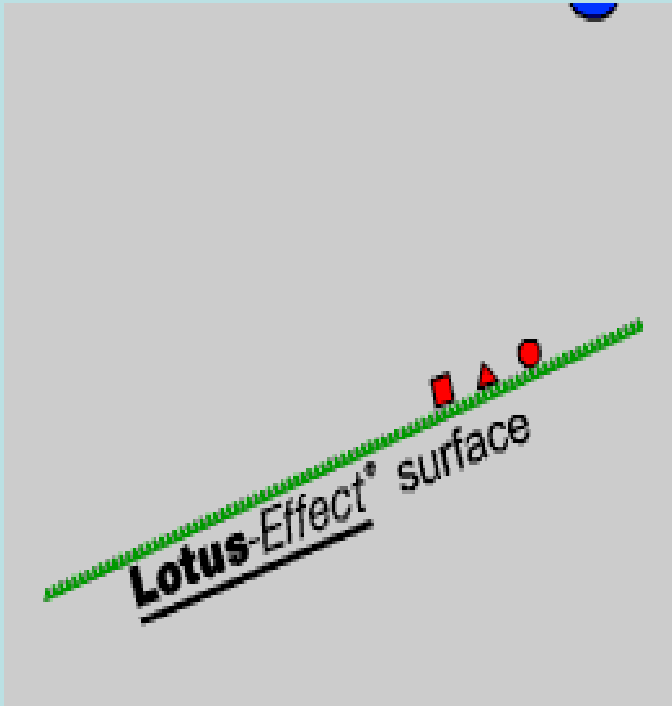
# Surface tension and wetting angle





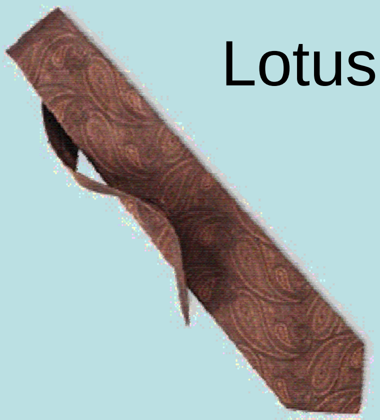
# Mechanism




Test areas at the wall of a house after 4 years


Lotus-Effect® roof tile



Lotus-Effect® tie

Prof. Wilhelm Barthlott

# *High fuel efficiency concept vehicle based on the body shape of Boxfish*

Bionic car, 20 percent lower fuel consumption and up to 80 percent lower nitrogen oxide emissions.

(Source: DaimlerChrysler 2007)


The Mecedes-Benz **Bionic Car Concept** 2007 was inspired in the boxfish be due his anatomic characteristics.

PHOTO: DOMINIK BUTZMANN
COURTESY: MERCEDES-BENZ

**COOL SCHOOL: Dieter Gurtler discovered that the fastest fish aren't the most efficient, a principle he then applied to car design.**

# *Octopus to Jet Engine*

# Eyes of Moth to Autoflex MARAG

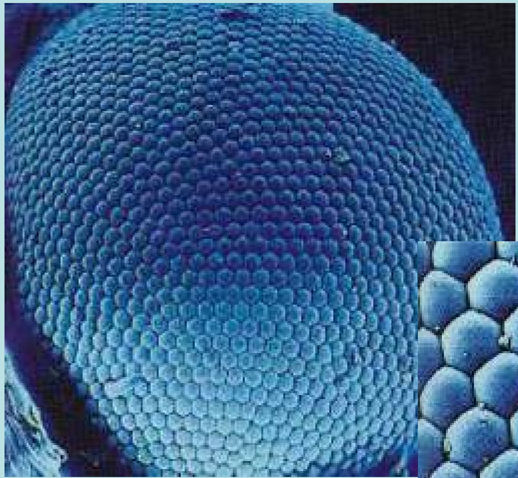
## (MothEye Anti-Reflective, Anti-Glare)


These compound eye structures have evolved to collect as much light as possible without reflection, in order to prevent moths being detected by night time predators. Applications include flat panel displays, touch screen interfaces, electroluminescent lamps and lenses for mobile phones and PDAs.

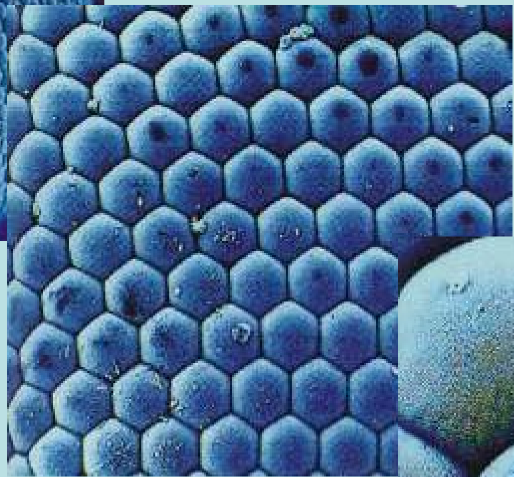
Autotype, one of the world's leading developers and manufacturers of film and chemical products, recently launched a new anti-reflective, anti-glare film inspired by the eye structure of night flying moths. Developed jointly by Autotype and the Fraunhofer Institute for Solar Energy in Germany, the new Autoflex film replicates the nano-structures found in the eyes of moths.

# Micro-optics of the moth eye

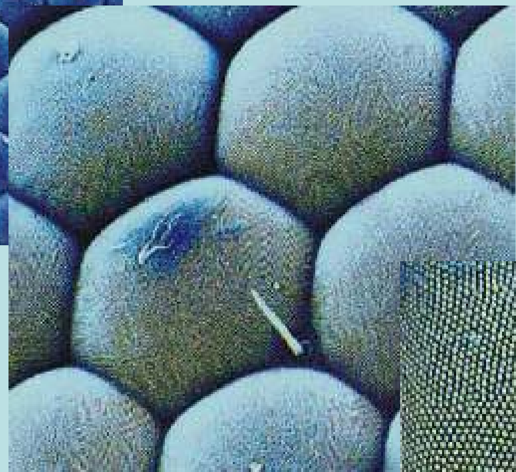
130 x



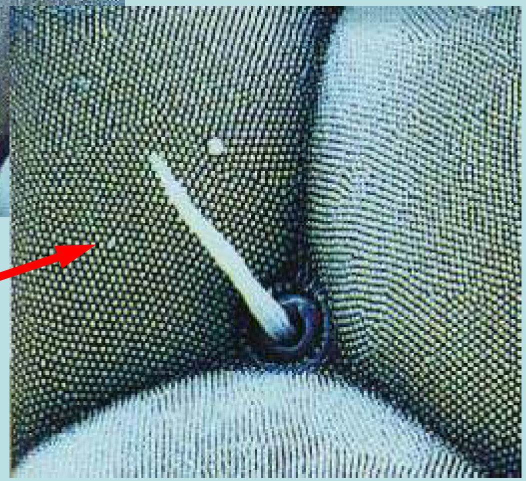
420 x



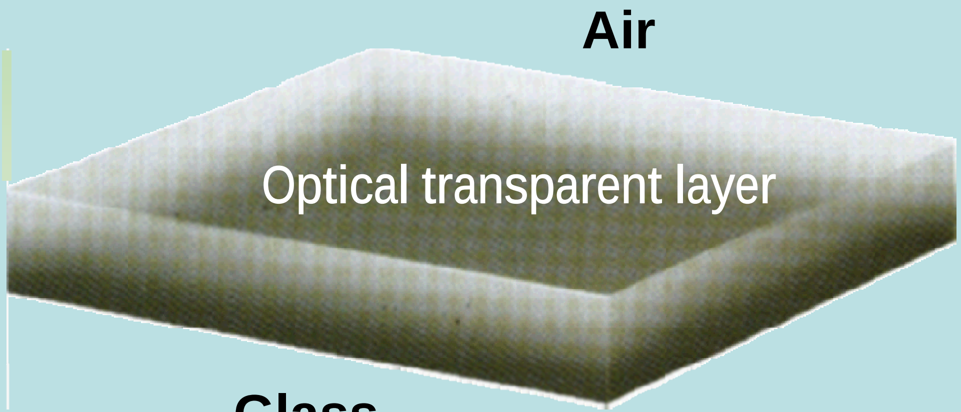
1050 x



4120 x

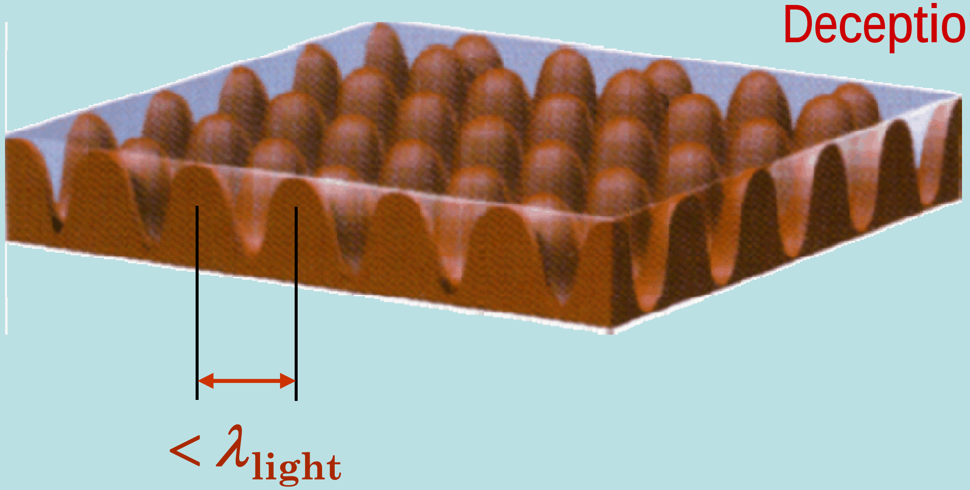


**Micro-burls**
100 nm Ø




Reflection of the light is avoided by a continuously increasing refractive index of the optical medium

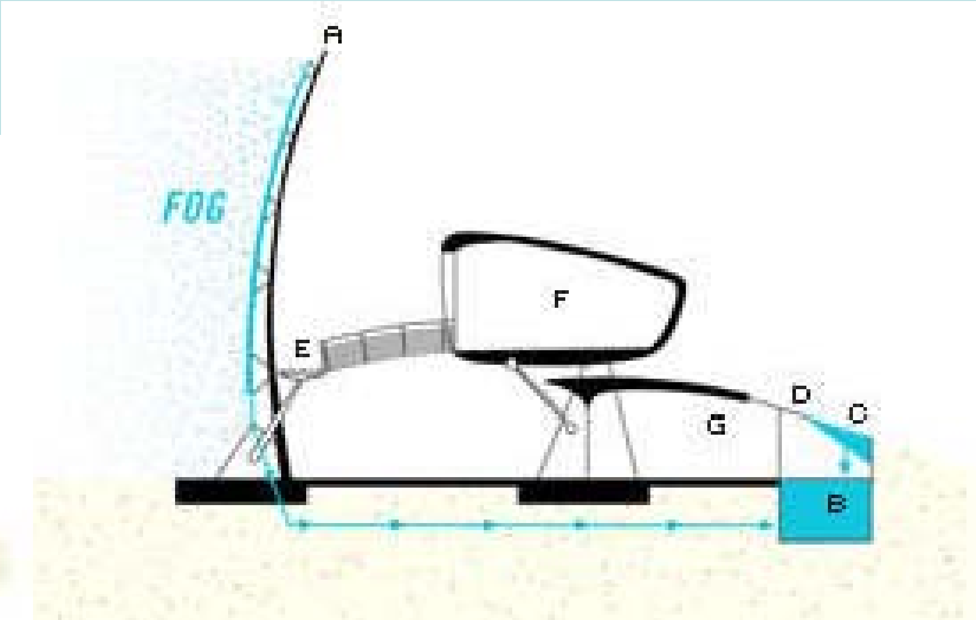
Deception of the light




The little burls on the surface of the optical medium work as a gentle increase of the refractive index

Namib Desert beetle

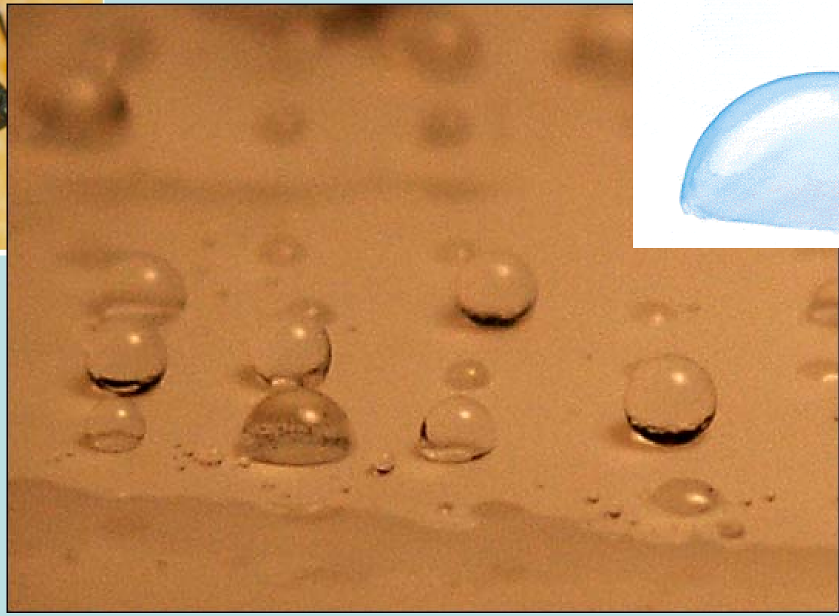
# Beetle-inspired water harvester: The pose

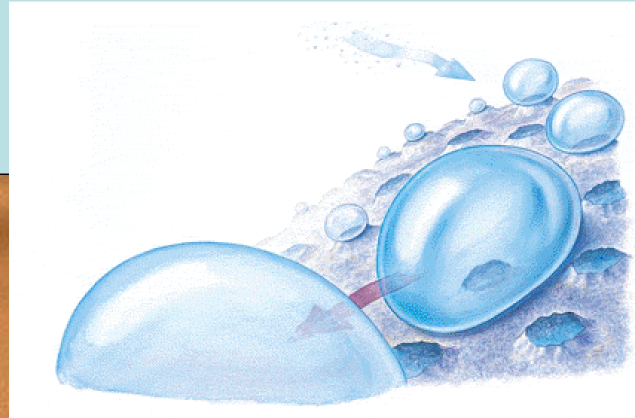



A nylon-mesh sail (a) collects the fog as it rolls in. As the mesh becomes saturated, gravity feeds the water into an underground tank (b), where it joins pumped-in seawater (c) that has been desalinated using photovoltaic panels (d). A footbridge (e) leads to a classroom pod (f), under which is office space (g).

Photos: Left, courtesy QinetiQ; right, courtesy KSS Architects, Ltd.

# *Beetle-inspired Material for water harvester: the patterning*





New material that copies the properties of the wing surface of the Namibian desert beetle for collecting precious drinking water from an invisible mist. Inventa Partners: Air Conditioning for recycling water. 2004 (Original research by MIT)

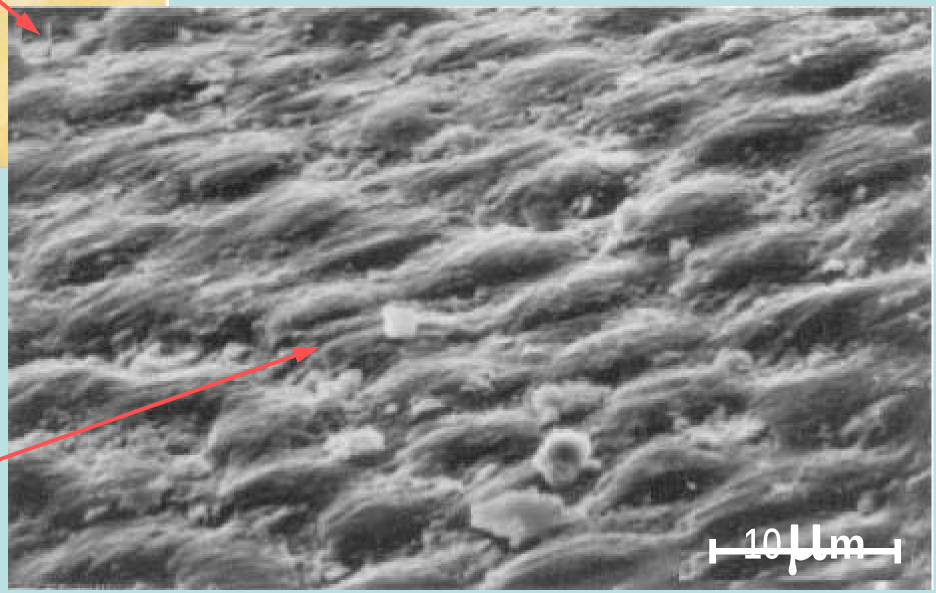
Darkling beetle of the Namib desert

(*Stenocara sp.*)

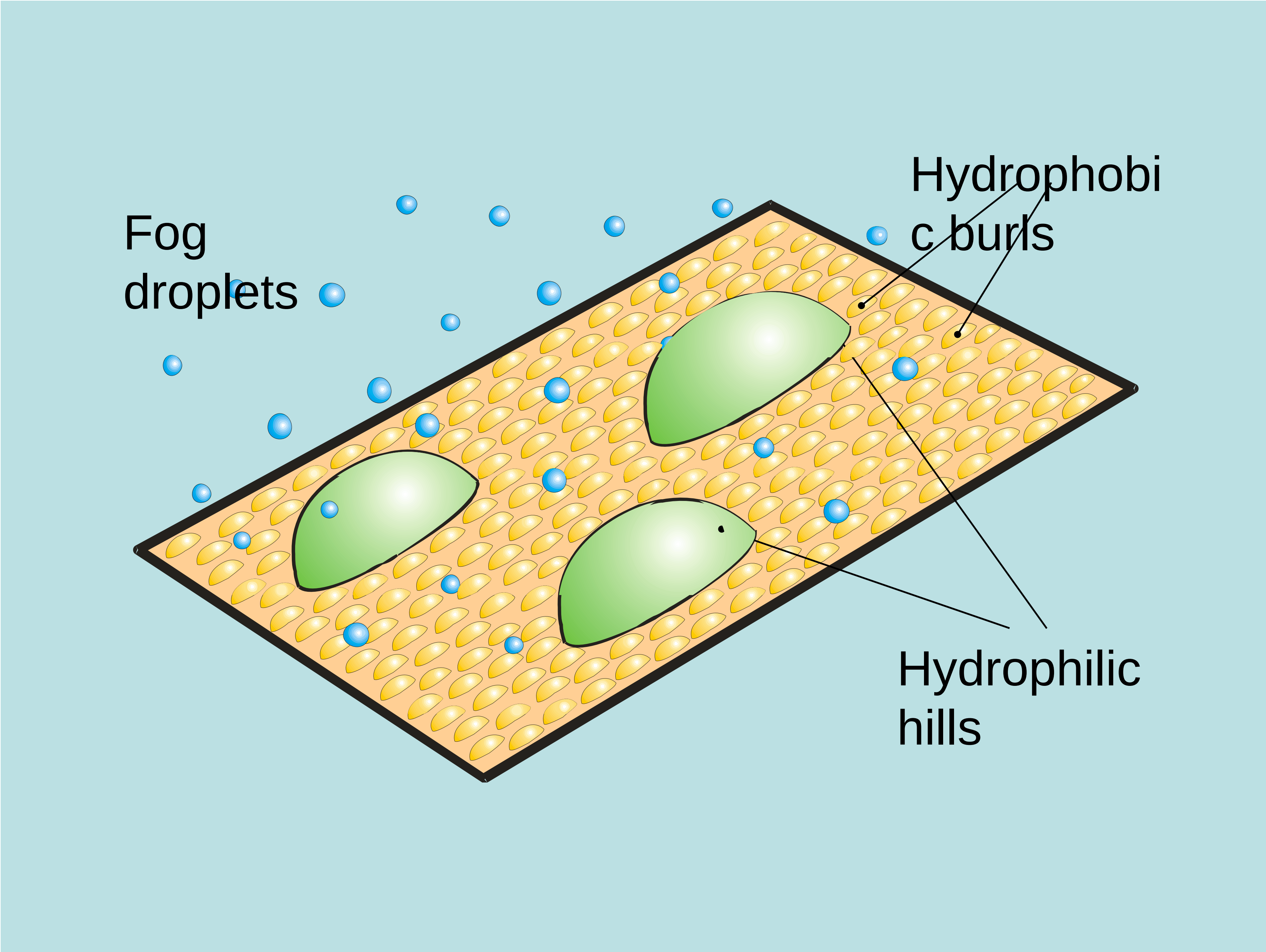
Hydrophilic peaks

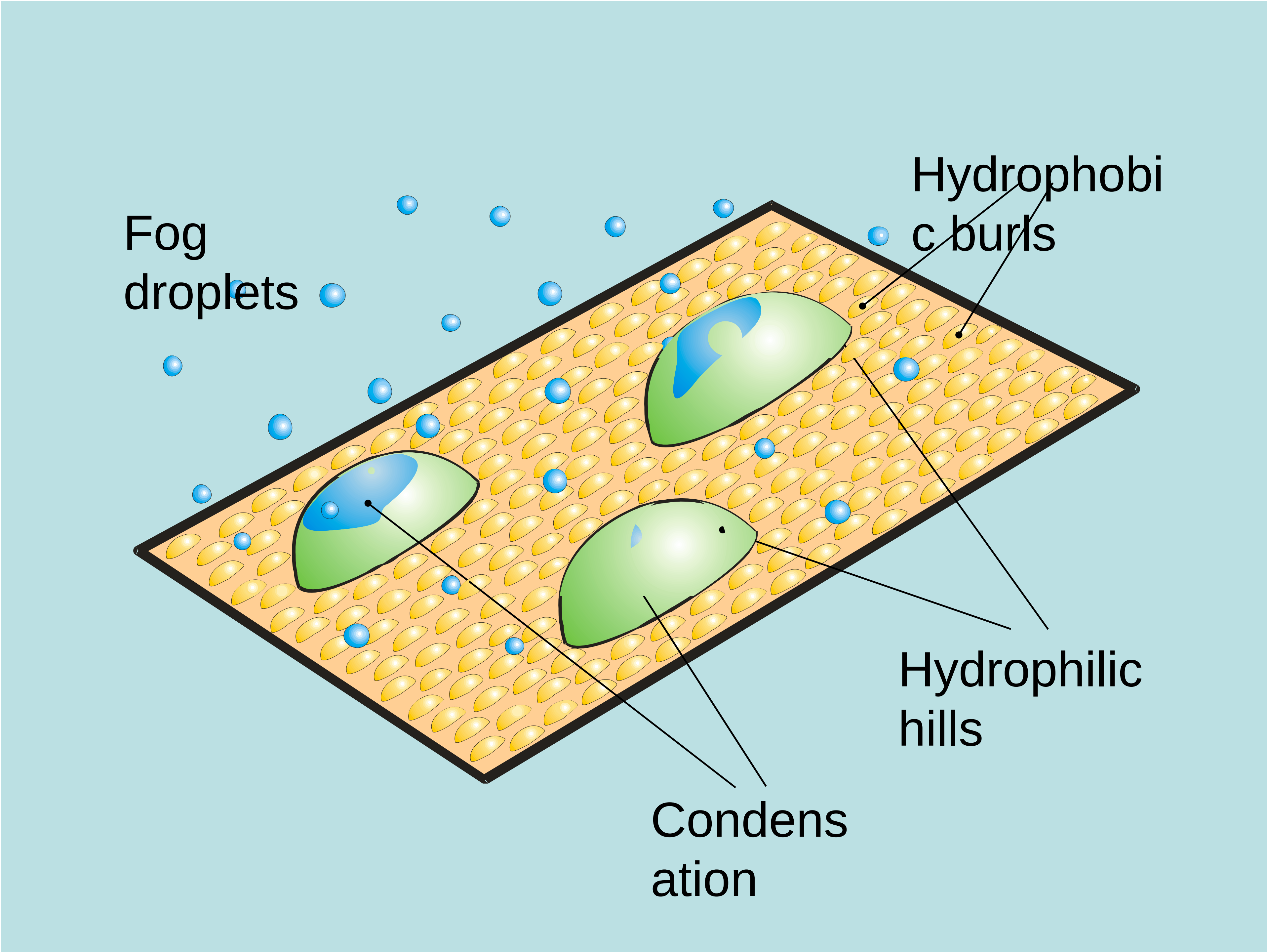
Hydrophobic burled lowland

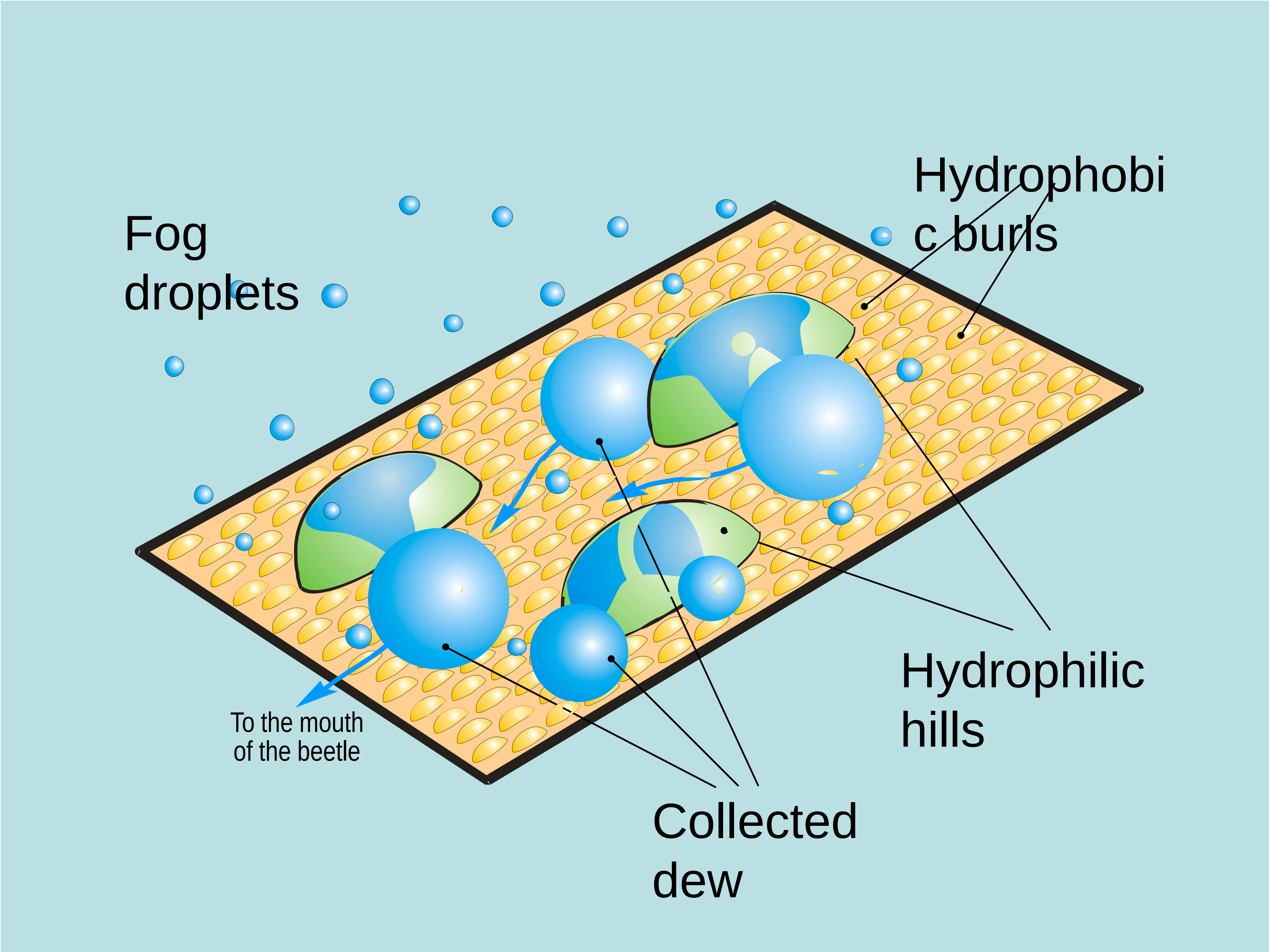
similar to the Lotus-Effect®



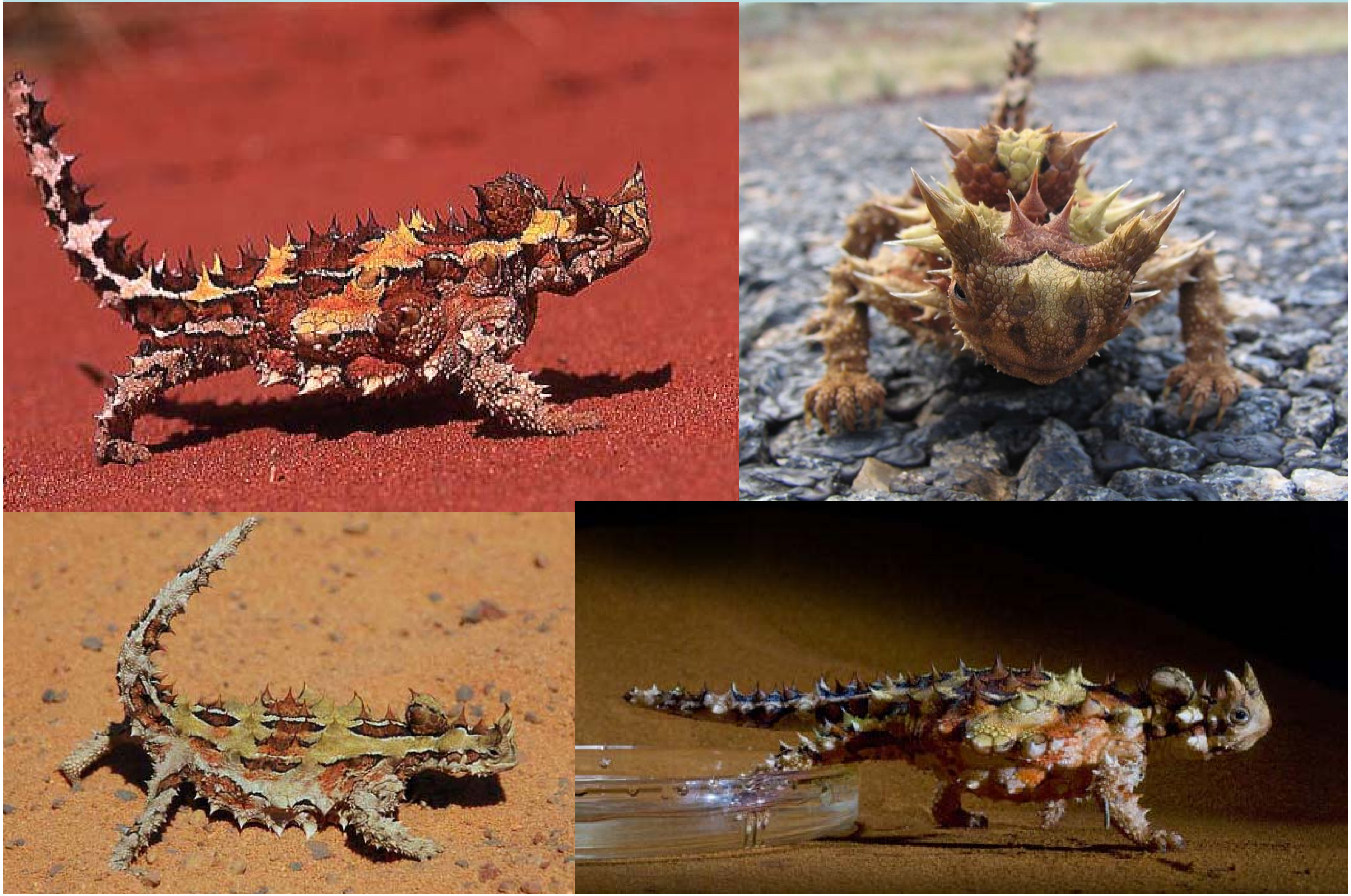

Andrew R. Parker and Chris R. Lawrence

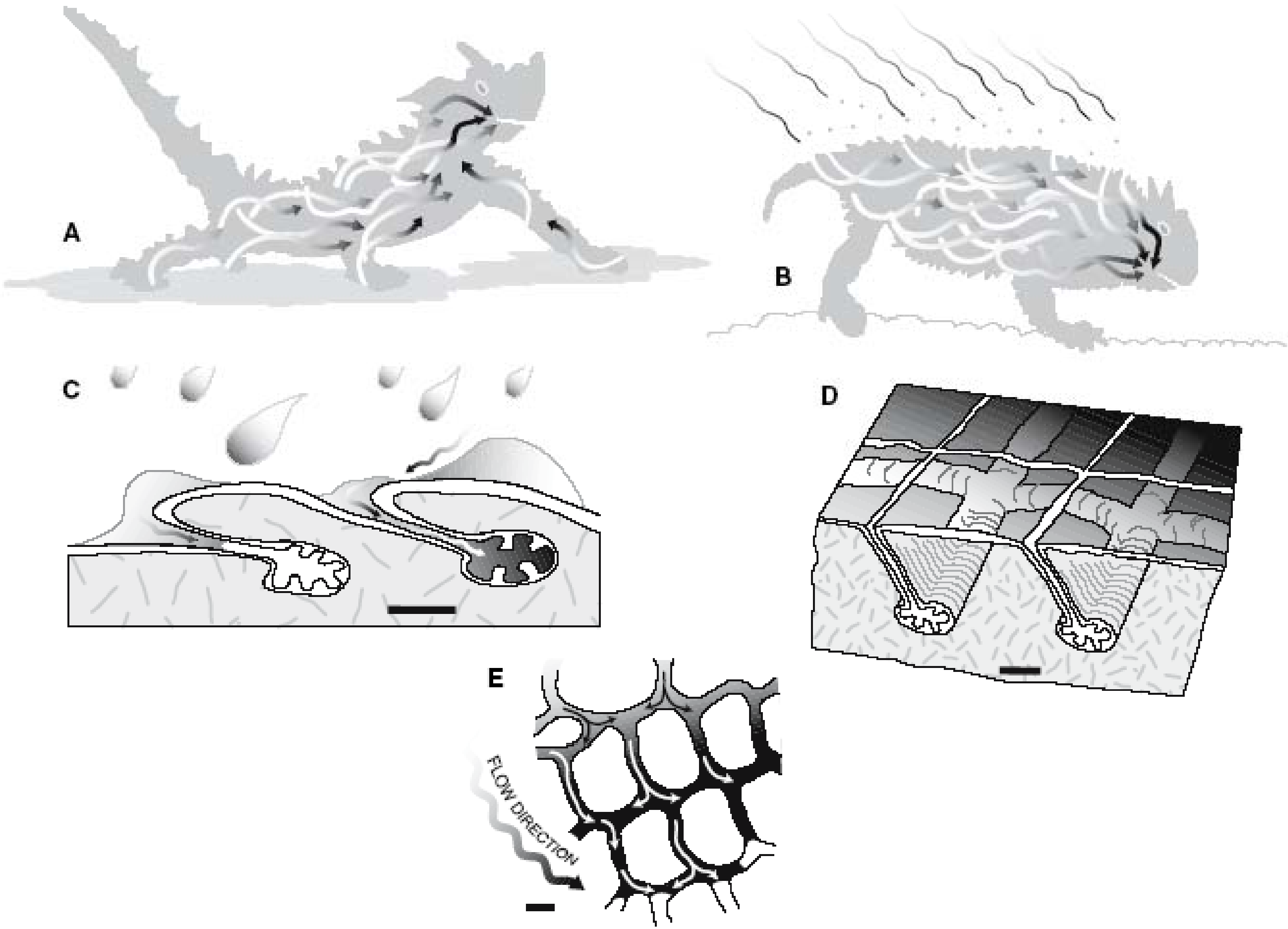

Fog
droplets
Hydrophobi
c burls
Hydrophilic
hills


Fog
droplets
Hydrophobi
c burls
Hydrophilic
hills
Condens
ation


Fog
droplets
Hydrophobi
c burls
Hydrophilic
hills
Collected
dew
To the mouth
of the beetle

# Thorny Devil Lizard

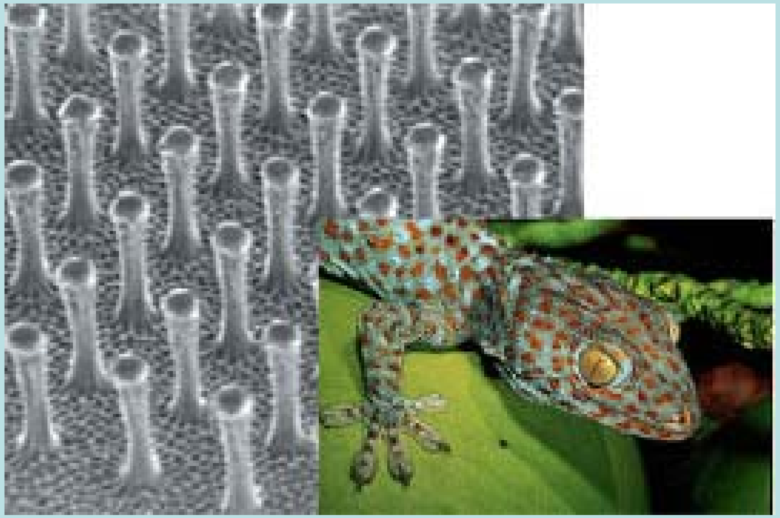


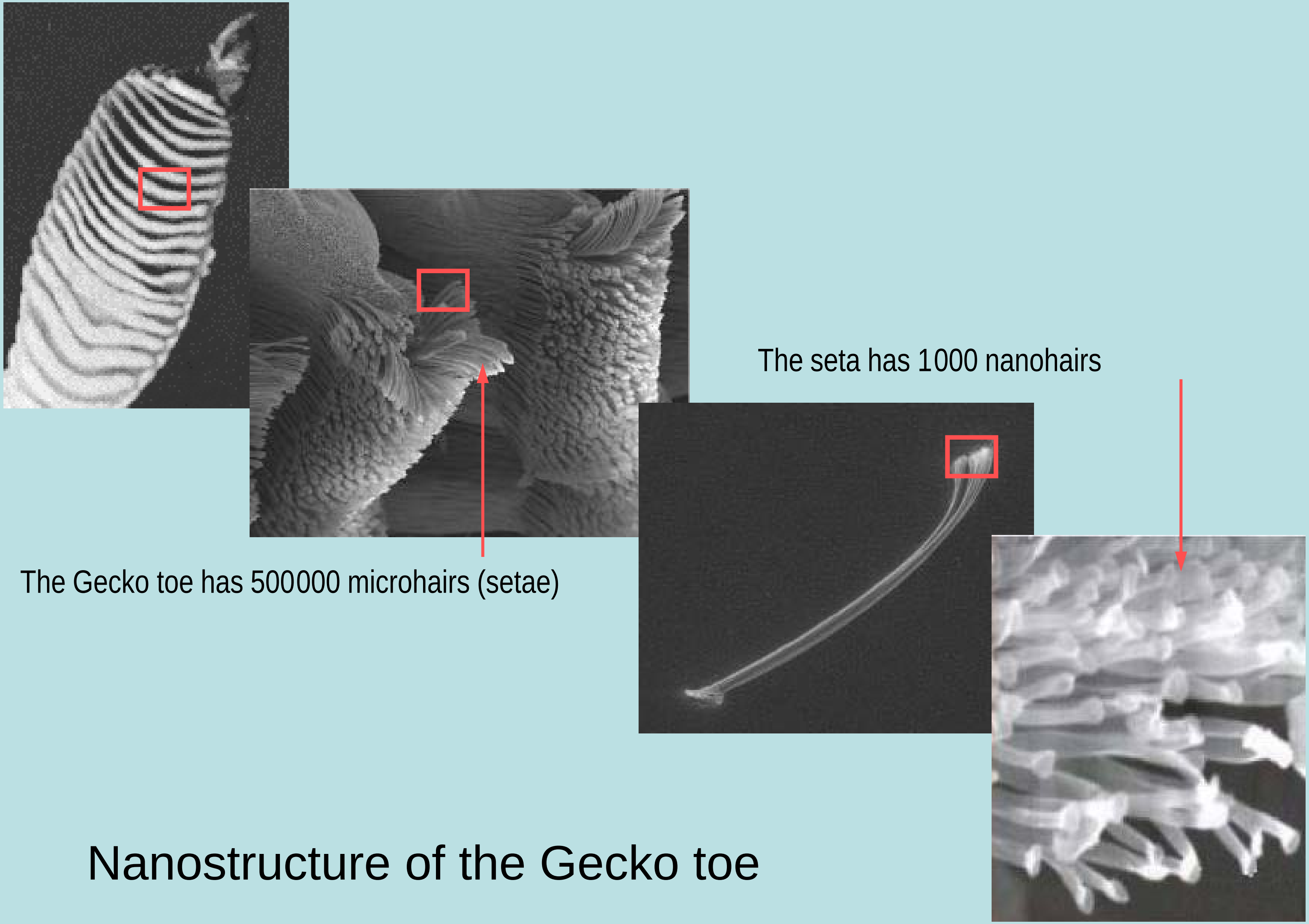


A
B
C
D
E
FLOW DIRECTION

# *Do you recognise this ?*

# *Gecko foot-hair to reusable adhesives I*

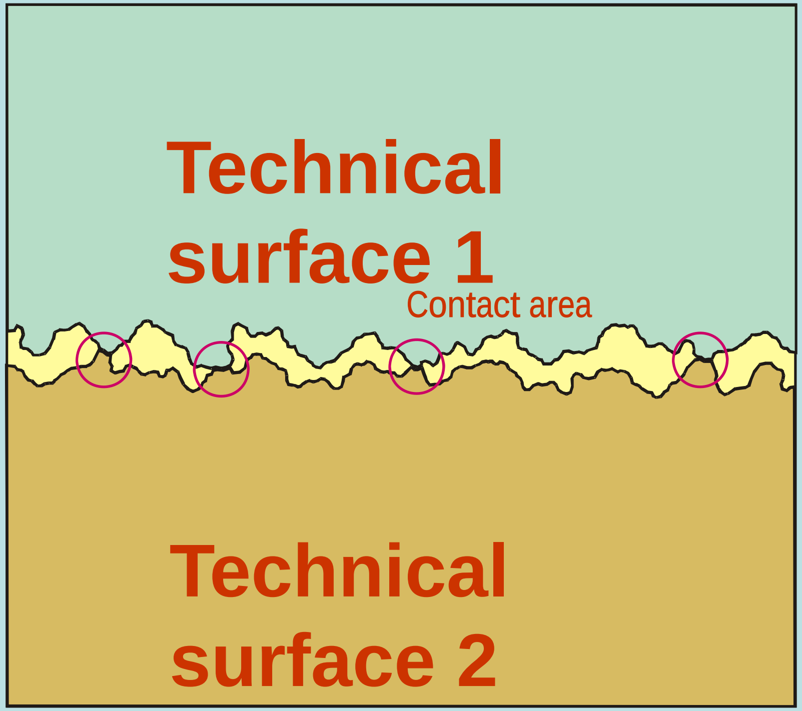


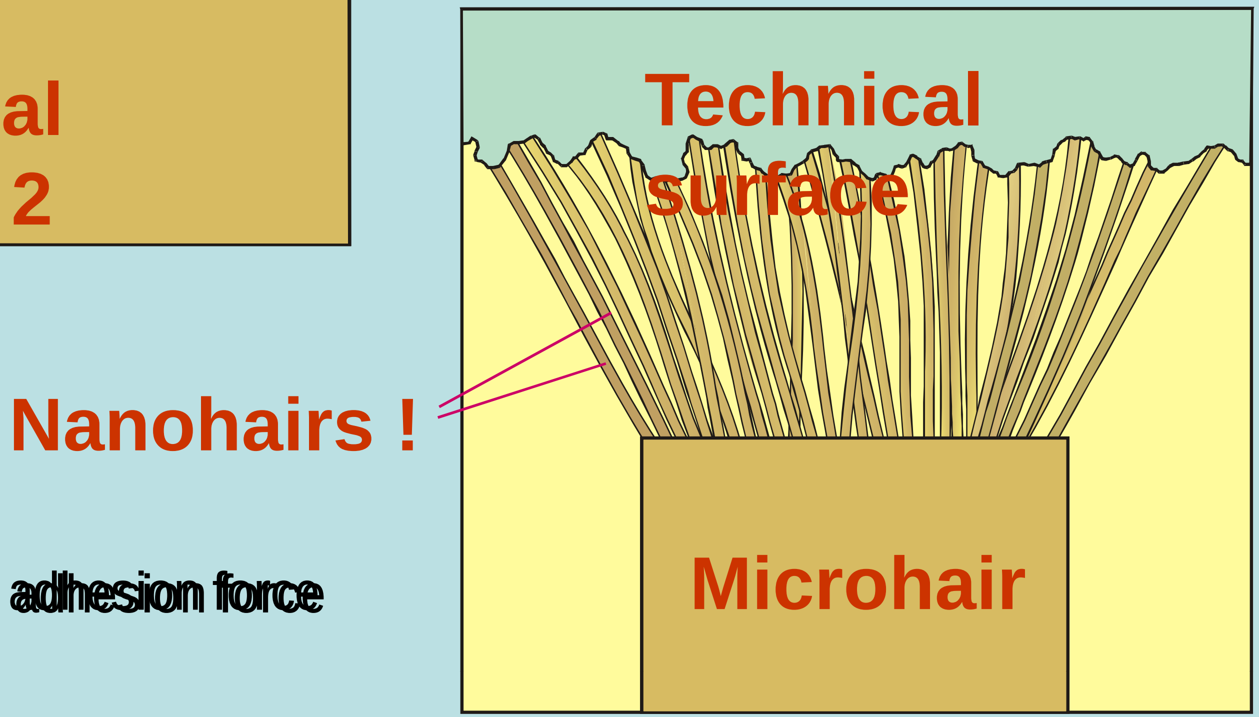



# Nanostructure of the Gecko toe

The Gecko effect

Adhesion effect through Van-der-Waals-forces



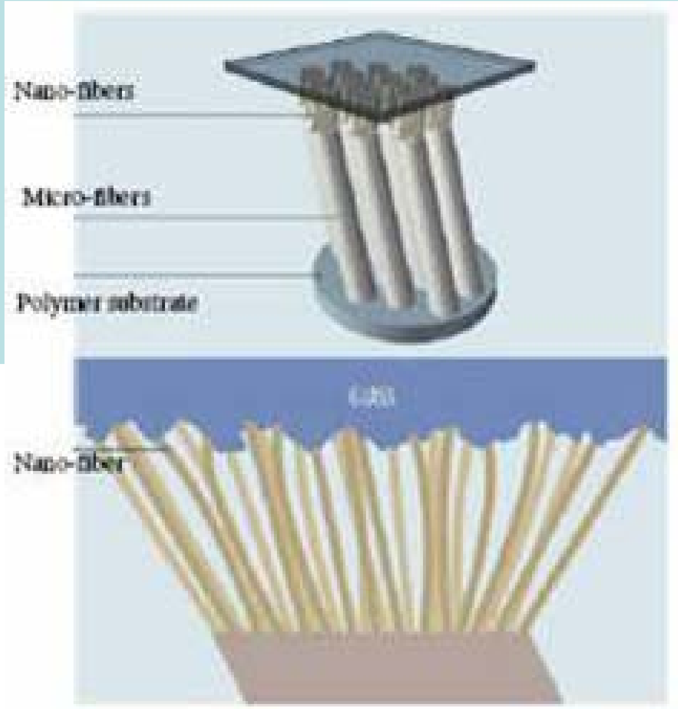

Small contact area

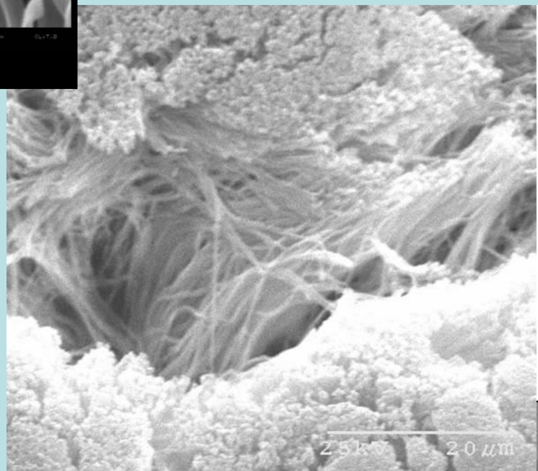
Large contact area

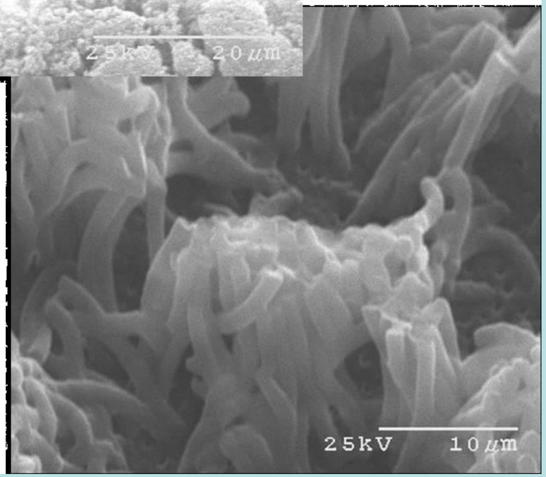
small adhesion force

large adhesion force

# *Gecko foot-hair to reusable adhesives II*

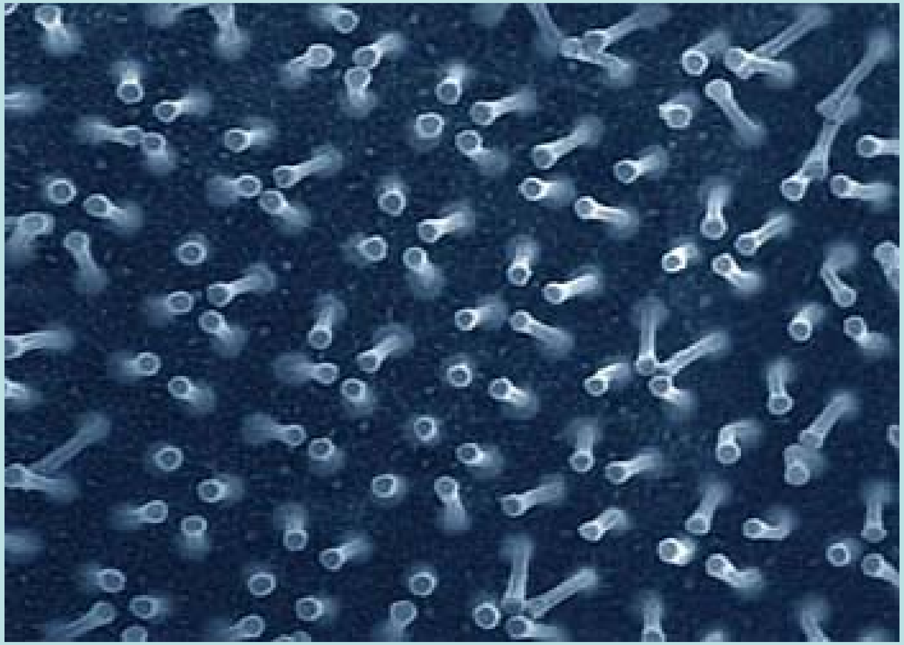





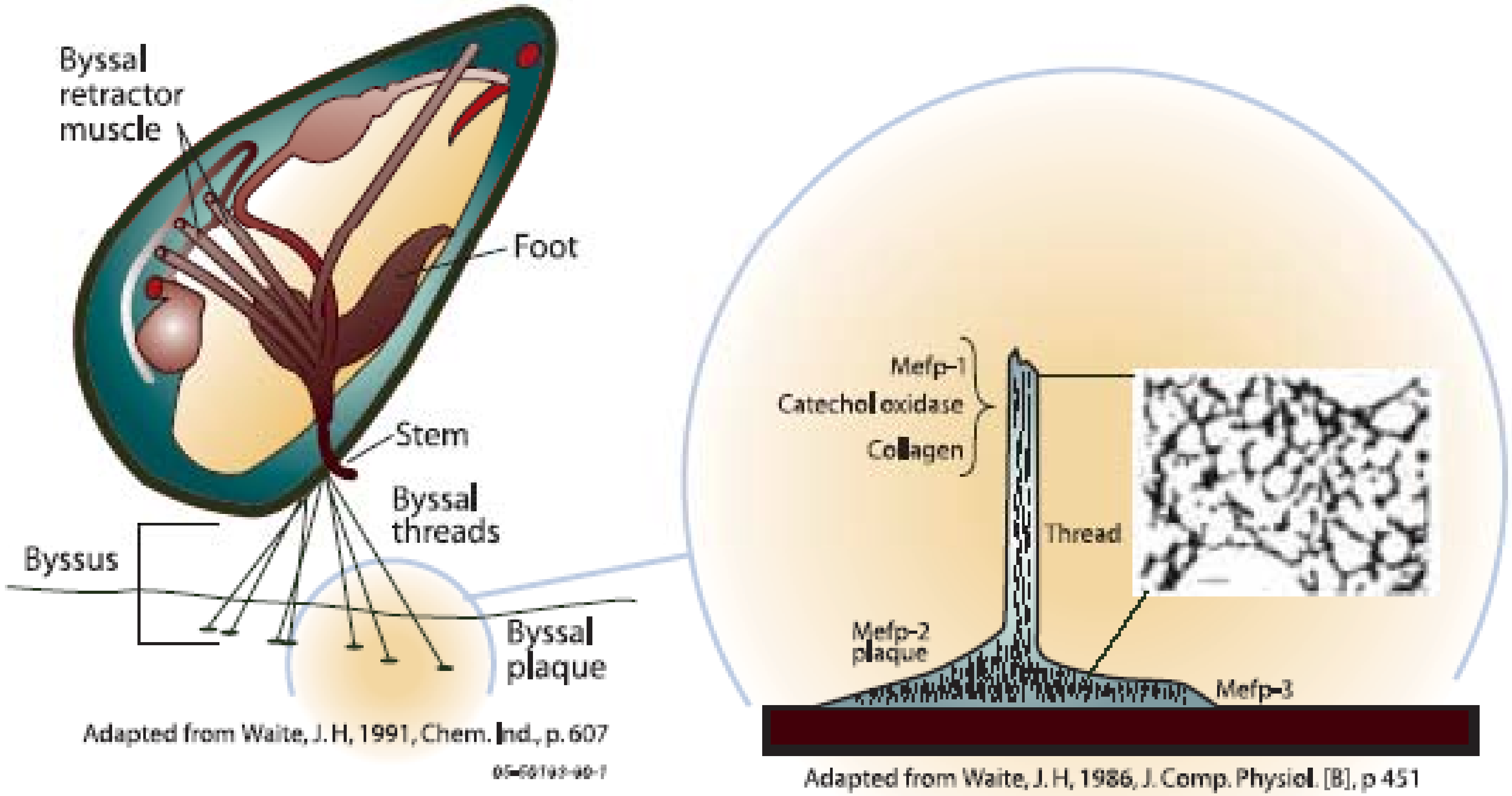

The designed hairs for adhesive pads

# Gecko-Tape



*Researchers at INL are defining natural adhesive systems at the molecular scale and are exploring ways to recombine proteins to improve adhesives. Such new adhesives may more strongly bond to a wide range of materials and do so in an environmentally friendly and safe manner.*

# Natural Adhesive Systems




***This illustration shows the Atlantic Blue Mussell, Mytilus edulis, and its adhesive structure–the byssus with byssal threads and byssal plaque–and includes a closer look at the byssal thread and plaque and the individual adhesive proteins with respect to a substrate surface.***

# *Mollusk Inspired Epoxy*

- the epoxy remain intact in seawater, but it is created at relatively low temperatures, and is environmentally safe.

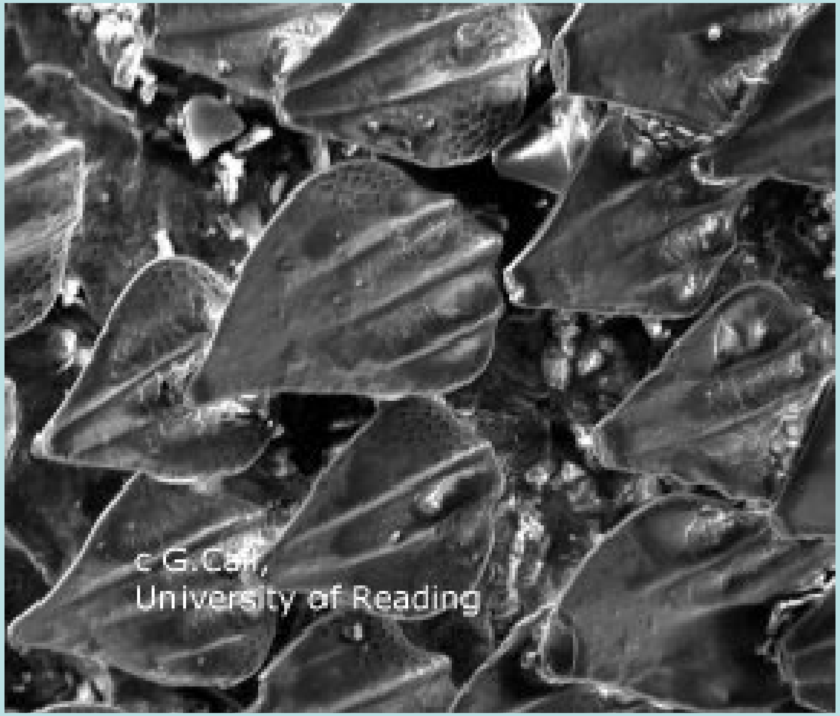

Seafood into 'super glue' (INEEL, 2000)
**DOE laboratory clones mussel proteins to create natural waterproof adhesive**

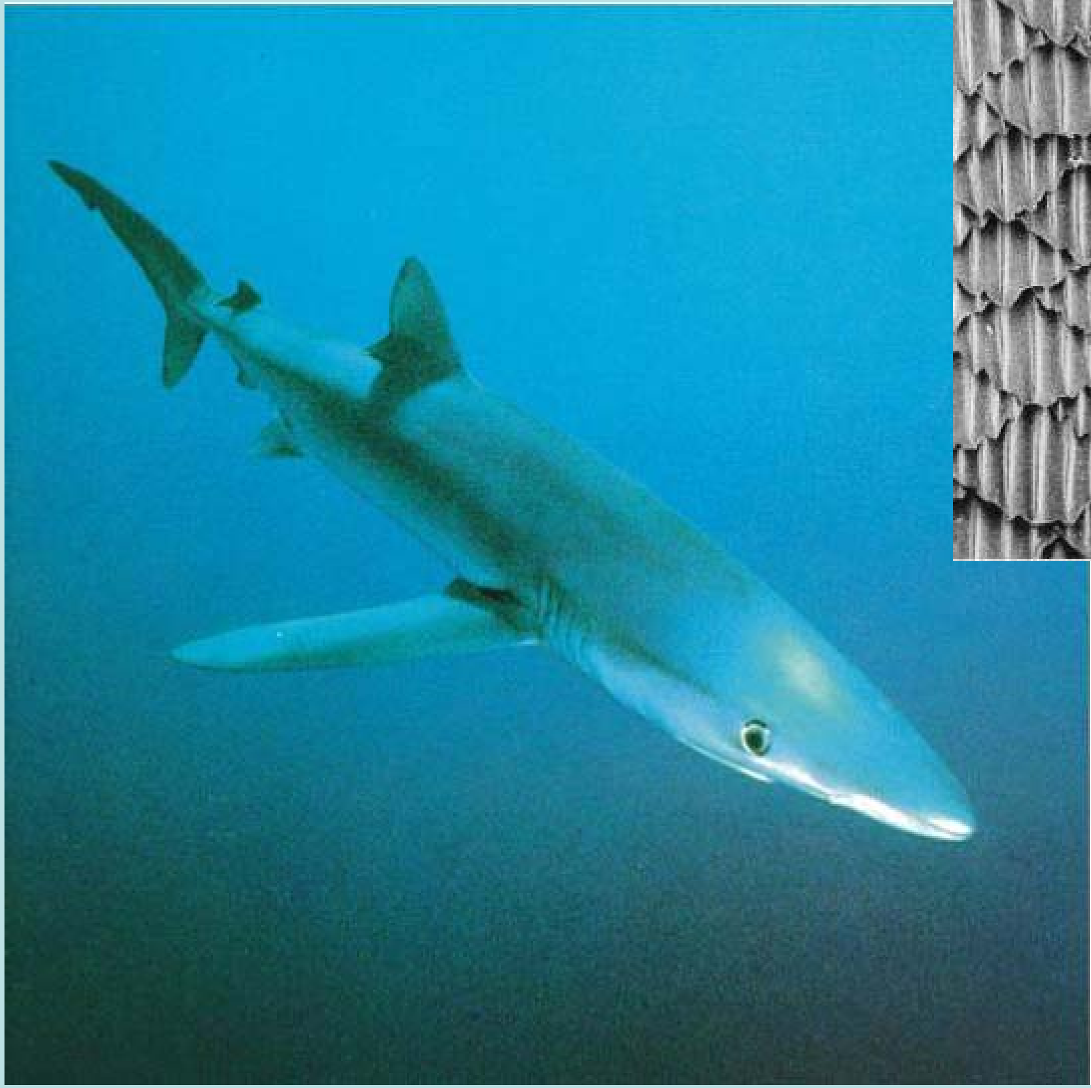
**Oregon State University**

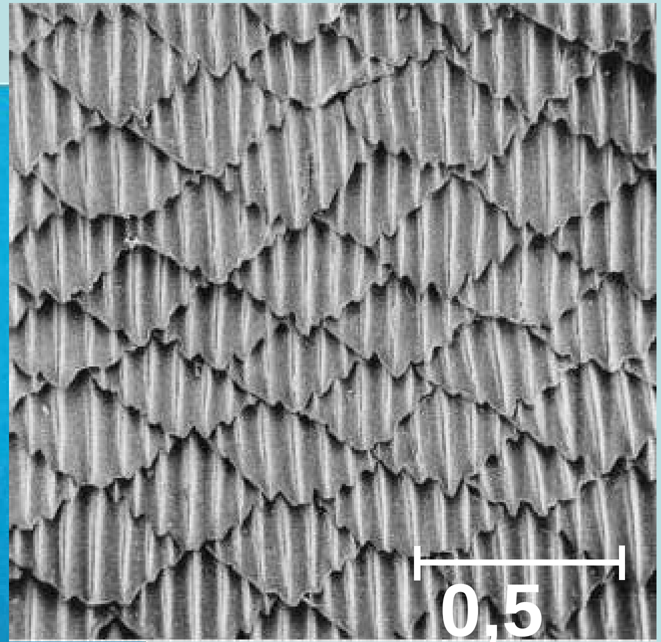
**Gecko** + **Mollusk** => Super Glue

# *Sharkskin Effect*

- Shark skin is very rough, in fact so rough that dried shark skin can be used as sanding paper.
- The skin is covered by little V-shaped bumps, made from the same material as sharks' teeth.
- The rough surface has been shown to reduce friction when the shark glides through water, which is why sharks are surprisingly quick and efficient swimmers.

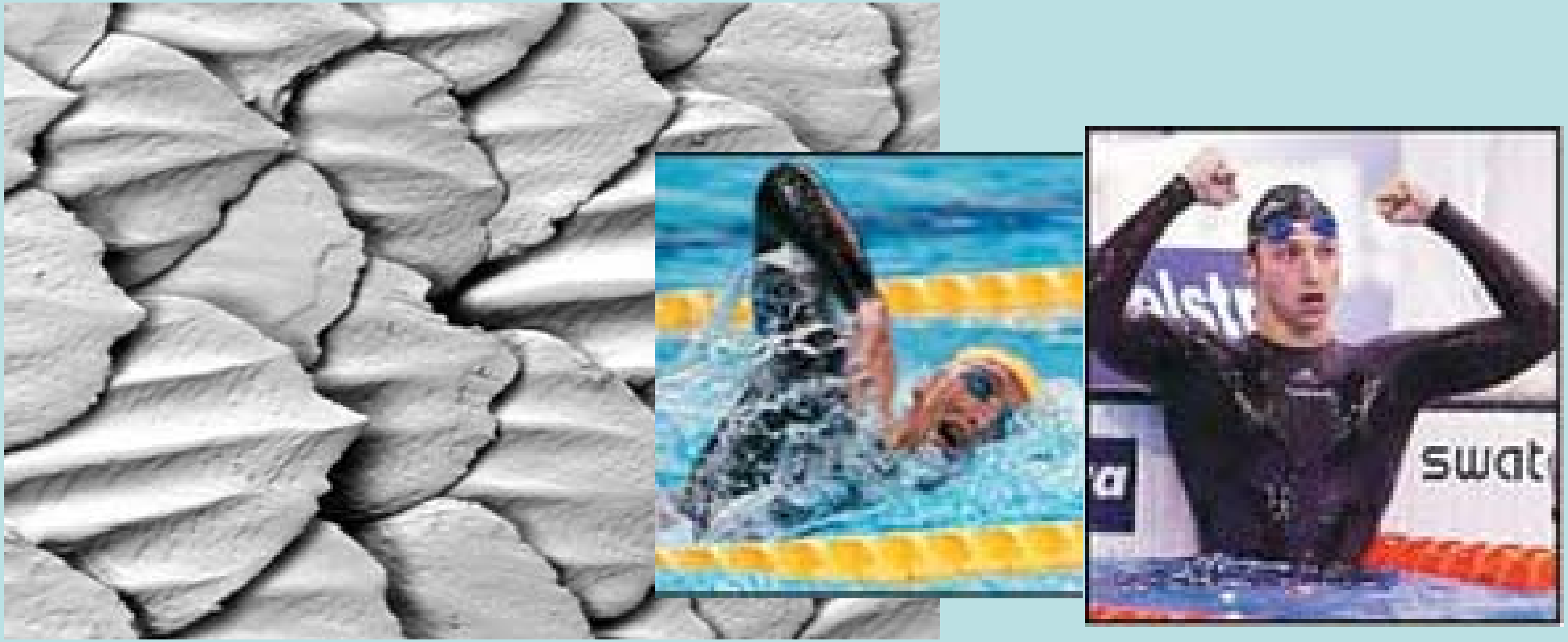







The groove structure of the shark scales

**The U-shaped channels on a shark's skin generate tiny vortexes, bringing the water closer to the body and reducing drag. The large picture on the left shows a scanning electron microscope image of shark skin. ("Fizik, Teknoloji ve Olimpiyatlar" Physics, Technology and Olympics, *Bilim ve Teknik*, 77.)**
**At the Sydney Olympics, all gold-medal-winning swimmers like the Australian Ian Thorpe, wore swimsuits with the same properties as shark skin. This important development led to a new sphere of business activity. Firms such as Speedo, Nike and Adidas, well known bathing suit manufacturers, hired many experts in the fields of biomechanics and hydrodynamics.**



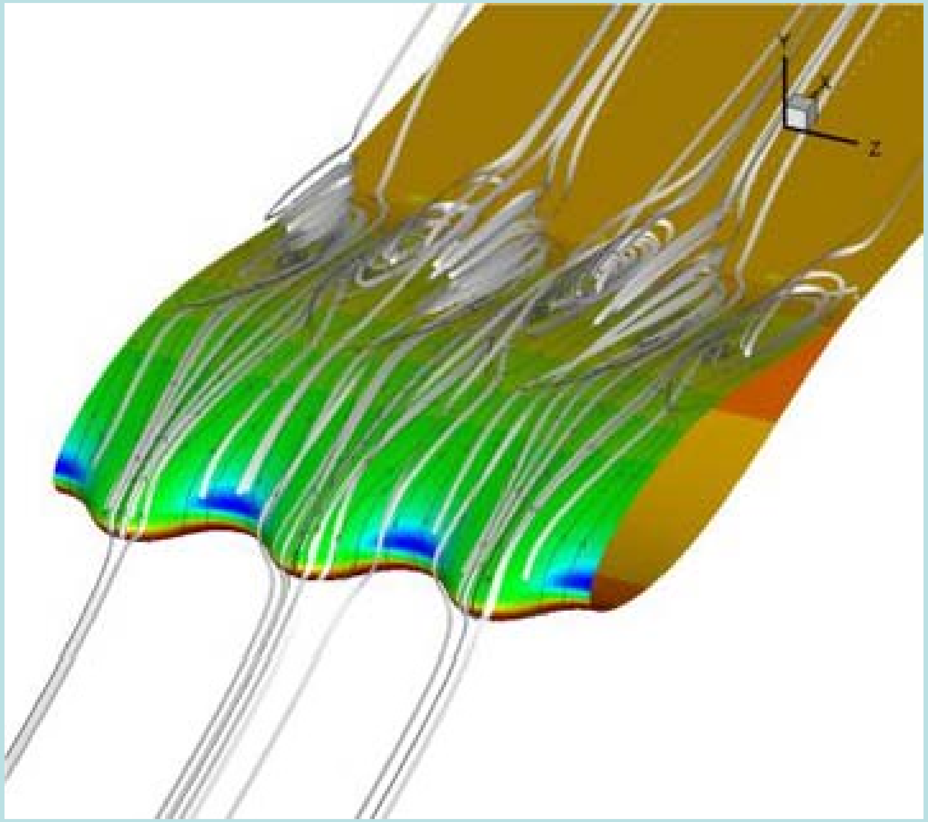
Swimsuits sharkskin inspired


Advertisement of a new swim suit

# whale flipper

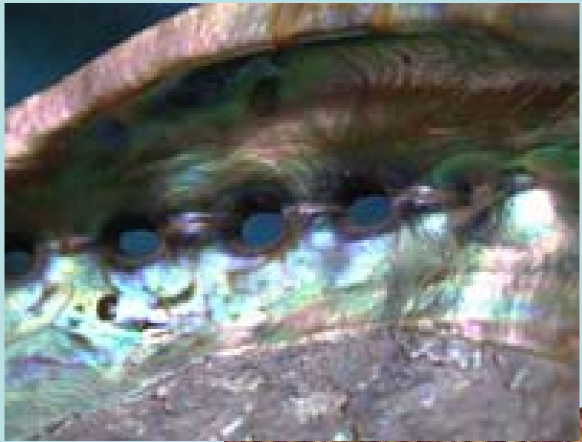
Translating whale power into wind power, biomechanist Frank Fish helped design turbine blades with tubercles (nodules) inspired by the flipper of a humpback whale (left, from a deceased animal). The flipper's scalloped edge helps it generate force in tightly banked turns. The whale-inspired blades are being tested at the Wind Energy Institute of Canada (below) to see if they can make more power at slower speeds than conventional blades, and with less noise.

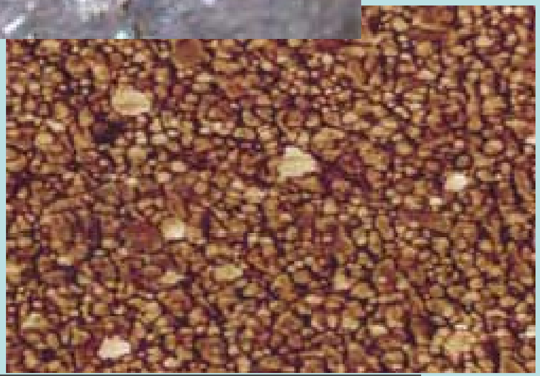

## Humpback whale

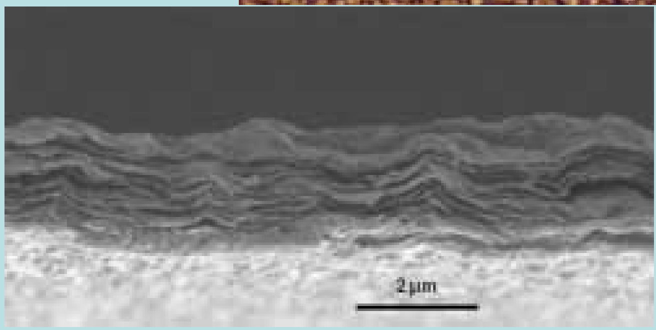


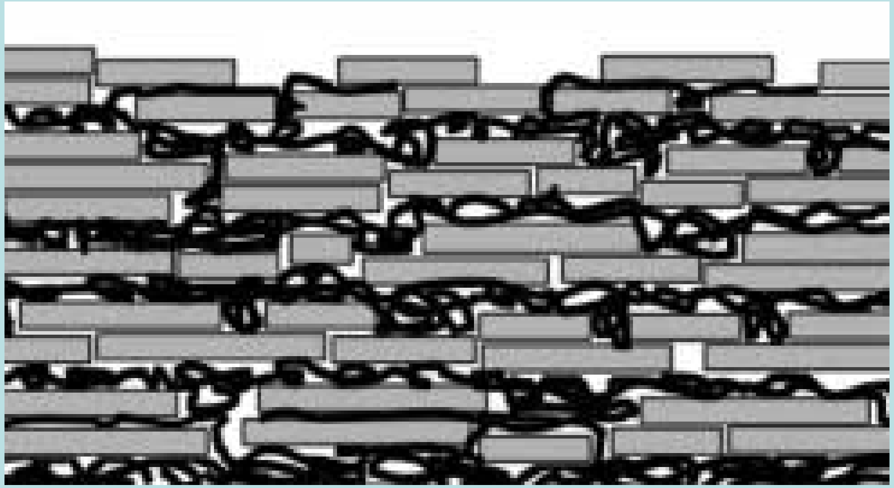
Large vortices are formed behind the troughs along the leading edge whereas flow behind the tubercles forms straight streamlines. The effect of these flow patterns induced by the tubercles is to delay stall.
(Credit: E. Paterson)

# *Mother-of-Pearl Inspires Lightweight Building Materials*







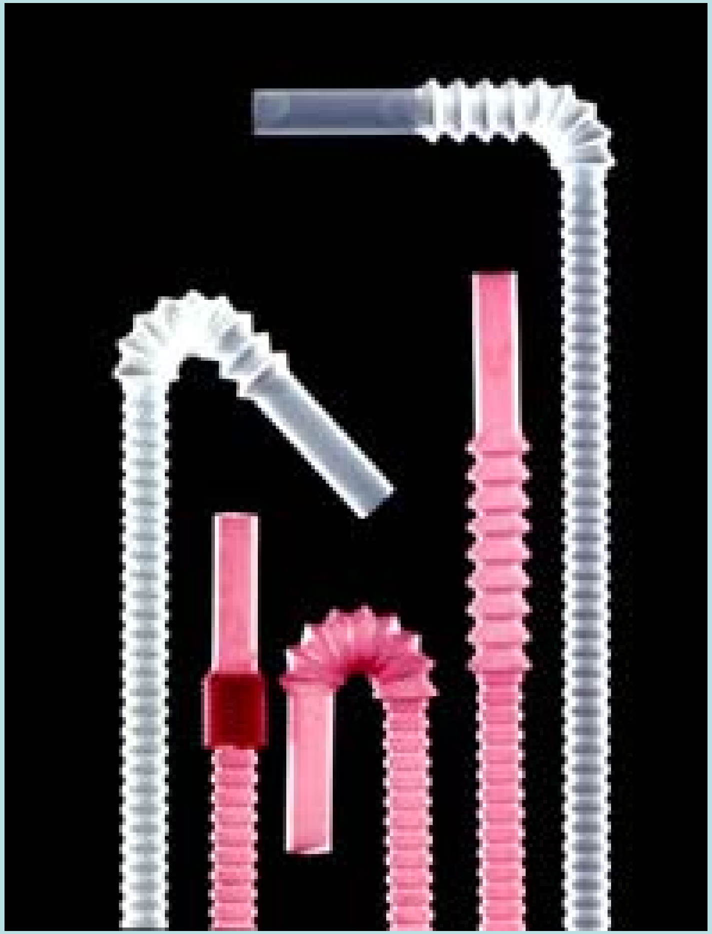
Mother-of-pearl, also called nacre, is composed of alternating layers of calcium carbonate (in a special crystal form called aragonite) and Lustrin-A protein. The combination of hard and elastic layers gives nacre remarkable toughness and strength, allowing the material to slide under compressive force.

Nicholas Kotov, Oklahoma State University

# Rattlesnake and heat-sensing

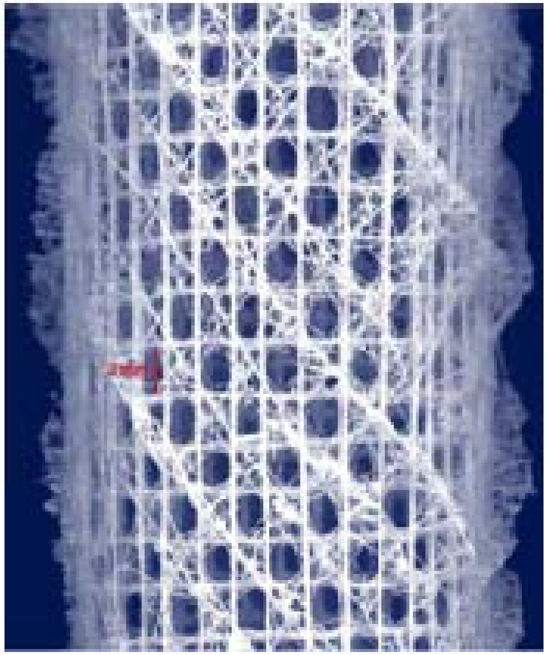
งูหางกระดิ่ง

# Butterfly Mouthpart to Drinking Straw



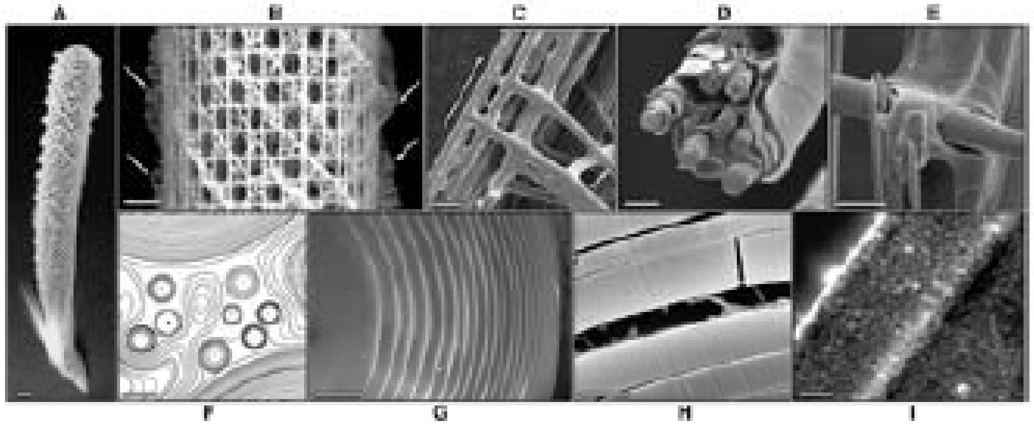
Modern-day architects and engineers can gain much insight and inspiration by studying living things. This building, the Swiss Re Tower in London, resembles a microorganism called a glass sponge. By looking even deeper into biology, at the level of genes and DNA, civil engineers may be able to develop a completely new approach to their work. Using so-called genetic algorithms, they may be able to imitate the biological processes of genetic crossover, mutation and evolution in computer simulations to create optimized designs.

# Biomimicry



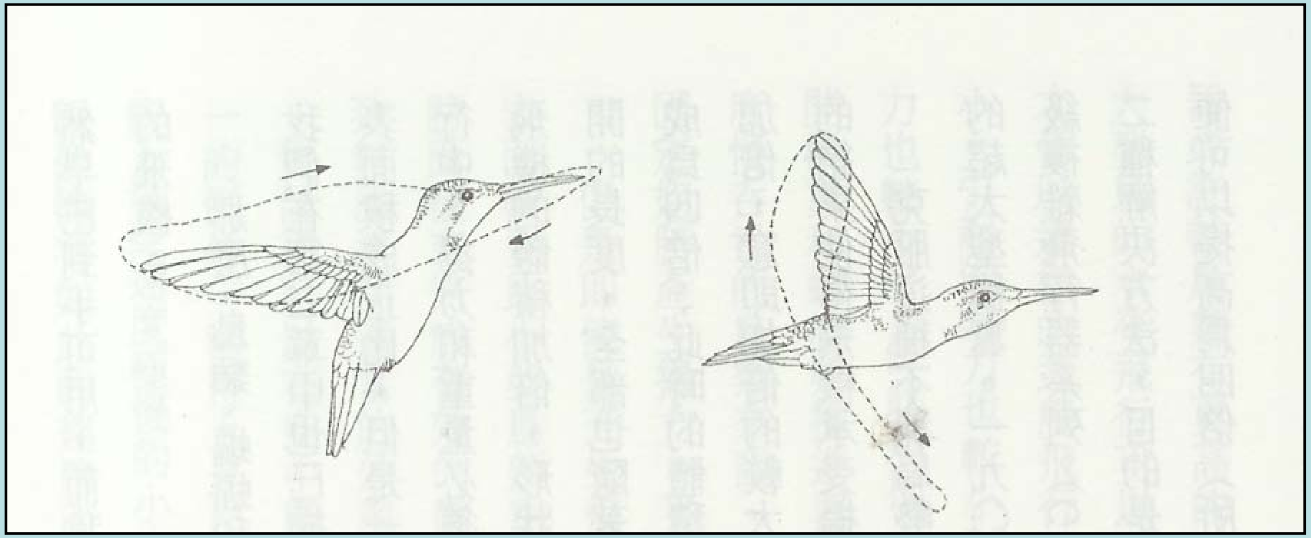
deep sea glass sponge

*Euplectella apergillum*



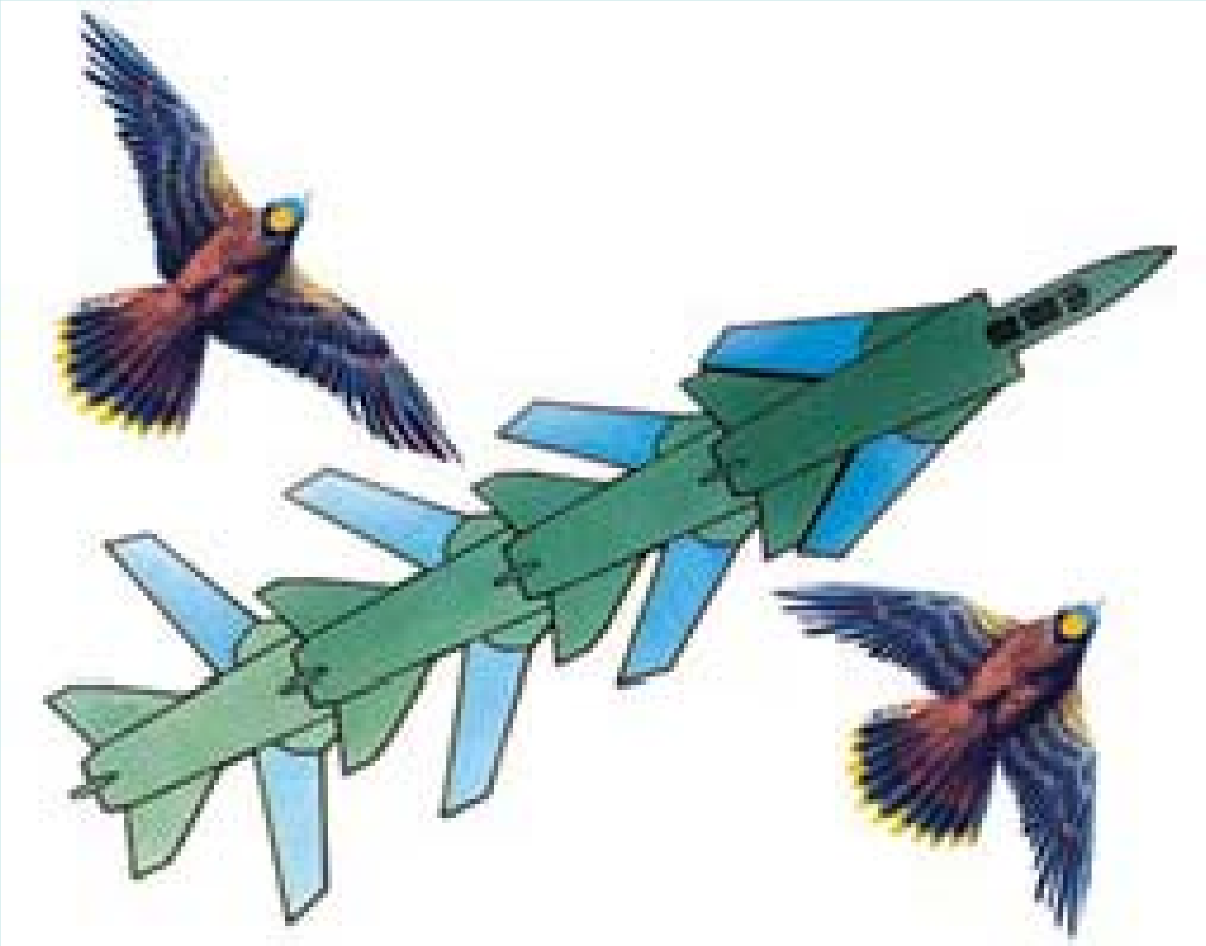

J. Aizenberg et al., Science 309, 275-278 (2005)

# Honey Bird to GR7



**Owls silently glide at night to catch their prey unawares, then suddenly swoop down. According to the findings of researchers at NASA's Langley Research Center in Virginia, an owl's flight feathers—unlike most birds, the flight feathers of whose have a sharp, clean edge—have soft fringes that decrease the turbulence, and thus the noise, of air as it flows over wing. Military designers hope that stealth airplanes can be made even stealthier by imitating the owl's wings. It is hoped that planes now invisible to radar will be completely silent.**

**(R. Meadows, "Designs from Life," *Zooger*, 1999.)**



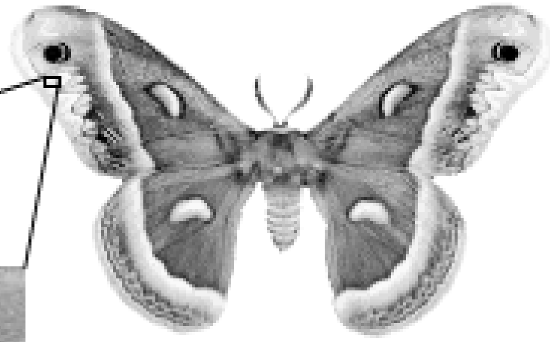
**The shape of birds' wings is the determining factor in their ability to fly. Wings of fast-flying birds like the falcon, hawk, and swallow are long, narrow and pointed—features that have served as a guide to flight engineers.**

**(Perfect Flight Machines, *Bilim ve Teknik*)**

Transportation: How does Nature travel quickly and smoothly?

The Shinkansen Bullet Train in Japan

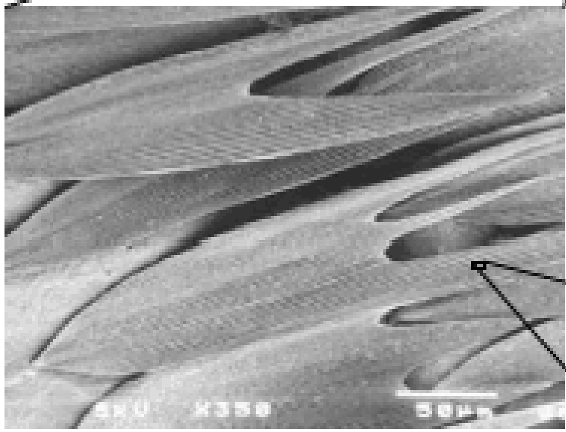
# Butterfly Wing Structure, EM



Used with permission of
Jim Kalisch, University of Nebraska
at Lincoln Entomology

**Moth scales X 175**

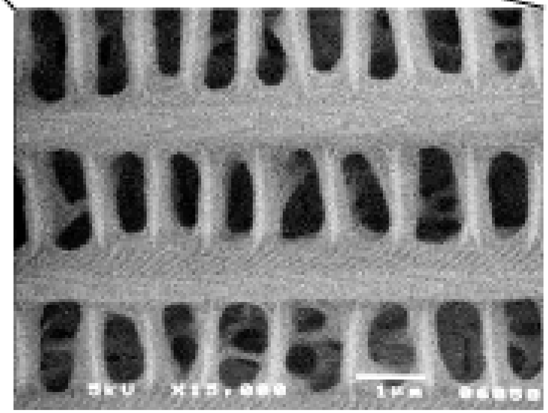
The scales easily detach from the wings. This may be an adaptation for escaping spiders and other predators.



Used with permission of
the Museum of Science, Boston

**Scale structure X 7,500**

To fly moths must be light. A close-up of a scale shows that it is mostly open space, adding little weight.



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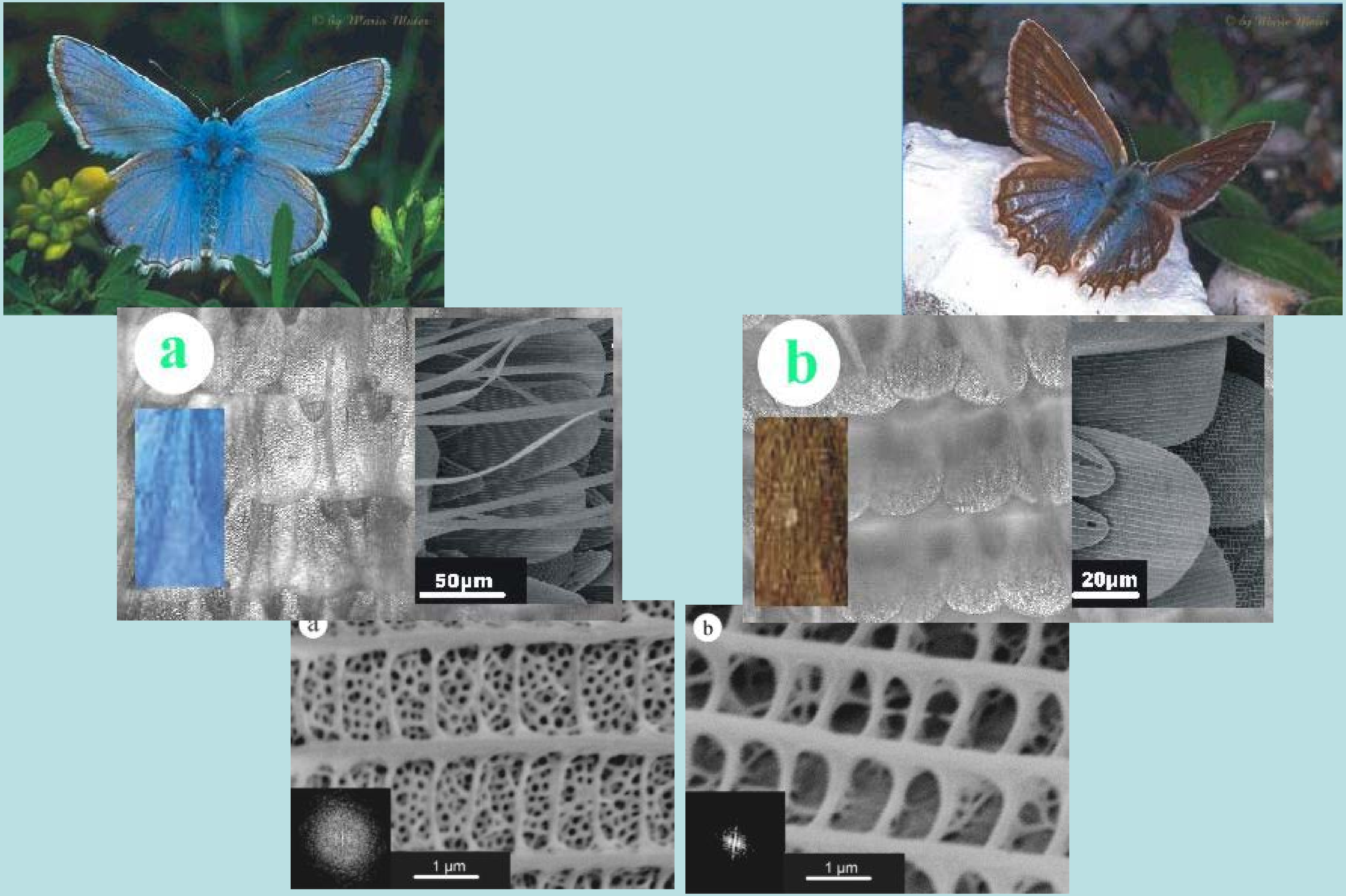
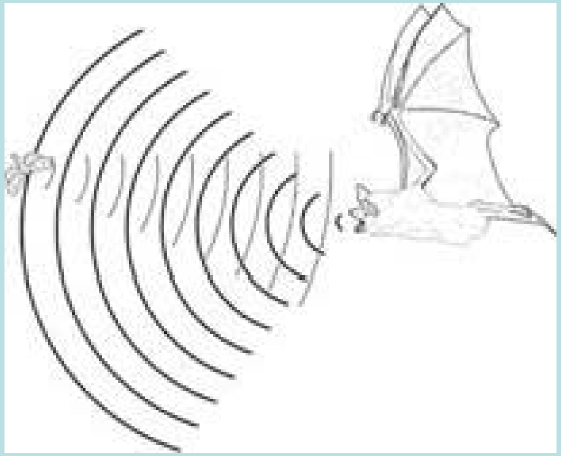
# Butterfly and Pigment-free Color



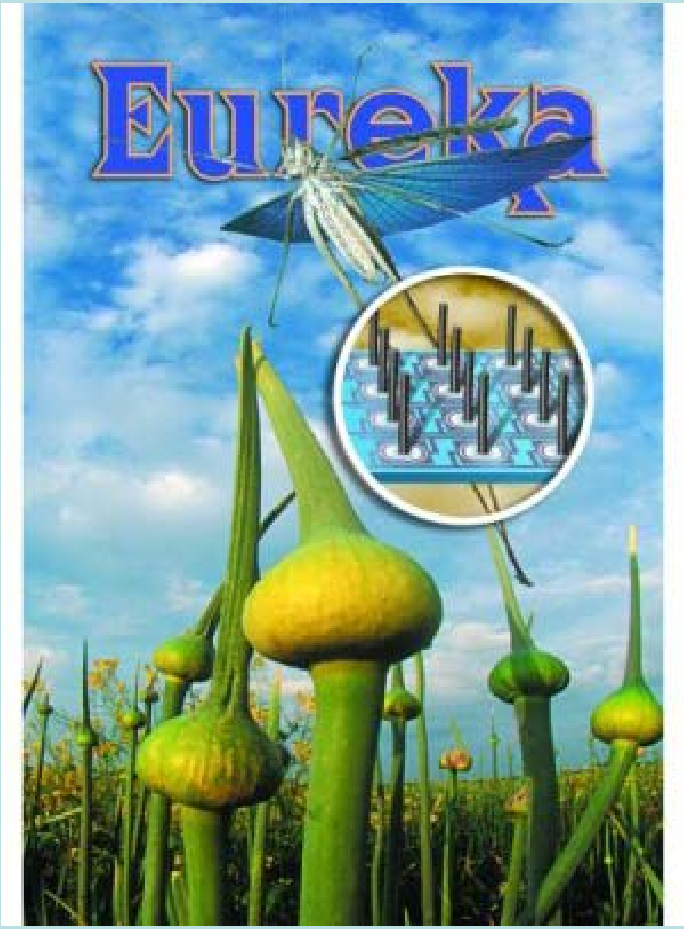

**BRIGHT IDEA: Research on MEMS technology led Iridigm, a startup acquired by Qualcomm, to insects whose wings reflect specific wavelengths of brilliant color.**

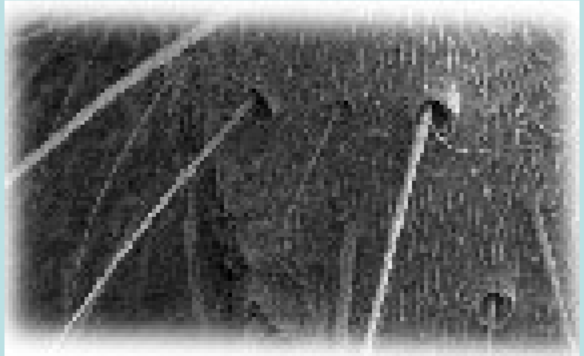
# Bat Inspired Walking Cane



*Dean Waters, University of Leeds*

# Crickets inspire fine hair sensors



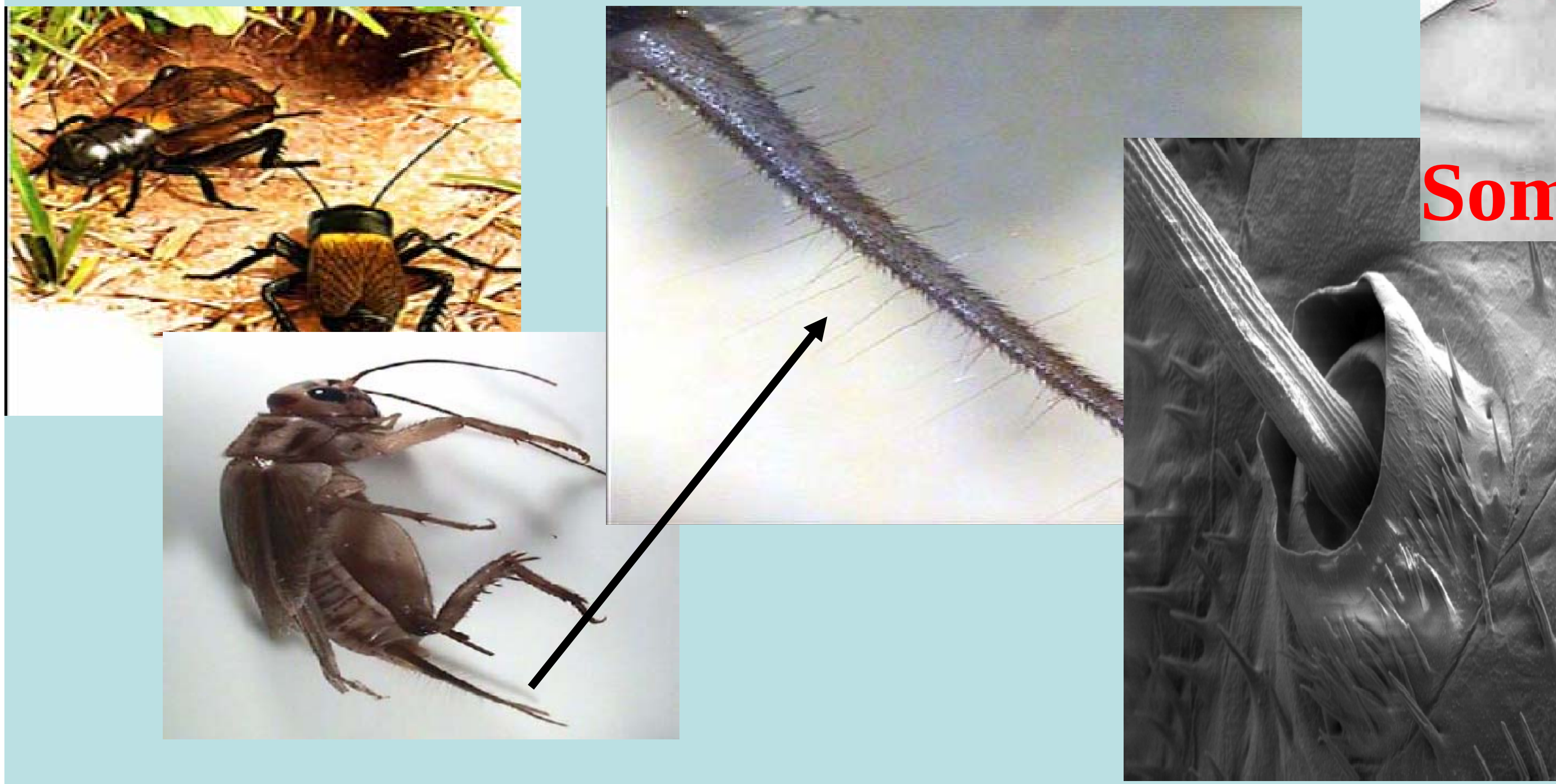



Adult crickets have around 1000 or more hairs, 100 to 1500 microns long on organs called cerci, which allows them to detect air movements down to 1mm/s or less, indicating the possible approach of predators. The high sensitivity comes about because the tilting hairs apply pressure to neurons at their bases, greatly enhanced by mechanical lever amplification.

CICADA (Cricket Inspired perCeption And Decision Automata), UK

# *Cricket-Inspired Hearing Aid*

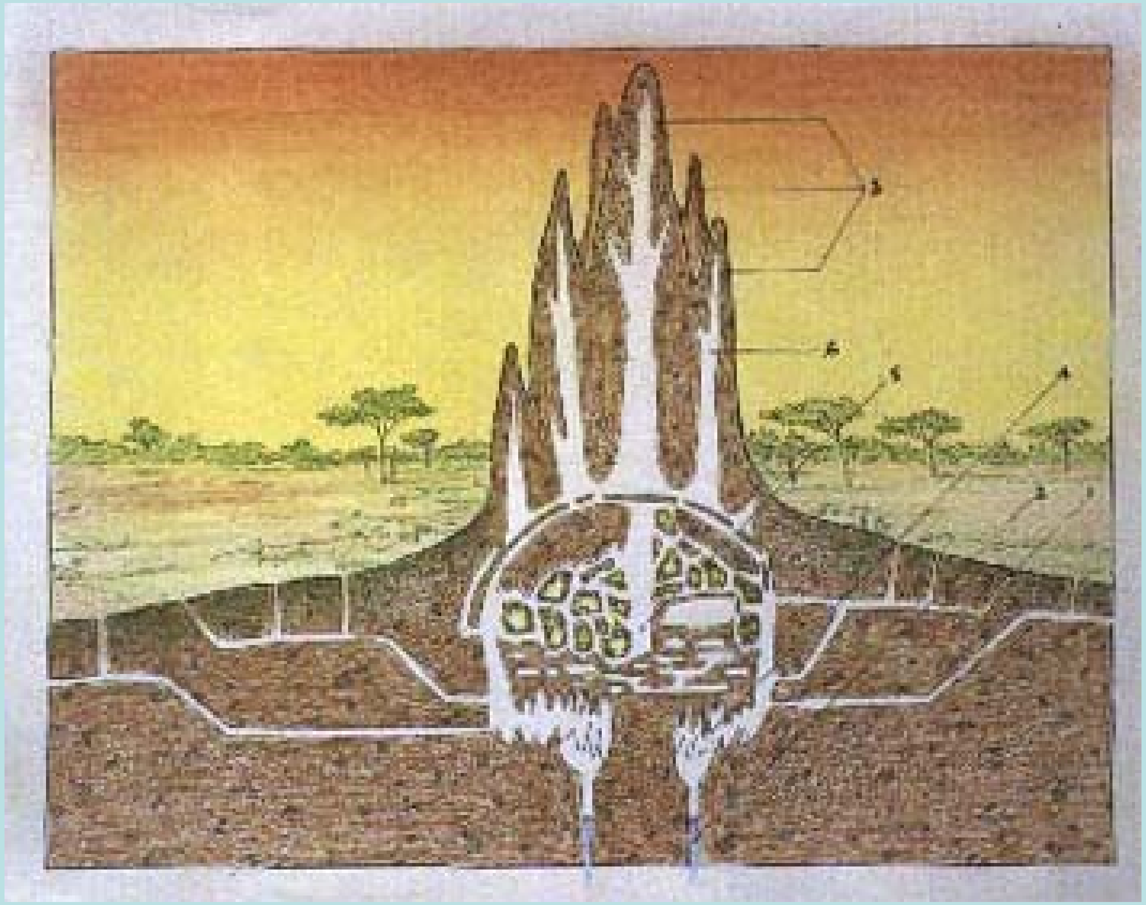
- CICADA, Netherlands-based University of Twente

# Termite-inspired Air Conditioning Simply by Architecture

**Green Building in Zimbabwe Modeled After Termite Mounds**

Eastgate Centre, Harare, Zimbabwe

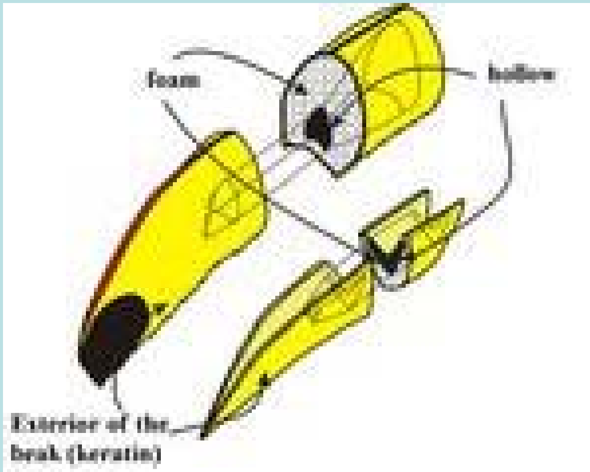


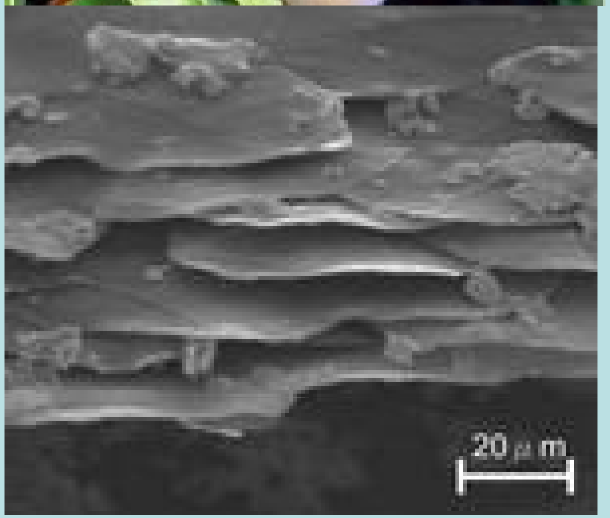
Air is continuously drawn from this open space by fans on the first floor. It is then pushed up vertical supply sections of ducts that are located in the central spine of each of the two buildings. The fresh air replaces stale air that rises and exits through exhaust ports in the ceilings of each floor. Ultimately it enters the exhaust section of the vertical ducts before it is flushed out of the building through chimneys.

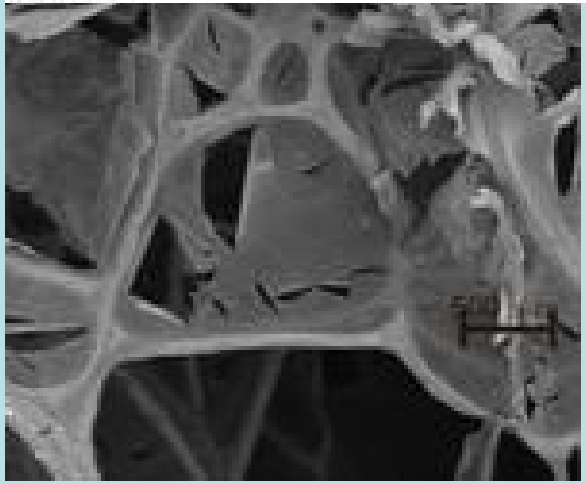
The Eastgate Centre uses less than 10% of the energy of a conventional building its size. These efficiencies translate directly to the bottom line: Eastgate's owners have saved $3.5 million alone because of an air-conditioning system that did not have to be implemented.


Toucan’s Beak

# The lightweight strength of the Toco Toucan's beak



The beak is mostly air: The beak has a hollow region in an interior region where the mechanical stresses were insignificant. The beak's interior is a highly organized matrix of stiff cancellous bone fibers that looks as if it was dipped into a soapy solution and dried, generating drum-like membranes that interconnect the fibers. The result is a solid "foam" of air-tight cells that gives the beak additional rigidity.

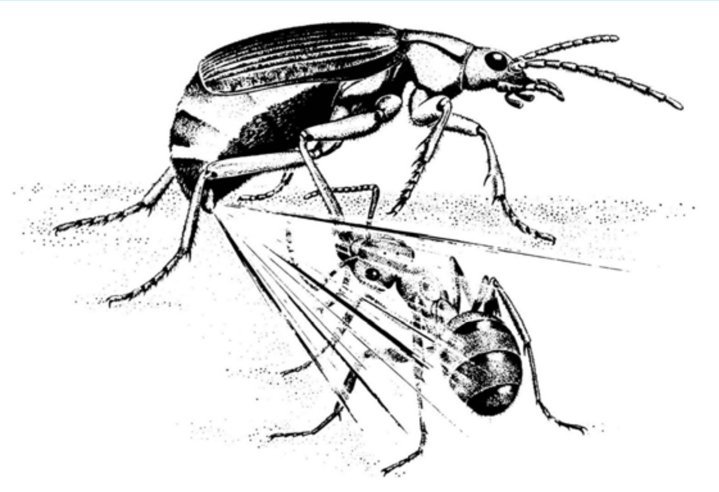
# The bombardier beetle, power venom, and spray technologies

## • Experimental work by Eisner on Bombardier Beetle

**Bombardier Beetle defence mechanism :**

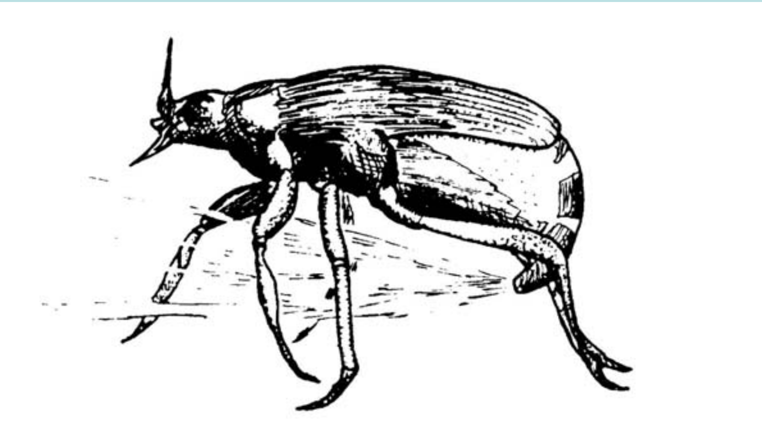


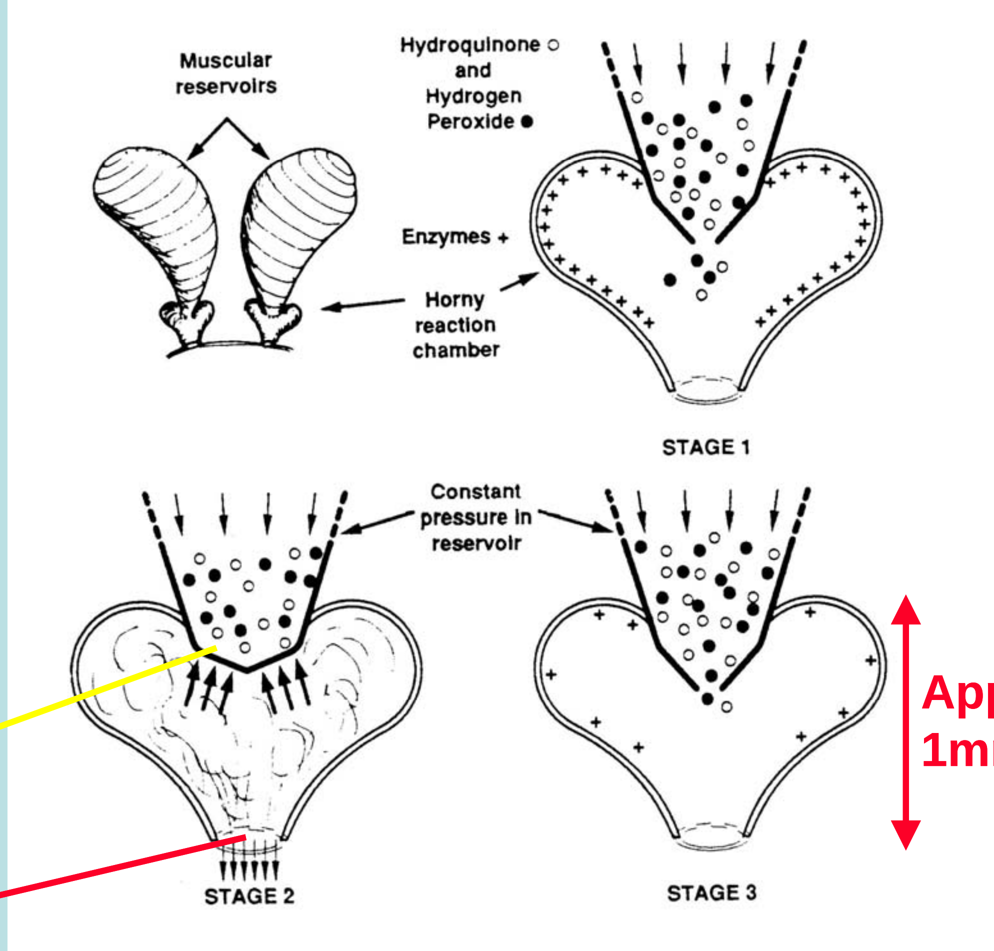
**<u>From work of Professor Tom Eisner of Cornell University</u> :** Eisner, T and Aneshansley, D. J, "Spray aiming in the bombardier beetle: Photographic evidence", *Proc. Natl. Acad. Sci. USA* Vol. 96, pp. 9705–9709, August 1999



## • Experimental work by Eisner on Bombardier Beetle

# Bombardier Beetle – Pulse combustion par excellence!






Approx 1mm

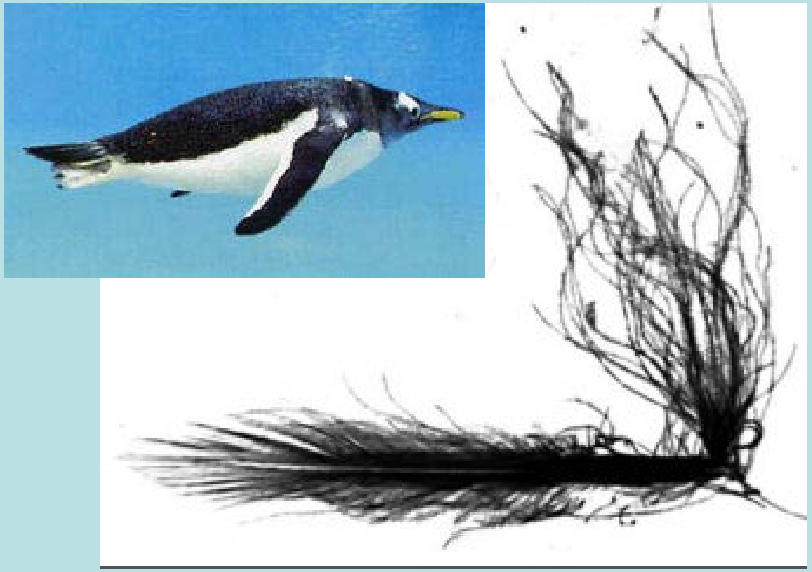
Fuel-inlet valve opened at low pressure, closed at high pressure.
Exhaust-outlet at high pressure………

…..but latest finding is of a sophisticated pressure release valve at outlet

# The bombardier beetle, power venom, and spray technologies

- The bombardier beetle is inspiring designers of engines, drug-delivery devices and fire extinguishers to improve spray technologies.
- The bombardier beetle, found mainly in Africa and Asia, is remarkable in that it can fire a powerful jet of hot, toxic fluid to fight off predators such as birds and frogs. While the chemical reaction that makes the venom has been understood for some time, the actual power behind the venomous squirt, which can travel as far as 20cm, has been cause for speculation.

# Penguin feather structure as excellent insulator



- They are compressed by the pressure of the water, they are bent and then jump back into shape like springs when the penguin leaves the water.
- When the penguin dives the air is pressed out of the feathers, the coat collapses and the penguin becomes thin and streamlined. When the penguin leaves the water again, the coat must inflate immediately.
- 

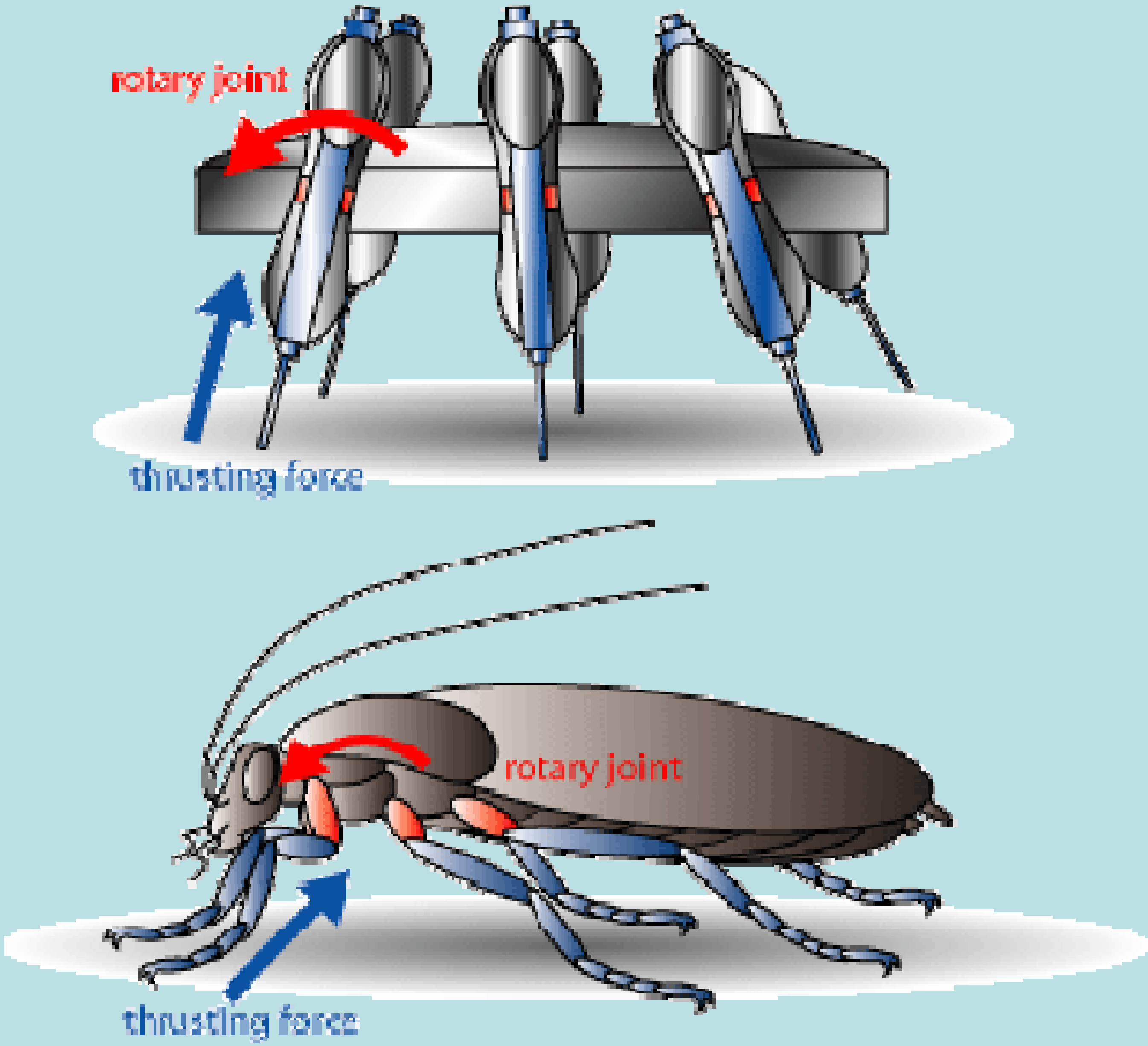
# Mollusk-inspired Fan: Energy Saver and Reduction of Noise

A three-dimensional logarithmic spiral is found in the shells of mollusks. Liquids and gases flow centripetally through these geometrically consistent flow forms with far less friction and more efficiency. Computational Fluid Dynamics and Particle Image Velocimetry tests showed the technology's streamlining effect can reduce energy requirements in fans and other rotors from between 10 and 85%, depending upon the application; the fan blade design also reduces noise by up to 75%.

***PAX Scientific (USA)***

# Smart fabrics

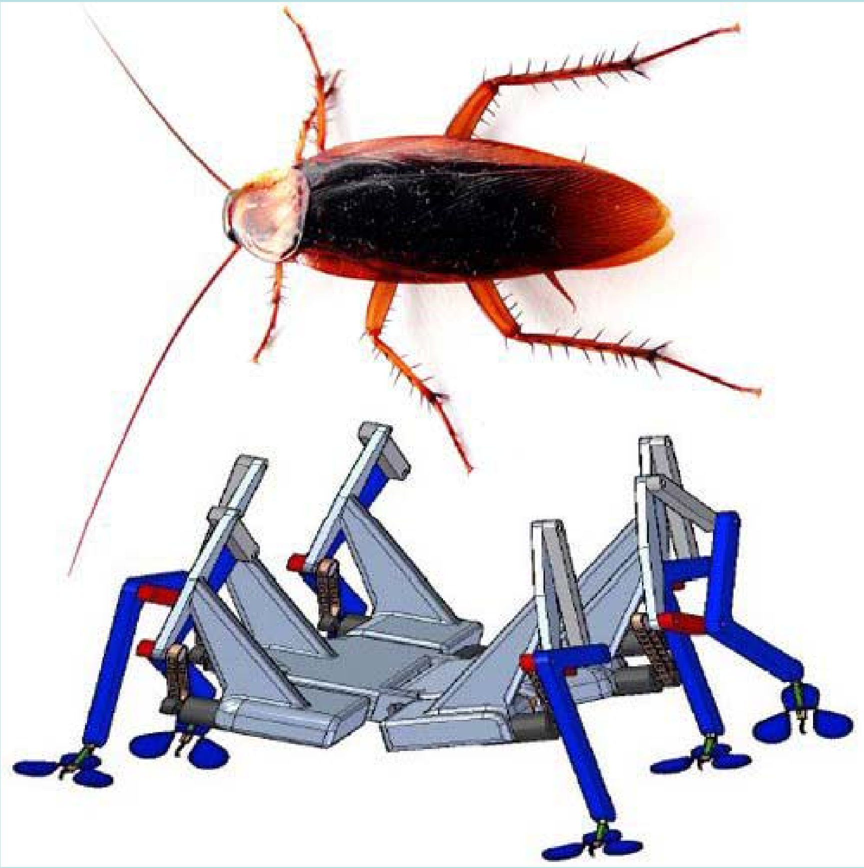
- By carrying out research on the opening and closing of pine cones and the insulation layers of penguins, we have worked on the principles of design of a fabric which can be used to make responsive clothing, with transpirational properties based on the state of activity of the wearer.
- e.g. a soldier in the deserts around the Gulf will otherwise need few layers by day in the baking heat, but lots of layers by night in the chill of the sand.




*NASA:The cockroach leg is a prime candidate for biomimicry*

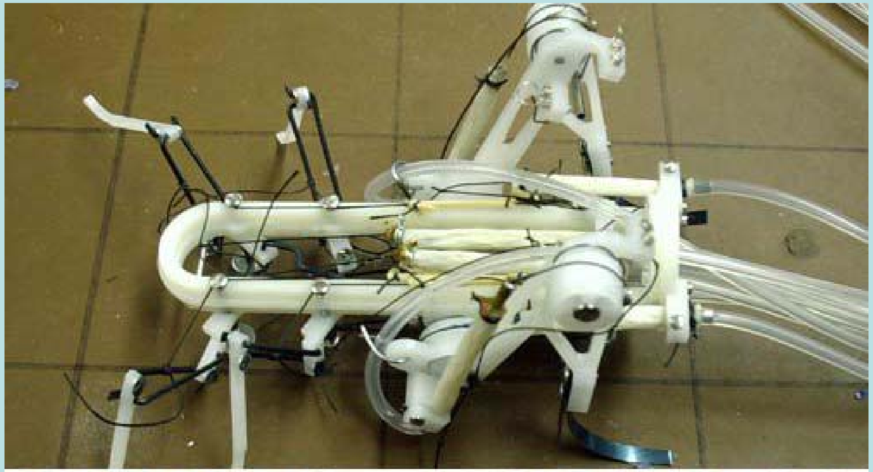
# RiSE

(Robots in Scansorial Environments)



It can climb all over the place. U of Pennsylvania.

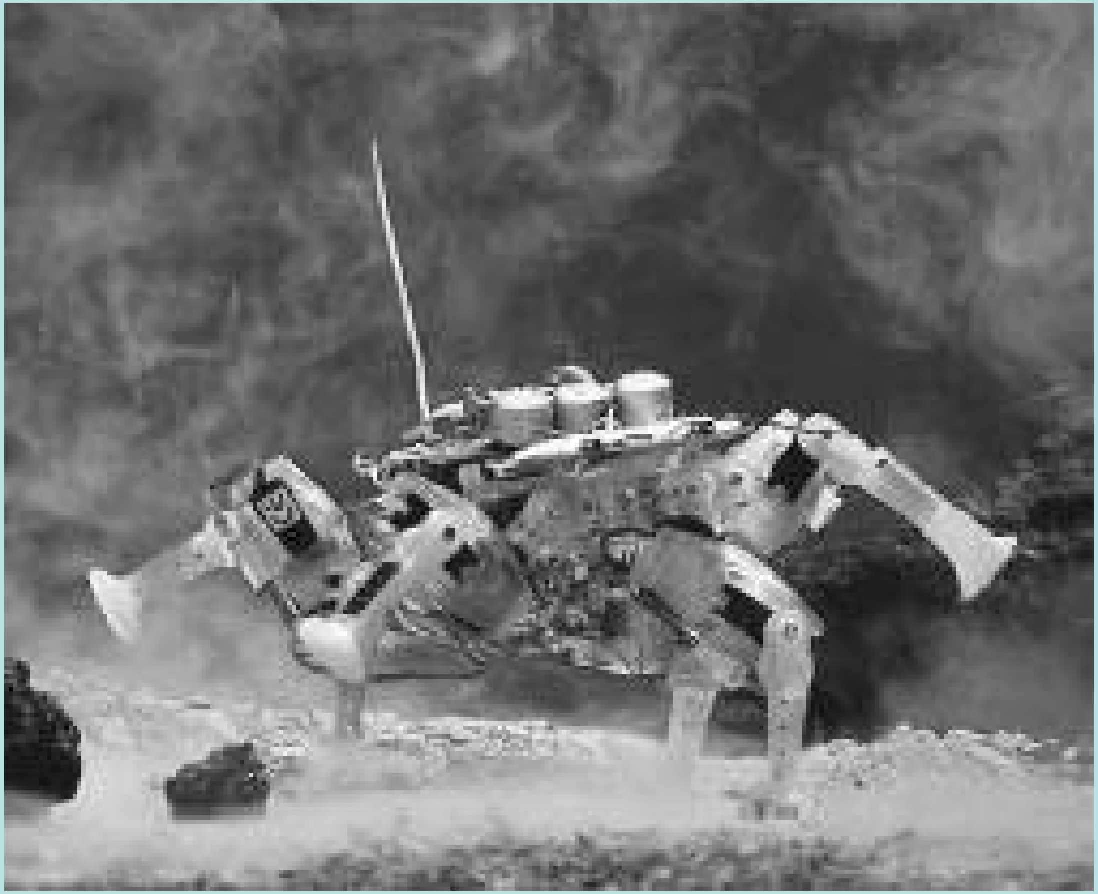
# Micro-Cricket Exploer



Biologically Inspired Robots Lab of Case Western Reserve University

funded by DARPA, the Office of Naval Research, NASA

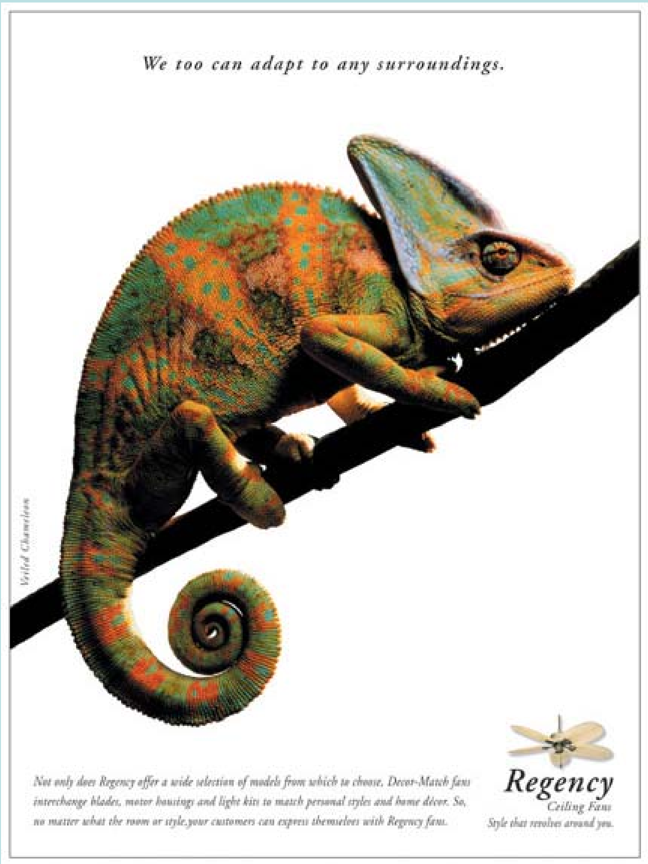
# Robot and AI



Spiderbot capable of negotiating difficult terrain

# Optical Camouflage

**chameleon**





Tachi Laboratory, University of Tokyo

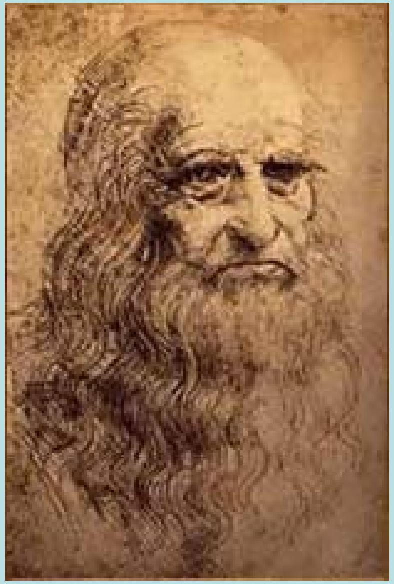
Transstudio

# Optical Camouflage

Optical Camouflage requires the use of clothing – in this case, a hooded jacket – made with a retro-reflective material, which is comprised by thousands of small beads that reflect light precisely according to the angle of incidence. A digital video camera placed behind the person wearing the cloak captures the scene that the individual would otherwise obstruct, and sends the data to a computer for processing.

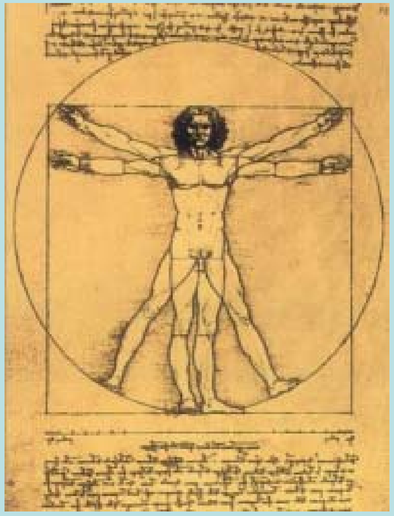
Transstudio Tachi Laboratory, University of Tokyo

# *Leonardo da Vinci*



As wrote in 16th century,

**"Human ingenuity may make various inventions, but it will never devise any inventions more beautiful, nor more simple, nor more to the purpose than Nature does; because in her inventions nothing is wanting and nothing is superfluous".**



# Q & A