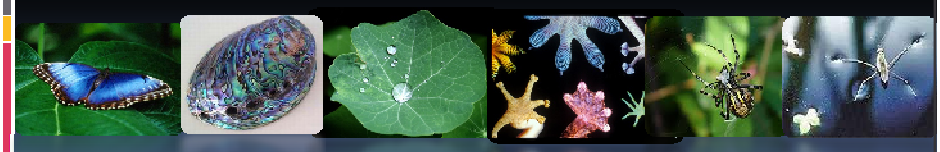
NANO-SCIENCE IN NATURE

Chularat Krongtaew, Dr. techn.
Chemical Engineering Department,
Faculty of Engineering, Mahidol University



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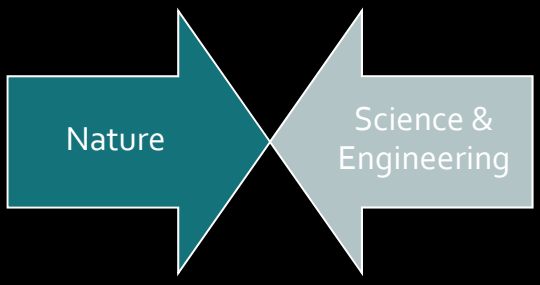
Inspiration of Biomimicry



"Mother Nature is the greatest teacher to mankind."
researcher Weihua (Marshall) Ming told nanotechweb.org.

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Nano in Nature

- The examination of nature …
  - Models and Structures
  - Elements
  - Processes and Phenomena

To solve human's problems

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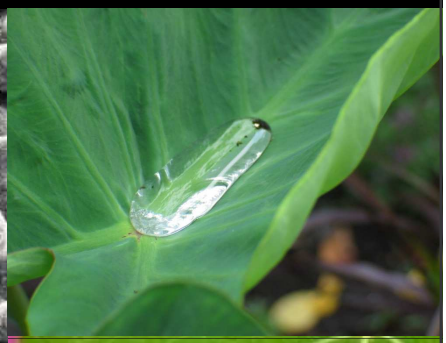
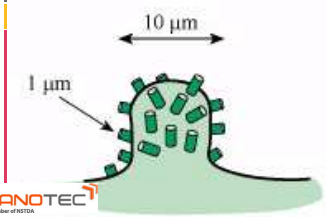
Lotus Effect (น้ำกลิ้งบนใบบัว)





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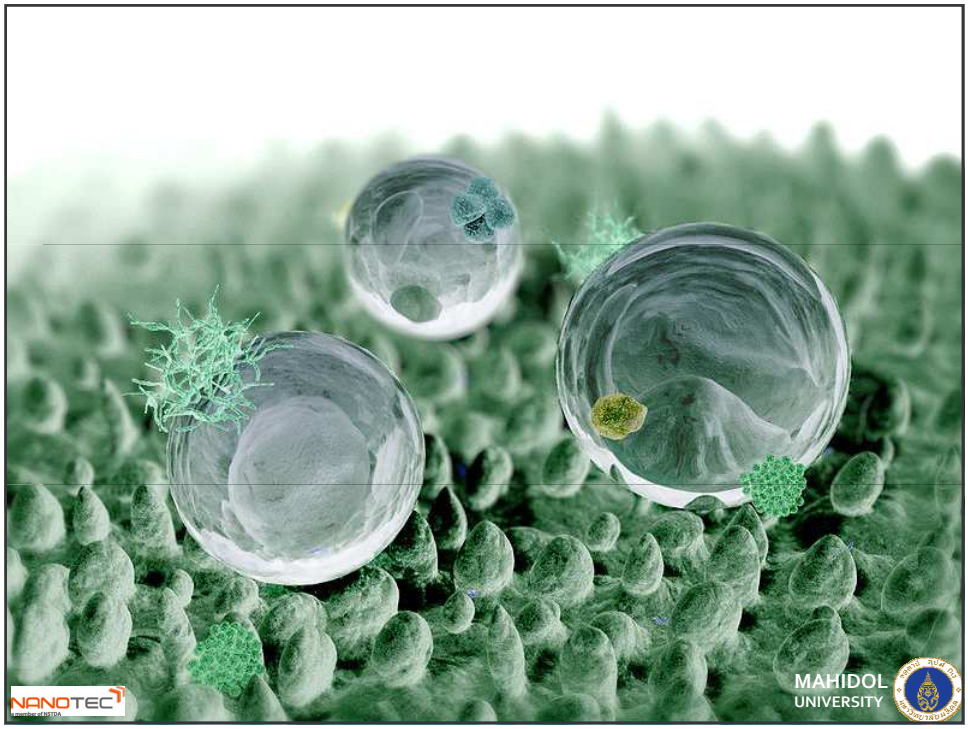
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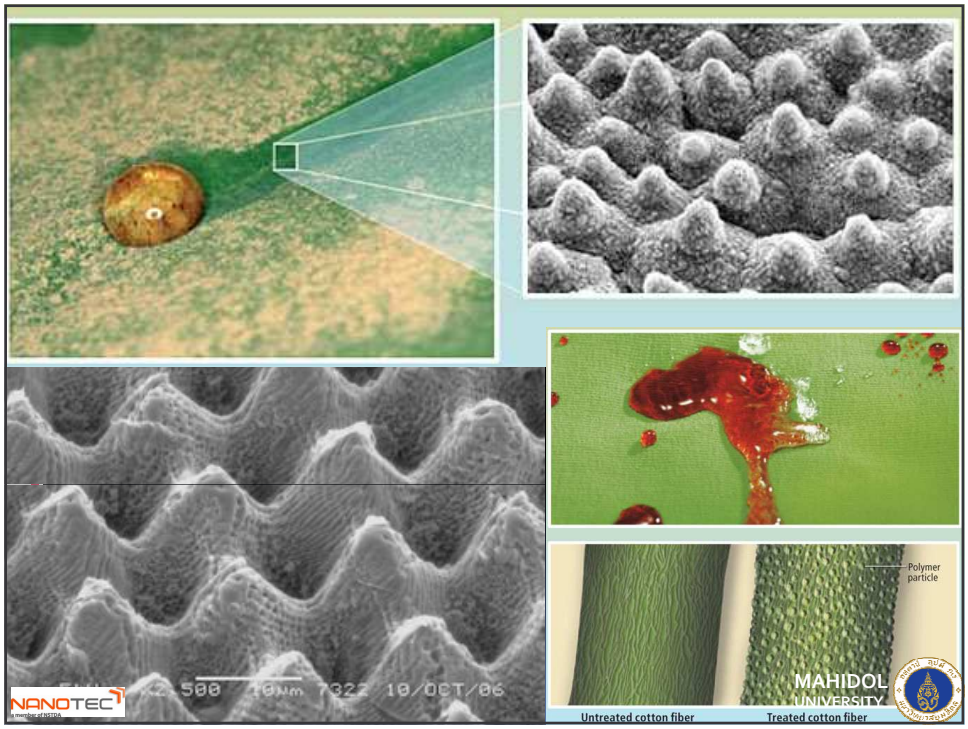
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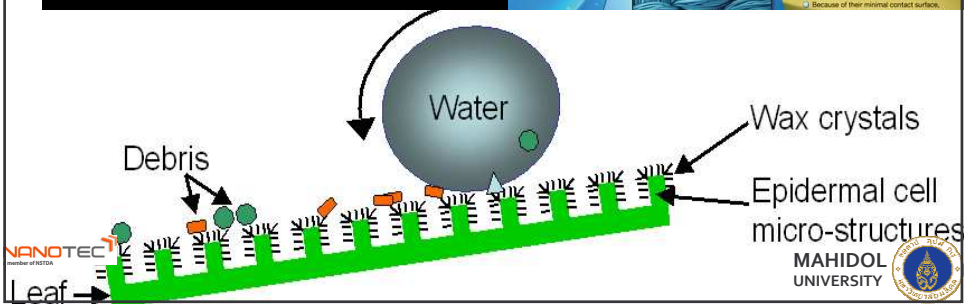
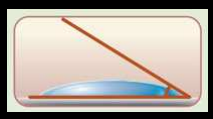
Polymer particle
Untreated cotton fiber
Treated cotton fiber

A special coating, which makes rain run off the glass, textile, etc. taking dirt with it.

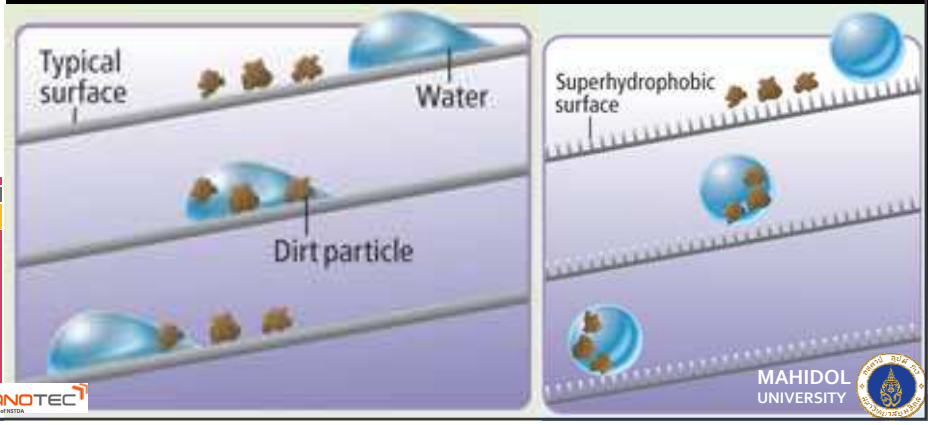




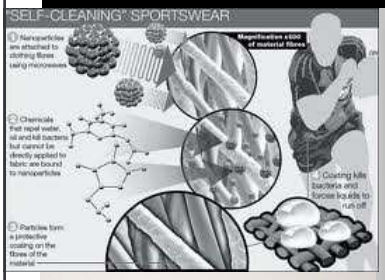
Hydrophilic surface: less than 30°

Hydrophobic surface: greater than 90°

Superhydrophobic surface: greater than 150°



Water Shield is a super-hydrophobic coating



Lotus Effect in action on a wall coated with Elite Water Shield

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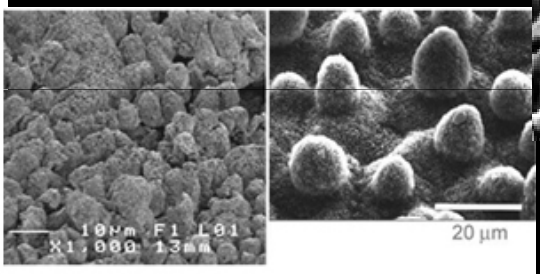
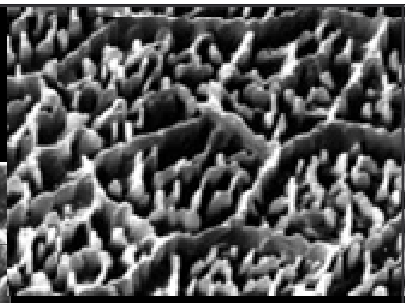
Super-hydrophobic polymer (PDMS) surfaces by pulsed laser treatment.



Left: SEM image of surface produced within the project.
Right: SEM image of the surface of a Lotus leaf.
(D. Chakarov, P. Holgerson)



Raspberry-like particles made of silica spheres bonded to an epoxy-based polymer film.

Eindhoven University, The Netherlands

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Shark skin

- The tiny scales on the skin of a shark, composed of dentines - a tough material denser than bone.
- The top is coated with smooth enamel preventing barnacles and parasites from attaching to them.

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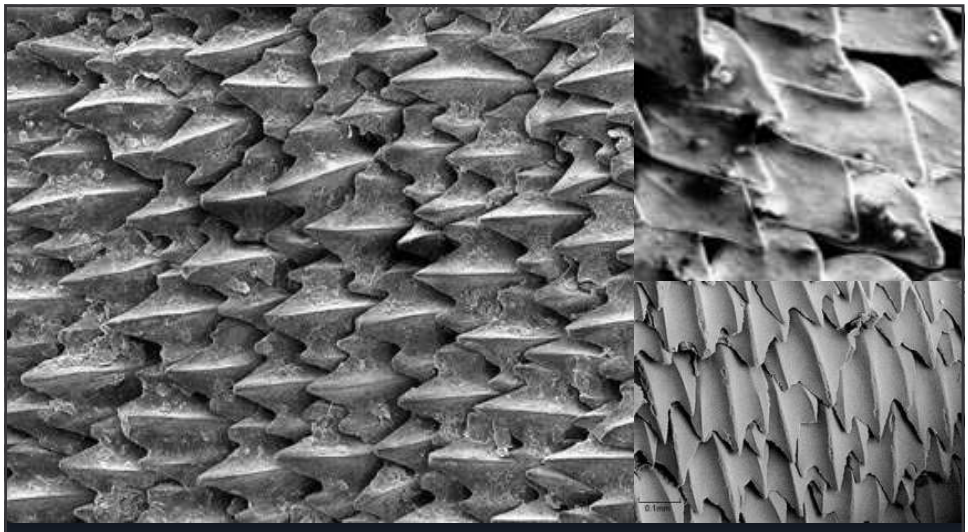

The various size/shapes and texture of shark skin at the micro and nano levels reduce drag and make sharks very fast in the water.

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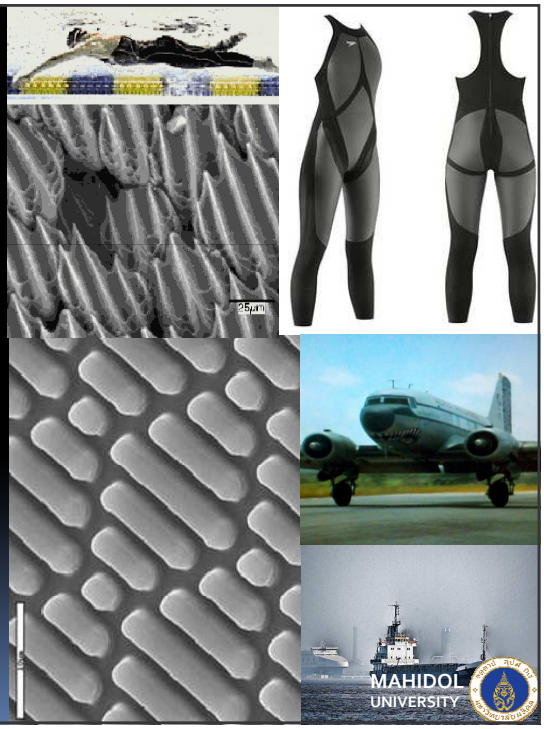
Swimming suit,Ship, Aircraft Coating

This idea has been used to create reduced drag suits for athletes, ship and aircraft surface (NASA)

Shark skin reduce airplane drag by 30%



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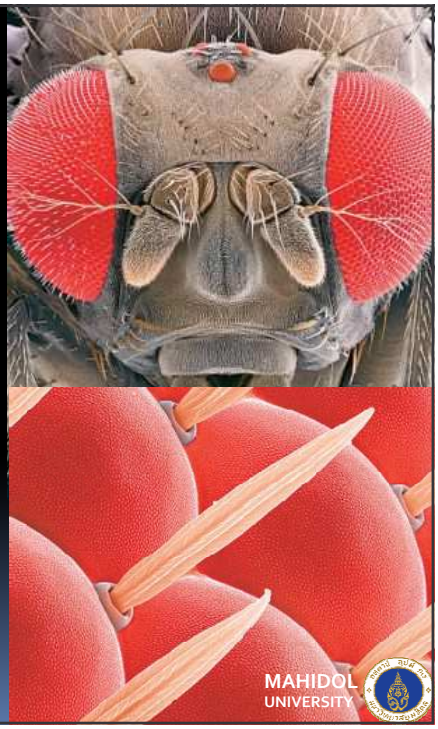
Fruit fly's eyes

- A fruit fly's eyes are made up of many individual 'ommatidia' units, stacked together in a dome, with each functioning as a separate lens



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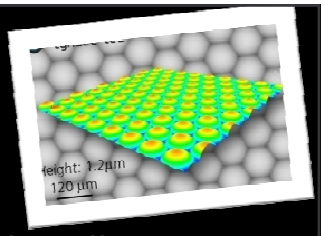
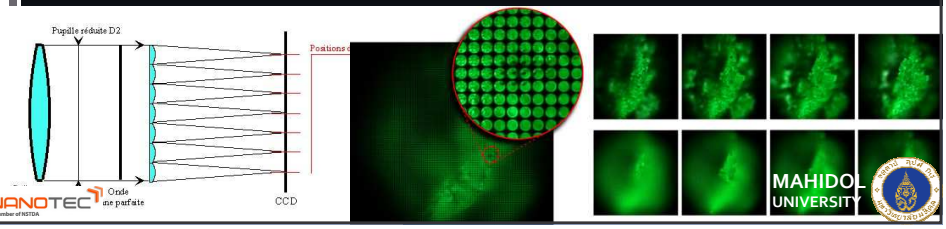
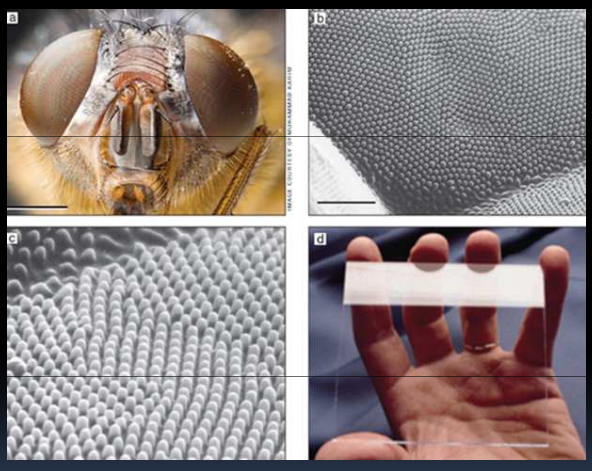
Microlens Array



- Microlens arrays increase the light collection efficiency of CCD arrays used in some digital projectors (LCD).
- Current research relies on microlenses of various types for electricity production.



Animal visual systems



The sub-wavelength anti-reflective structural elements enhance the function of its visual system.

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Gecko's foot

- 500,000 hairs per toe
- Hundreds of nanoprojections (spatulae) per hair
- Adhesive force in one foot = 100 newton

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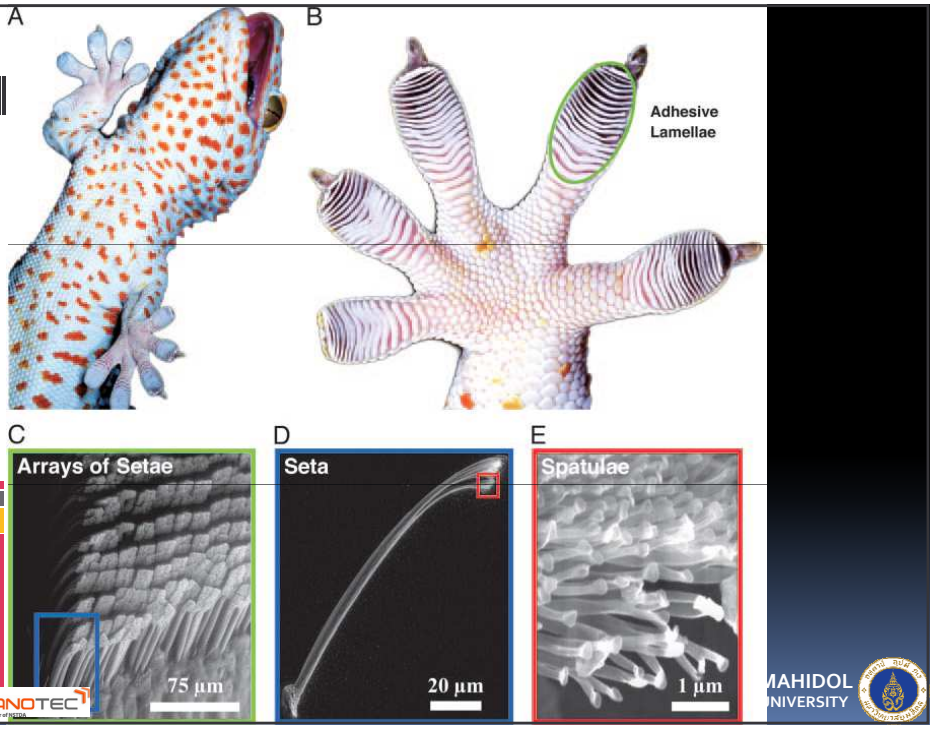

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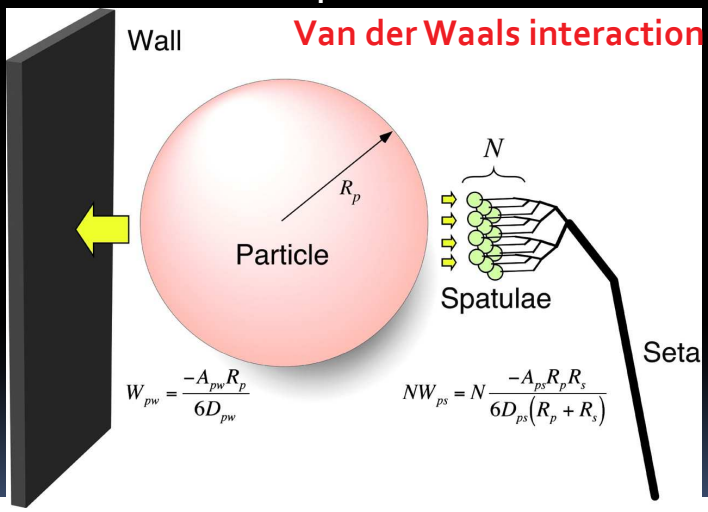
Model of interactions between N gecko spatulae of radius Rs, a spherical dirt particle of radius Rp, and a planar wall.



Hansen W R , Autumn K PNAS 2005;102:385-389

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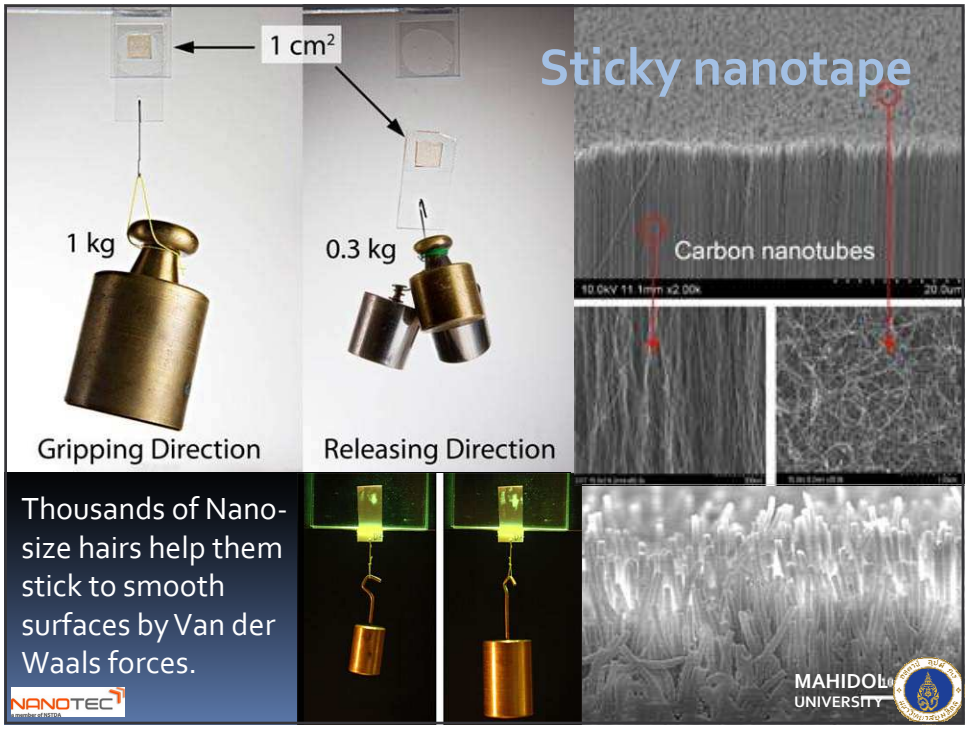
PNAS




Gecko Glue
SURF WAX
GLASS
AS STICKY AS A GECKO...BUT TEN TIMES STRONGER!
Curly on top
Straight nanotubes
Glass
Dry adhesive made of carbon nanotubes
As adhesive dragged downwards, curly nanotubes on top make more contact with glass, and cling tight
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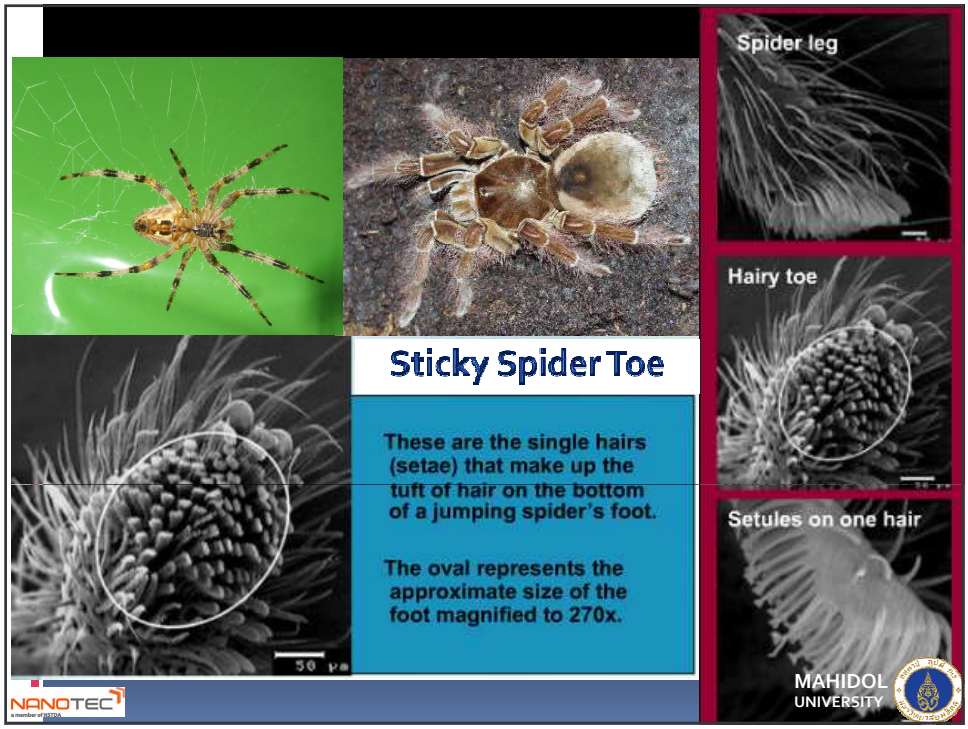
Spider leg
Hairy toe
Setules on one hair
Sticky Spider Toe
These are the single hairs (setae) that make up the tuft of hair on the bottom of a jumping spider's foot.
The oval represents the approximate size of the foot magnified to 270x.
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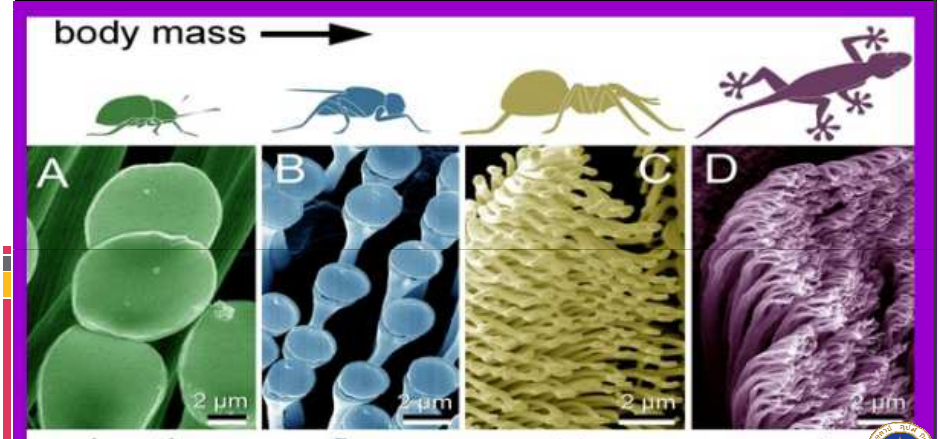
Lots of Nano-toes

- Beetles and flies also have nanostructures that help them stick to walls, ceilings and smooth surfaces



Why don't water striders get wet?

"Walk on water"

Water strider is assisted by:

- Surface area
- Gravitational forces
- Surface force (Van der Waals forces)
- A waxy (hydrophobic) surface on their legs
- Nano-Groovy hairs

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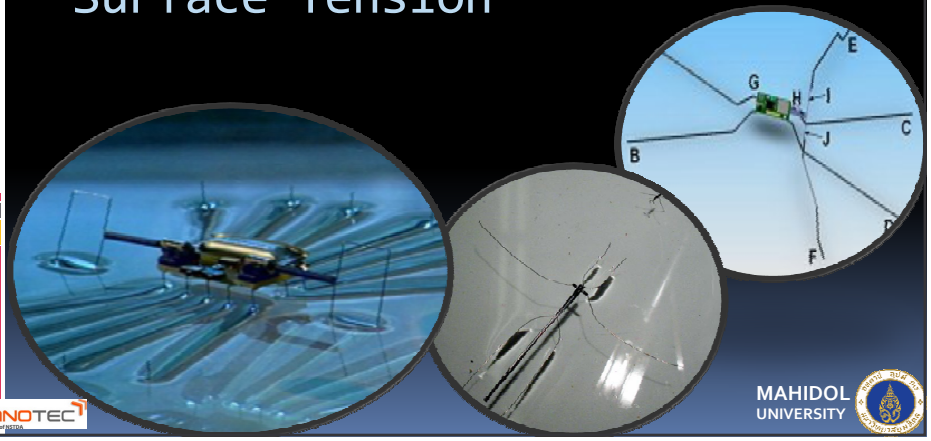
Robot Walks on Water Mimicking Insects to Avoid Sinking Using Surface Tension



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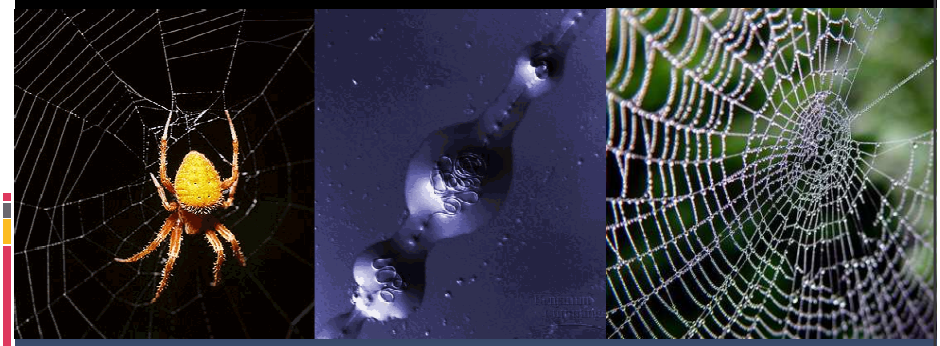
How strong?
As strong as … silk?



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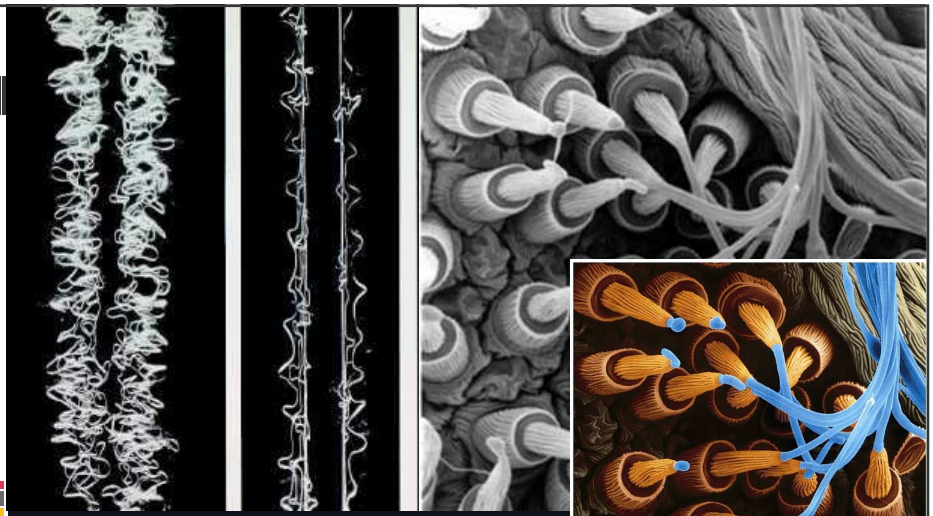

- Nano-biodegradable threads of spider silk are stronger, by weight, than high-tensile steel.
- It is elastic enough to stretch up to 10 times its initial length.

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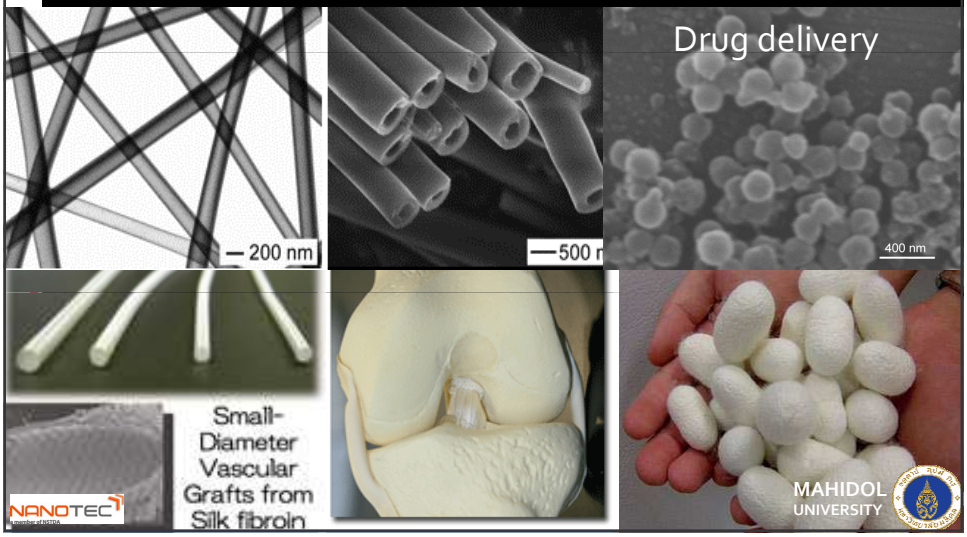
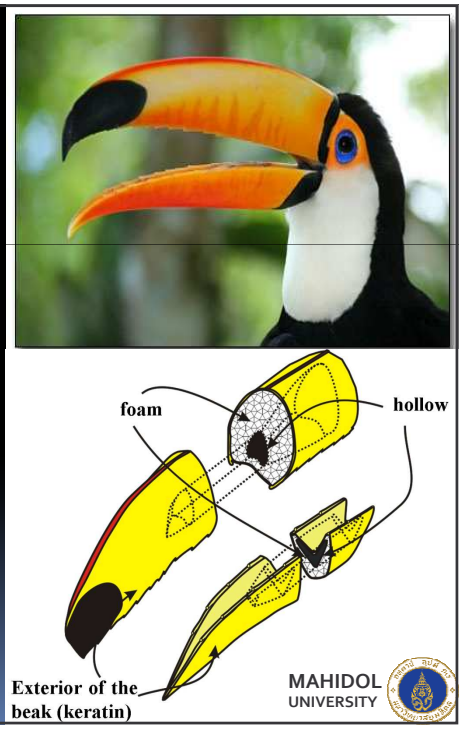
Silk fibroin for medical purposes

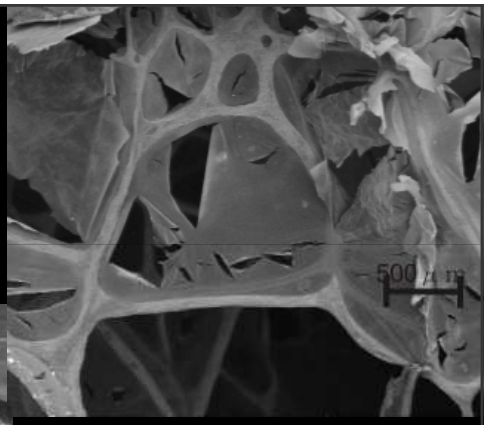


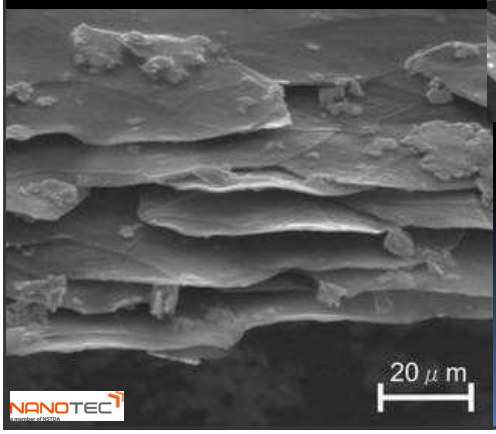
Toucan Beaks

- Toucans have very large beaks for the size of their bodies.
- Its nano structure makes Toucan Beaks incredibly light and strong.



Rigid foam-like interior made of a network of nanosixed bony fibers connected by membranes





Overlapping nanosized keratin tiles glued together

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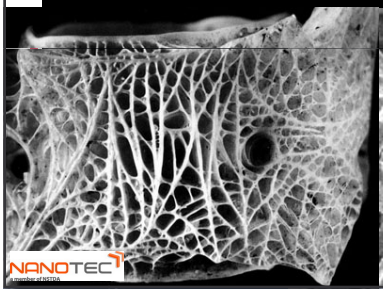
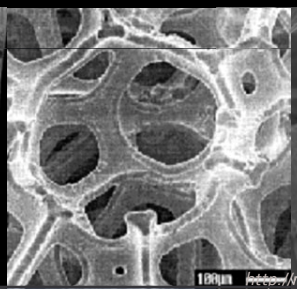
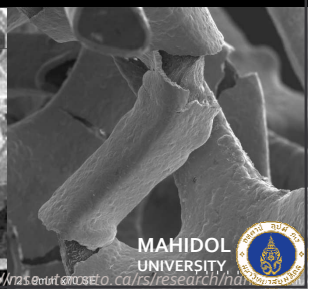
Lightweight & Ultra-Strong Nanomaterials

- The Hybrid nanomaterials in which the density of the parent material
- The application is significant in the automotive and aerospace industries







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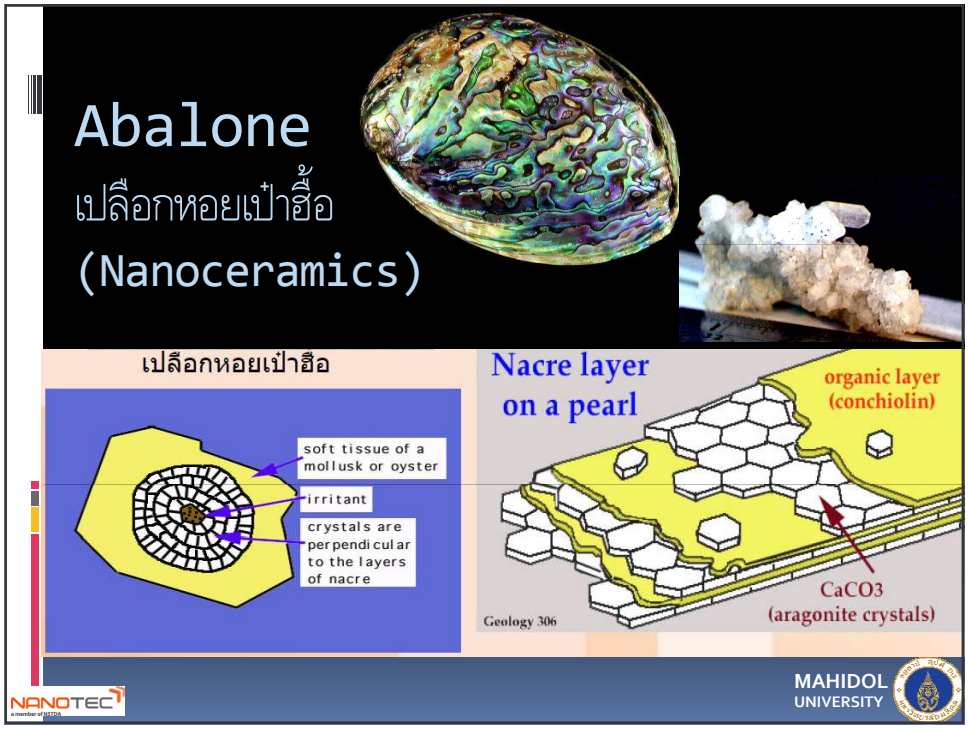
Abalone
เปลือกหอยเป๋าฮื้อ
(Nanoceramics)
เปลือกหอยเป๋าฮื้อ
soft tissue of a mollusk or oyster
irritant
crystals are perpendicular to the layers of nacre
Nacre layer on a pearl
organic layer (conchiolin)
CaCO3 (aragonite crystals)
Geology 306
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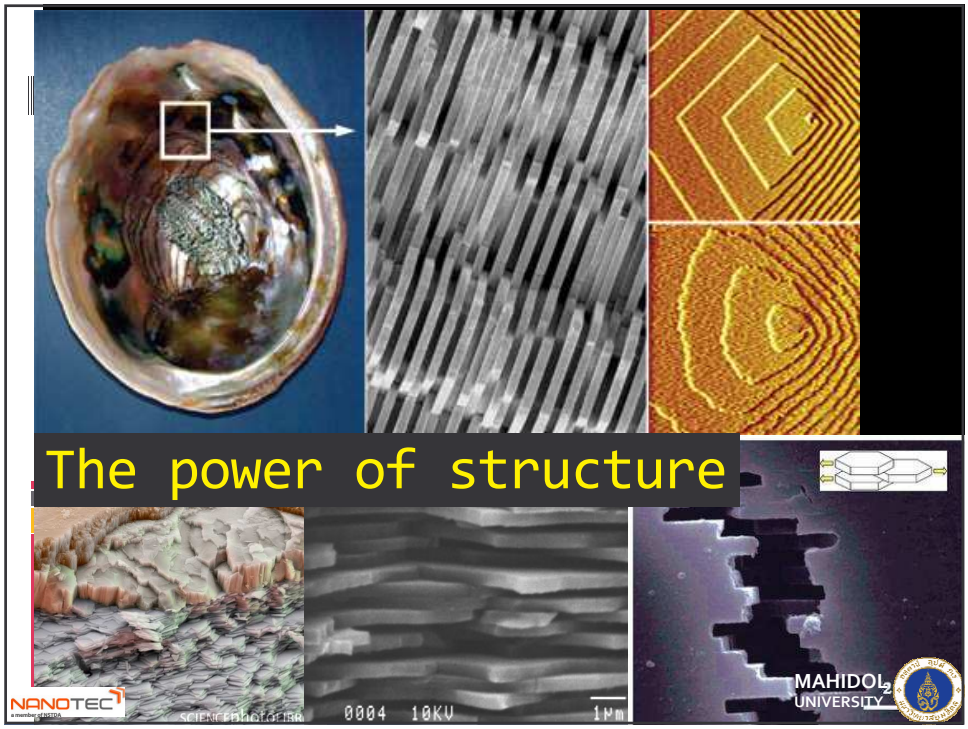
The power of structure
NANOTEC
0004 10KV
1μm
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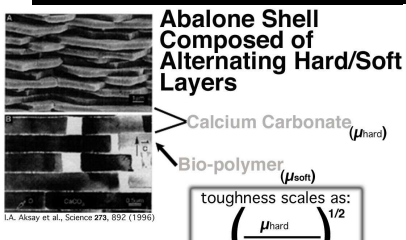
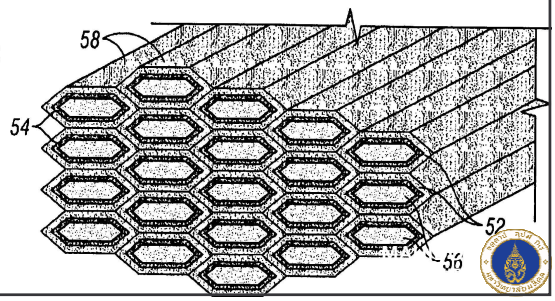
Multi-functional composite structures (US Patent 6805946)

- Including one or more components comprising:
  - an inner ceramic phase
  - an intermediate metal phase; and
  - an outer ceramic phases,





What makes color?

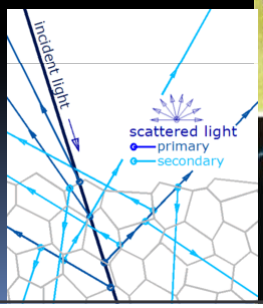
There are three possible reasons for color :

1. **Pigment** – if color is due to pigment, the color never change.

   Example : Blue parrot is always blue as the color is based on pigment not nanoscience

2. Nanoscopic color (Nature Photonic)

- The colors of beetle and butterfly wings come from the scattering of light.
- Light hits the nanostructure on their scales typically smaller than the wavelengths of visible light (< 400 nm)



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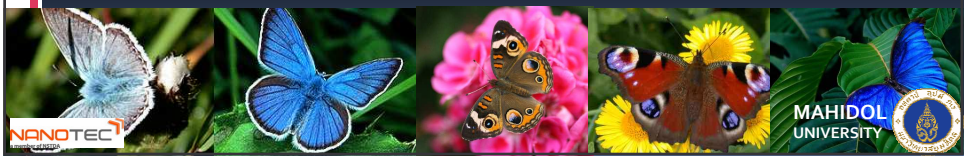
Butterfly wing

- Have you noticed that the colors on a butterfly wing change based on the angle you look at them?



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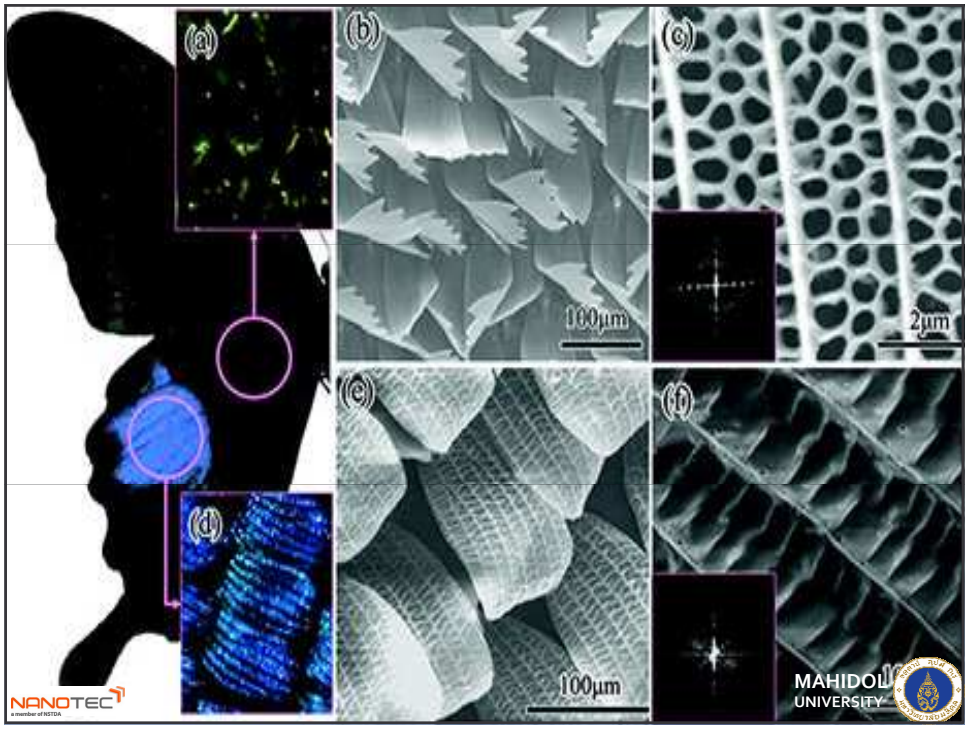
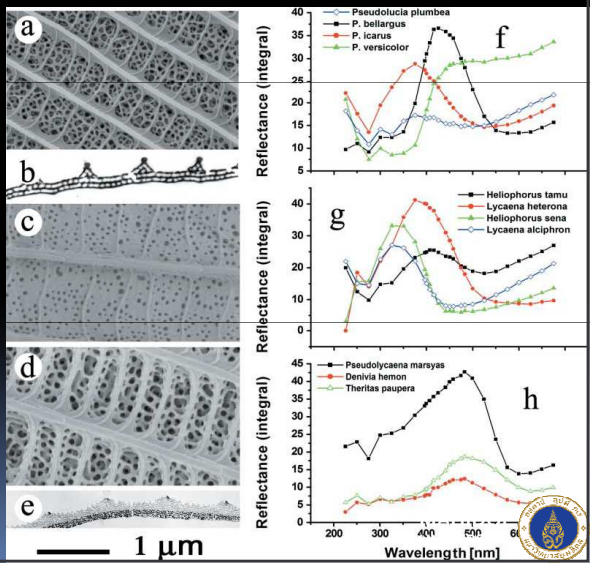


Reflection and/or transmission spectra of entire wings



Journal of Microscopy, V. 224(2006) 108–110.

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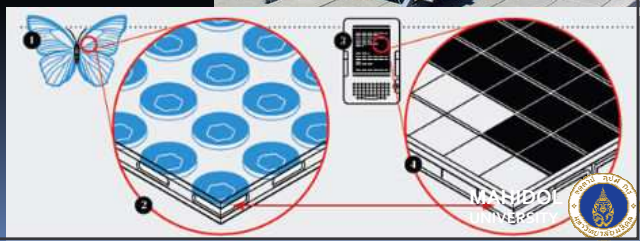
Butterfly Wings

- The wings are made up of nano-thin layers that cause light to reflect differently
- Scientists and engineers are using this to hopefully develop a new type "intelligent" solar panel and iridescent materials



3. Iridescent color

- The interference of different wavelengths of light makes color like oil on water
- Thin films made of nanoparticles smaller than 400 nm produce iridescent (rainbow) colors when light strikes them.
- At different angles, the color changes

Examples of Interference in Nature

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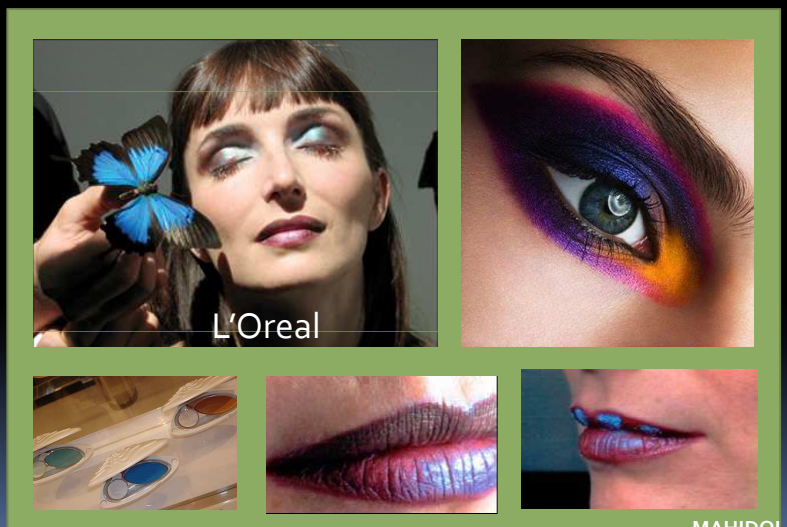
Photonic-based cosmetics



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Squid skin

- Scientists have produced metamaterials that are adaptive and responsive to their environment
- Organized nanostructures of materials that can change colors quickly like television screen

Thu 9 Dec 10 *from PhysOrg*

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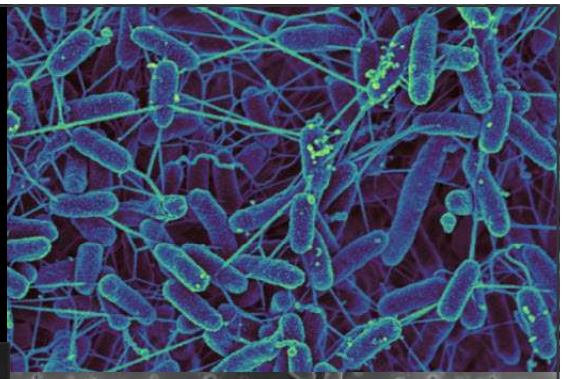
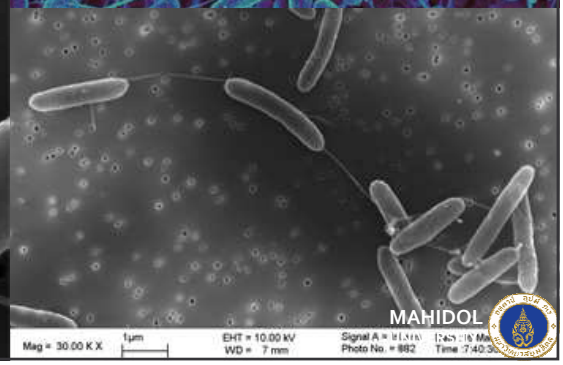
Bacteria Nanowire





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Nanowire fuel cell produces electricity from biological fluids like blood