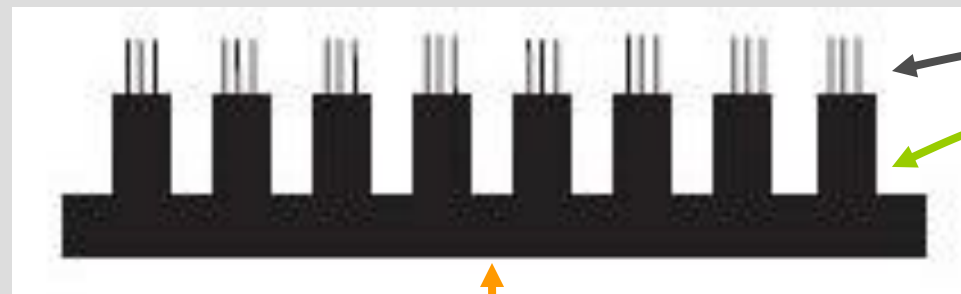
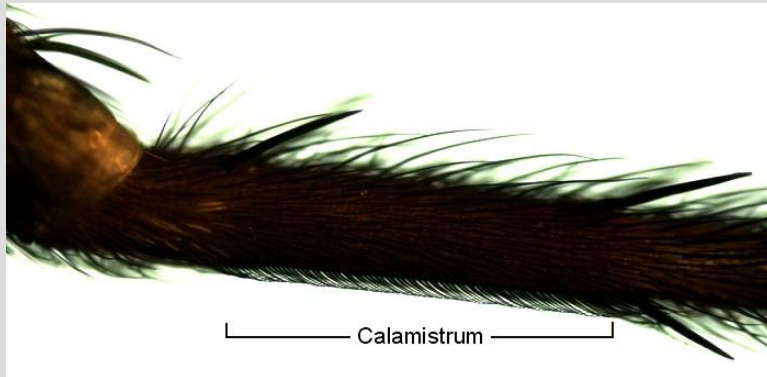
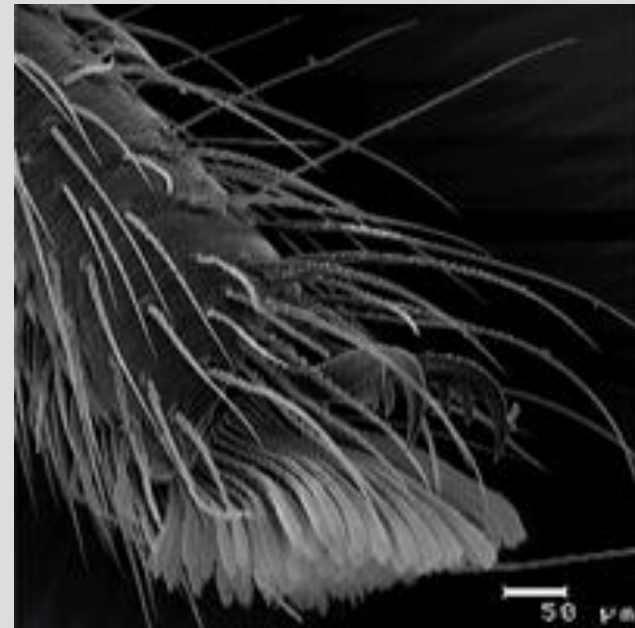


# Let's become Spiderman

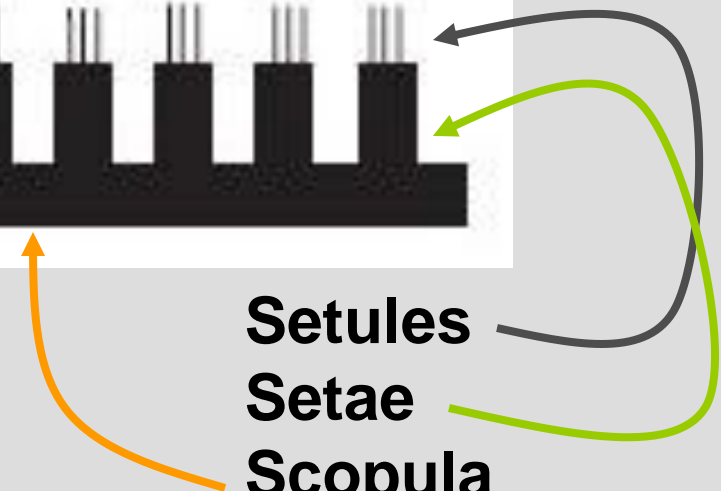


# Peter Parker is not a child's play!





Setules  
Setae  
Scopula



1 Scopula (area) =  $37,000 \mu\text{m}^2 = 0.037 \text{ mm}^2$

78,000 setules in one foot ( $\sim 200 \text{ nm}$  wide)

Surface area of each setule  $\sim 0.17 \mu\text{m}^2$

Total surface area available (all 8 feet)  $\sim 0.1 \times 10^{-6} \text{ m}^2$

van der Waals force (attractive) exerted by one setule  $\sim 41 \text{ nN}$

Total van der Waals force =  $24 \times 10^{-3} \text{ N}$

To overcome its body weight of  $15 \text{ mg} = 15 \times 10^{-6} \text{ kg}$

Downward pulling force  $\sim 0.15 \times 10^{-3} \text{ N}$

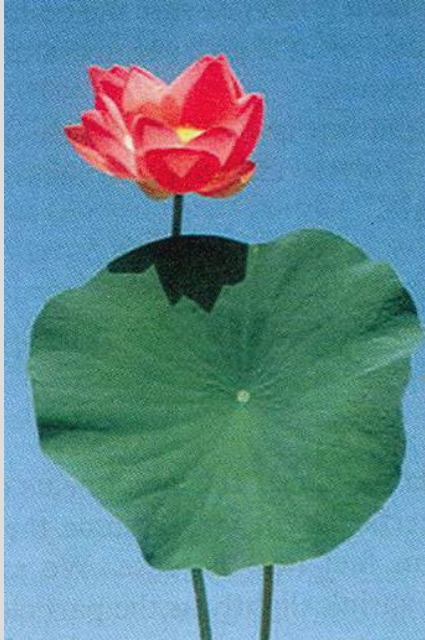
Safety factor = 160

# Gecko Feet





# Lotus effect

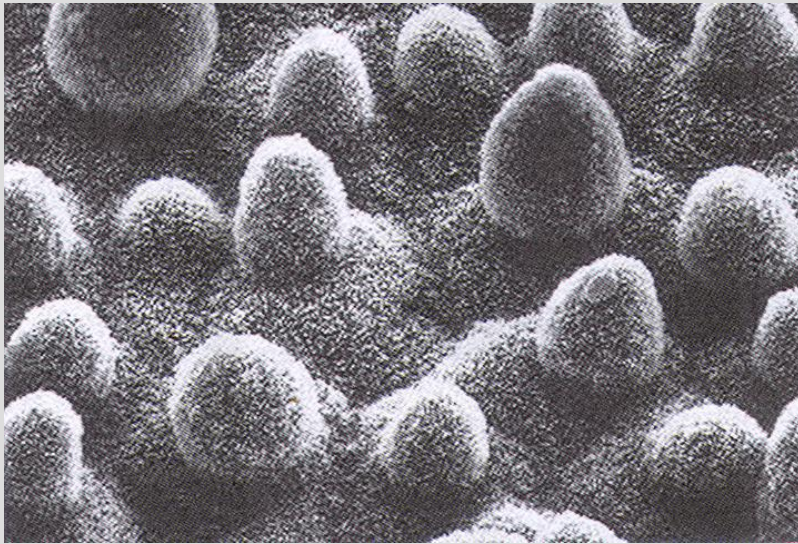


**Synthetic material  
showing lotus effect**

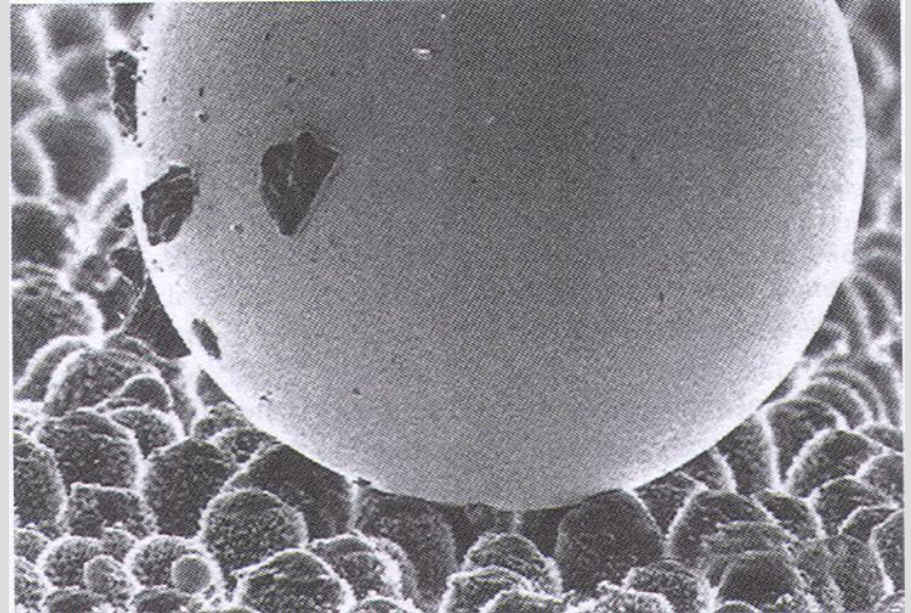


**Non-wetting and  
self cleaning surface**

# Fakir Bed



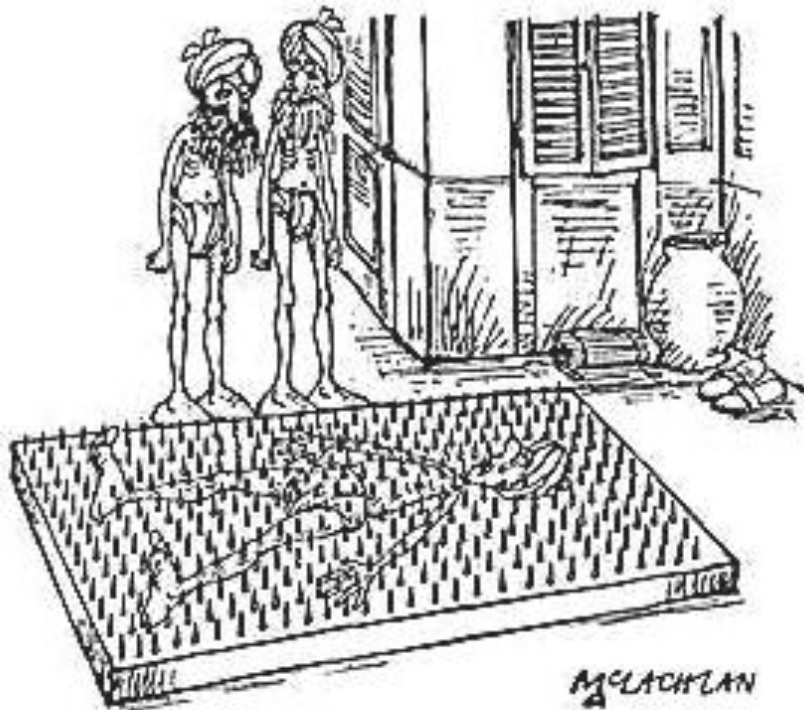
Tiny nano-sized structures protrude;  
**Fakir bed** type of situation



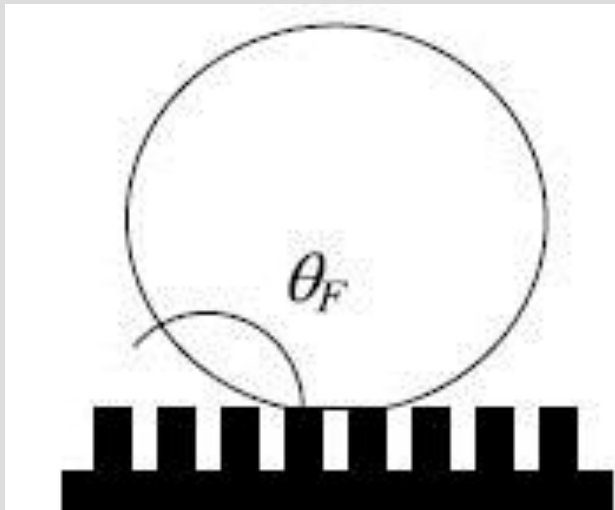
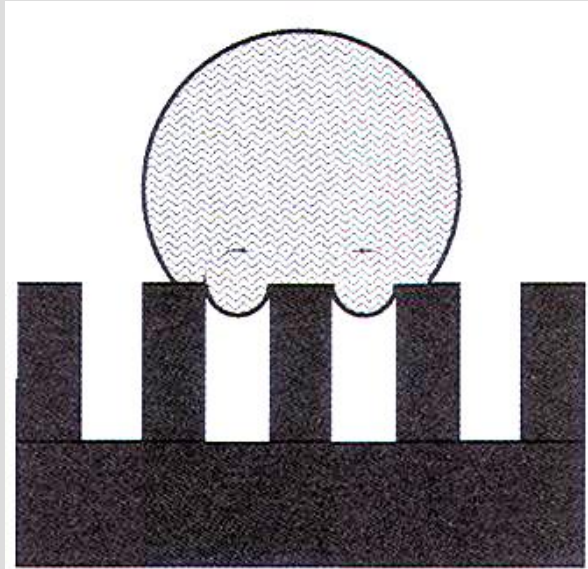
Water drop on leaf surface.  
Dust particles sticking to  
water drop; **self-cleaning**



# Fakir Bed

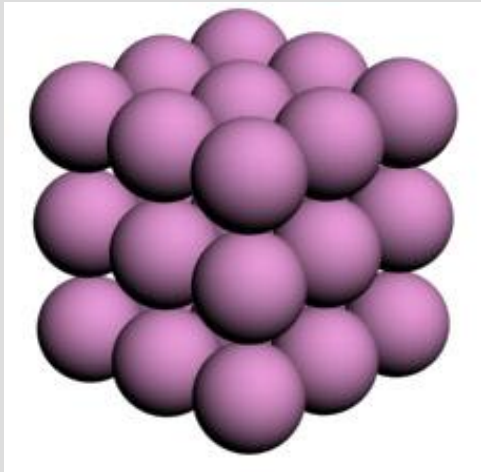
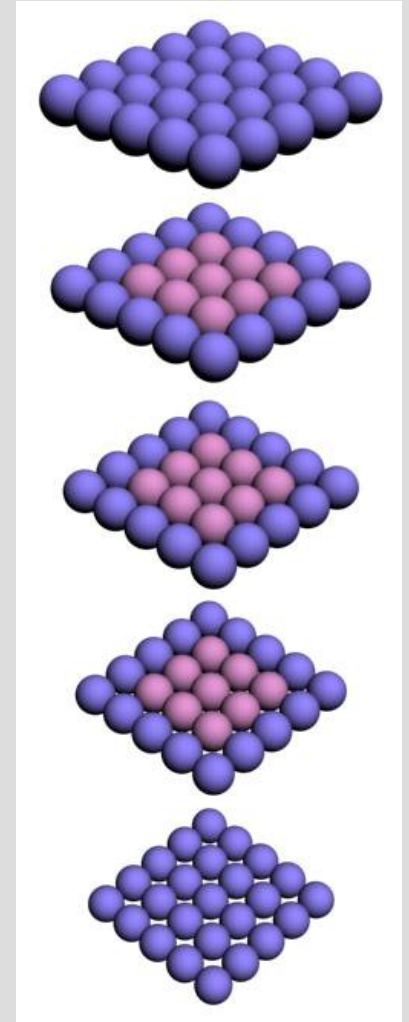
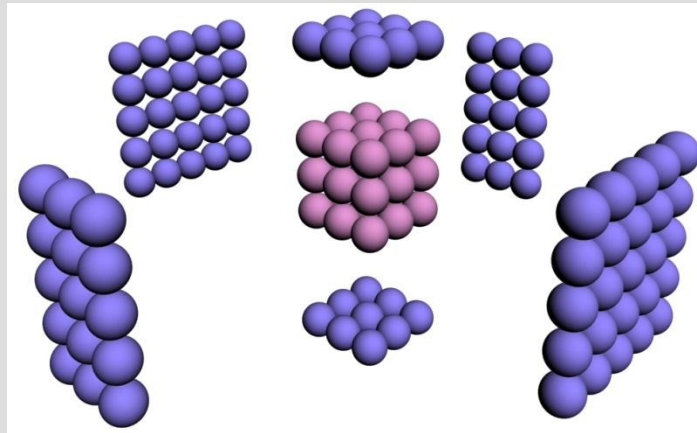
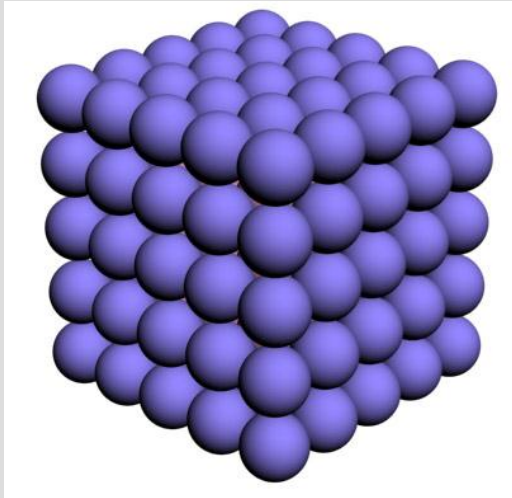


"There, what am I always telling you - young people today are soft".





# Faces are key to behaviour



# Considering Hydrogen atom (radius = 0.05 nm)

<b>n (atoms on edge)</b>	<b><math>N = n^3</math> (total atoms)</b>	<b>% atoms on surface</b>	<b>Size of cube</b>
<b><math>10^7</math></b>	<b><math>10^{21}</math></b>	<b>0.000006</b>	<b>1 mm</b>
<b><math>10^4</math></b>	<b><math>10^{12}</math></b>	<b>0.06</b>	<b><math>1\ \mu\text{m}</math></b>
<b>500</b>	<b><math>125 \times 10^6</math></b>	<b>1.2</b>	<b>50 nm</b>
<b>100</b>	<b><math>10^6</math></b>	<b>5.8</b>	<b>10 nm</b>
<b>10</b>	<b><math>10^3</math></b>	<b>50</b>	<b>1 nm</b>
<b>5</b>	<b>125</b>	<b>80</b>	<b>0.5 nm</b>

# **Exploring Nano: a Pedagogical Journey**



# Sunscreen Lotion

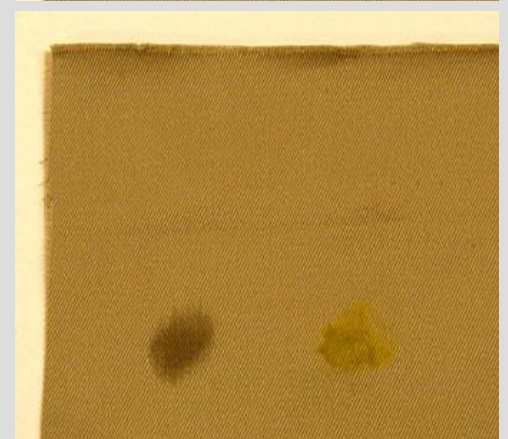
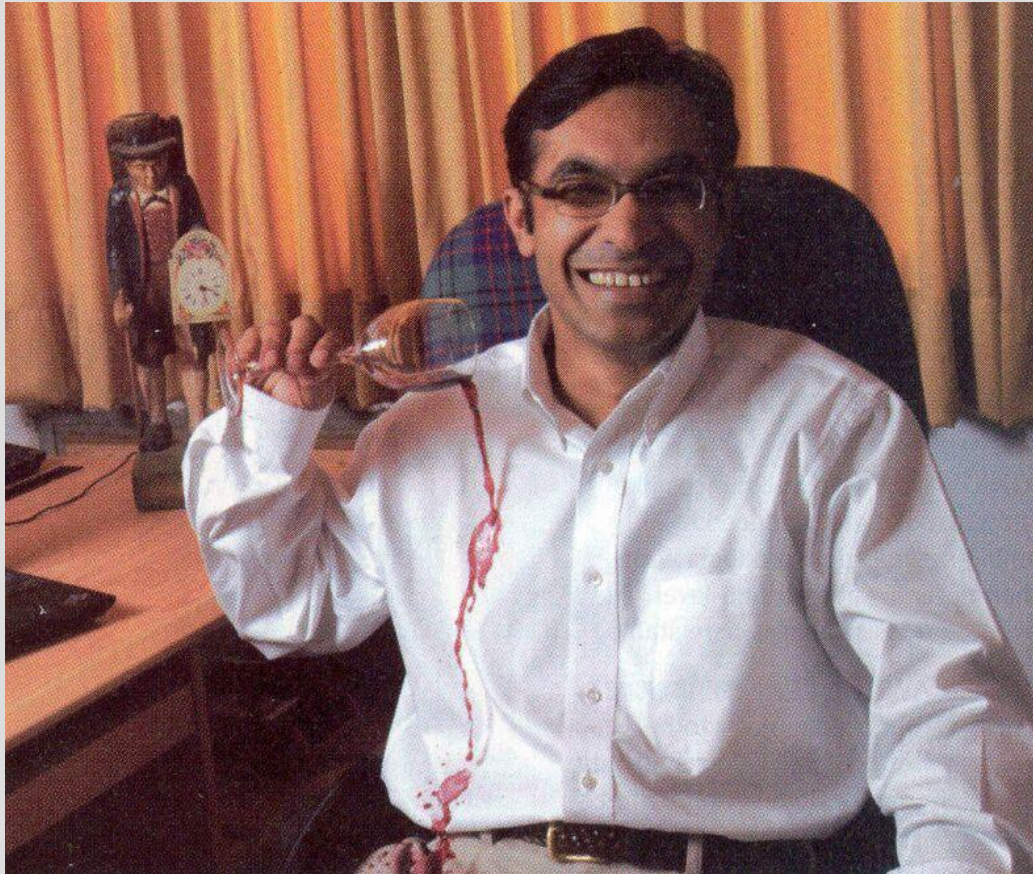


**Titanium oxide**

**Zinc oxide**

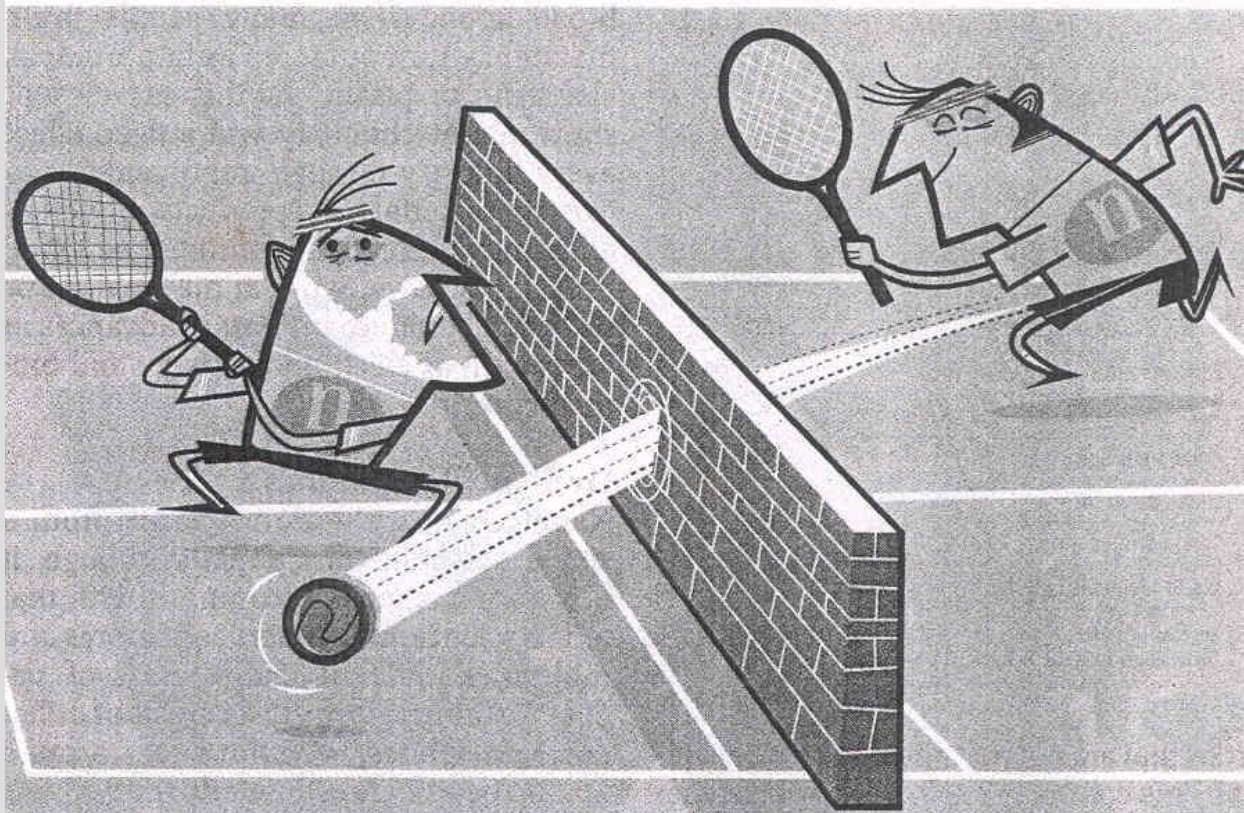


# Stain free, Water resistant fabric





# Expect the Unexpected





What is Nanotechnology?

# Understanding Effects

**Centimeter:** Gravity, friction, combustion

**Millimeter:** Gravity, friction, combustion, electrostatic

**Micrometer:** Electrostatic, van der Waals, Brownian

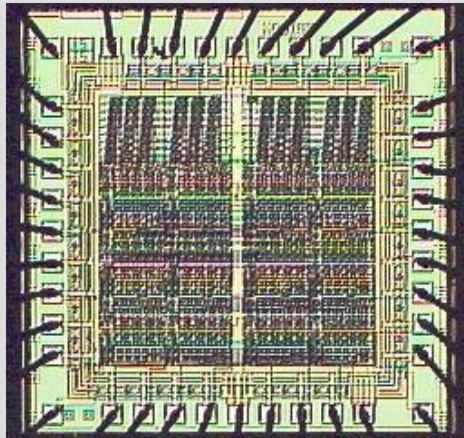
**Nanometer:** Electrostatic, van der Waals, Brownian,  
Quantum

**Angstrom:** Quantum mechanics

(1/10,000,000,000 meter)

Do you recognize this structure?

Nanotechnology is all about  
Arranging Atoms



- Diversity
- Precision
- Cost



# **Richard Feynman, 1959 (the great visionary)**

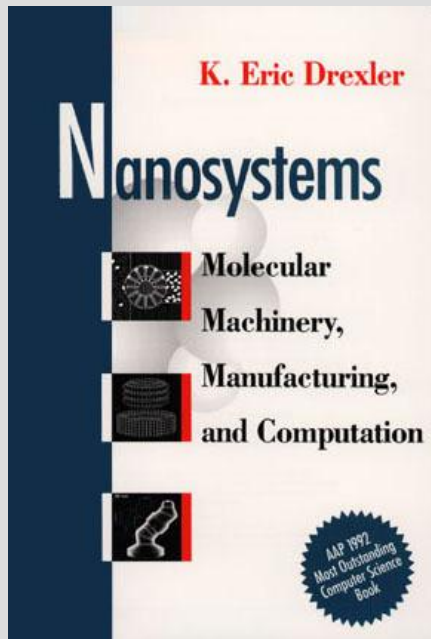


***There's plenty of room  
at the bottom***

**The principles of Physics,  
as far as I can see, do not  
speak against the possibility  
of maneuvering things atom  
by atom.**

Richard P. Feynman

# Eric Drexler, 1992 (the great pioneer)



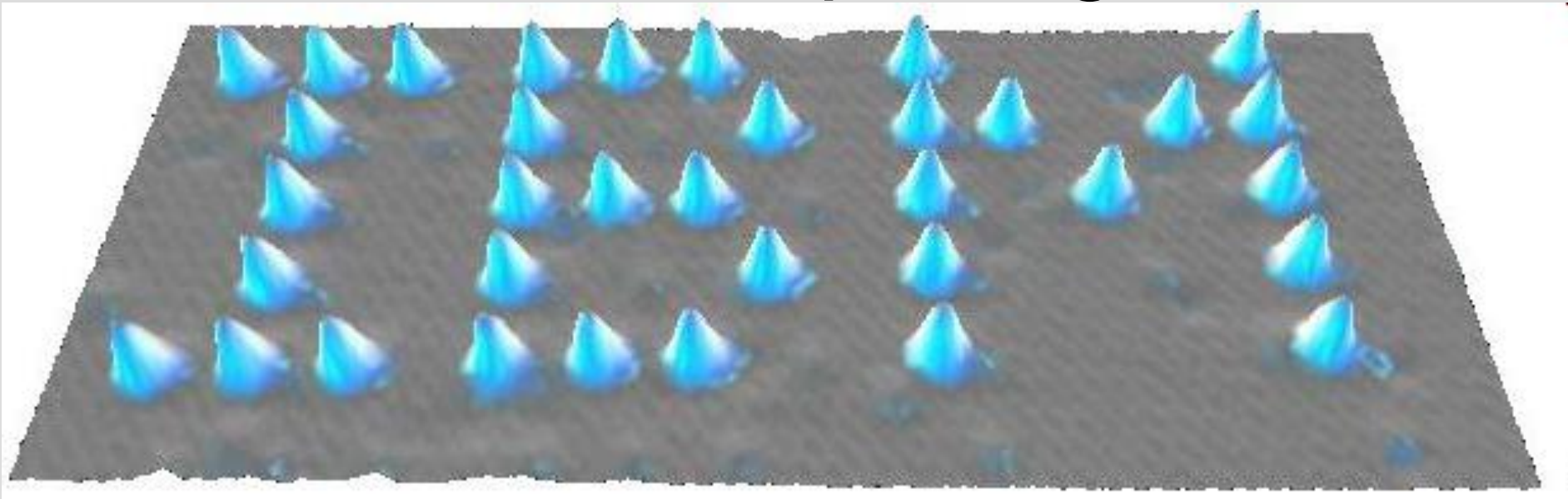
**Nanotechnology is the principle of atom manipulation atom by atom, through control of the structure of matter at the molecular level. It entails the ability to build molecular systems with atom-by-atom precision, yielding a variety of nanomachines.**

Eric Drexler

# *Manipulation Atom-by-Atom*

IBM

35 Xe atoms put together



**Don Eigler (IBM, California), 1989**

**Became the 1<sup>st</sup> person to move atoms**



**Nanotechnology is concerned with developing the tools for characterizing and manipulating materials on nanoscale (1-100 nm) and exploiting these tools for the development of new products and processes.**

**Narrow definition: at least 2 dim are below 100 nm**

**Extended definition: one dimension below 100 nm and a second dimension below 1  $\mu\text{m}$ .**

## **Nanostructure**

**Based on their geometrical dimension with reference to an external reference system, *viz.*, substrate.**

## **Nanodevice**

**At least one functional component is a nanostructure.**

## **Nanosystem**

**Consists of several nanodevices that are of importance for the functioning of the whole system.**

# ***Advantages of starting from “small things”***

you can dissolve sugar or salt quicker when it is in powder form and slower when it is in the form of crystals or blocks

***smaller can become more reactive***



# ***Advantages of starting from “small things”***

- Properties can be altered as desired
- More precision
- Less waste