

5 Maggio 2015  
Progetto Lauree Scientifiche

# Oh, i posti che visiterai!

(con il grafene ed i nanotubi di carbonio)



## Stefano Cicchi

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Università di Firenze  
[stefano.cicchi@unifi.it](mailto:stefano.cicchi@unifi.it)

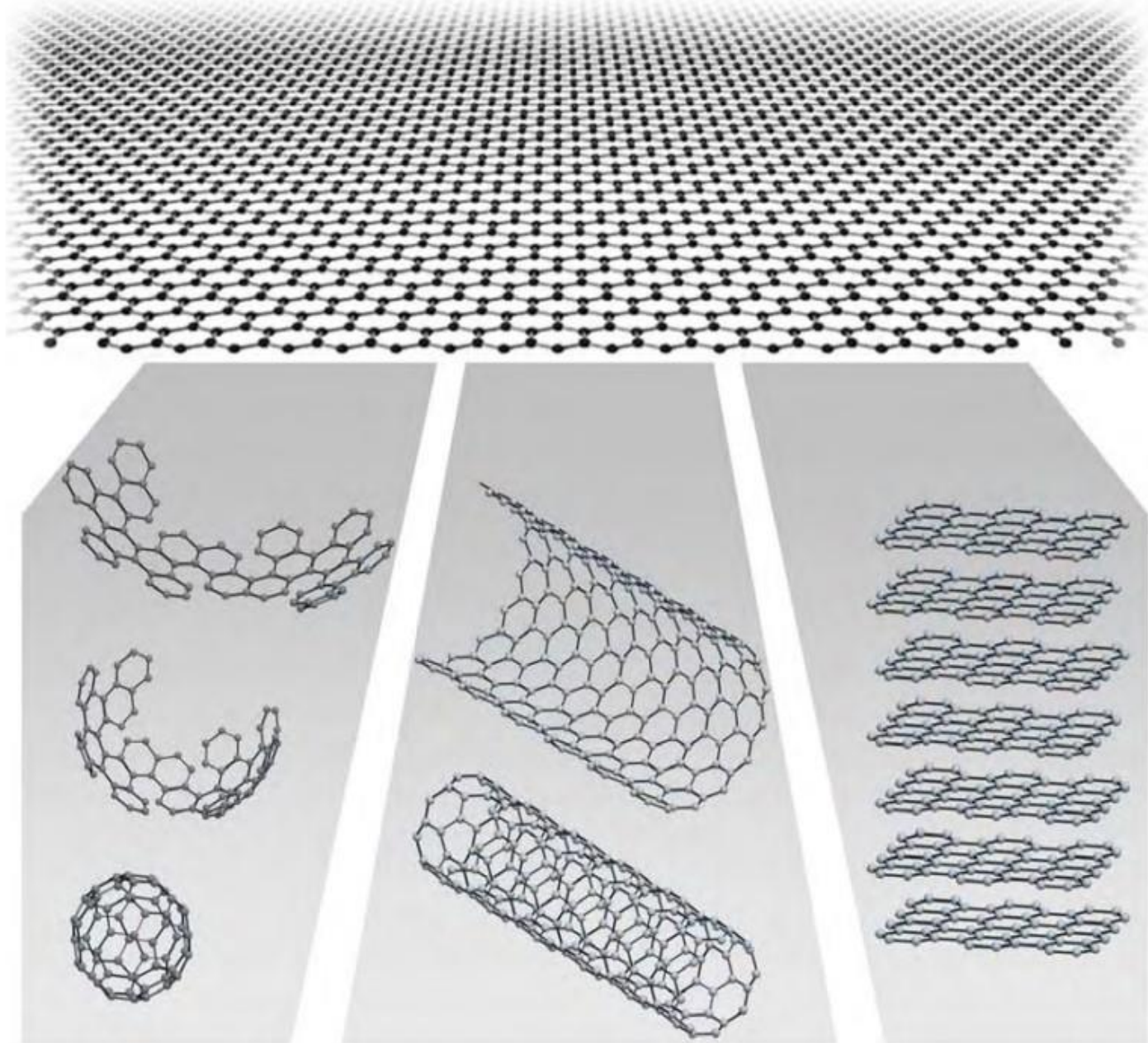


Figure 1. **Mother of all graphitic forms.** Graphene is a 2D building material for carbon materials of all other dimensionalities. It can be wrapped up into 0D buckyballs, rolled into 1D nanotubes or stacked into 3D graphite.



# The Nobel Prize in Chemistry 1996



Robert F. Curl Jr.

Prize share: 1/3



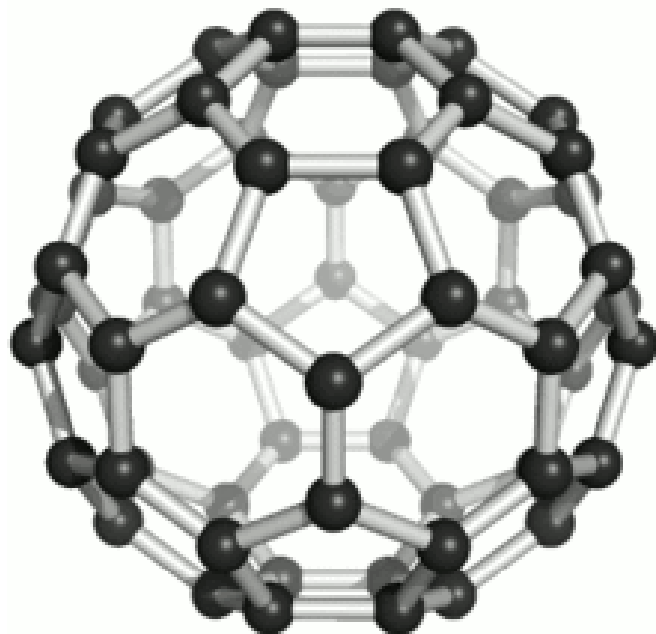
Sir Harold W. Kroto

Prize share: 1/3



Richard E. Smalley

Prize share: 1/3



The Nobel Prize in Chemistry 1996 was awarded jointly to Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley *"for their discovery of fullerenes"*.



# The Nobel Prize in Physics 2010



Photo: U. Montan

**Andre Geim**

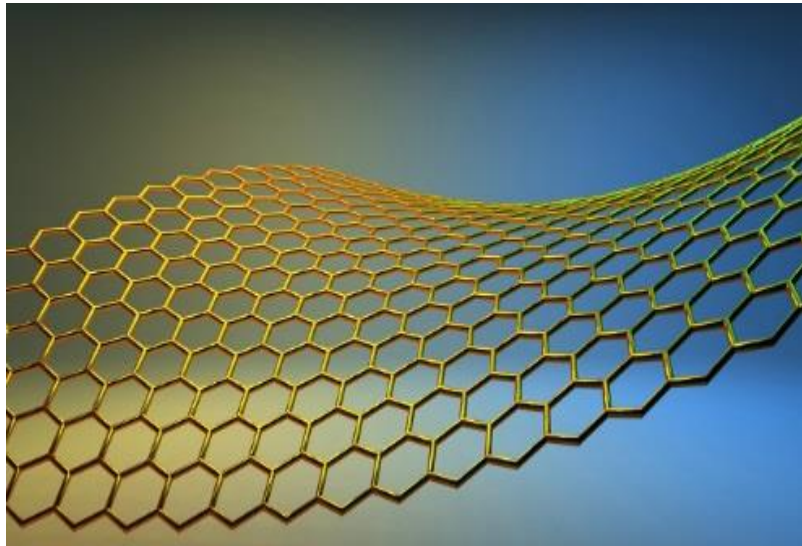
**Prize share: 1/2**



Photo: U. Montan

**Konstantin  
Novoselov**

**Prize share: 1/2**

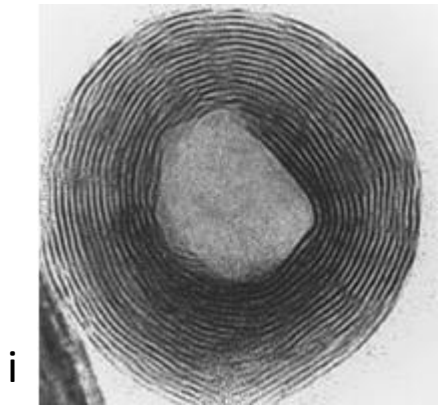
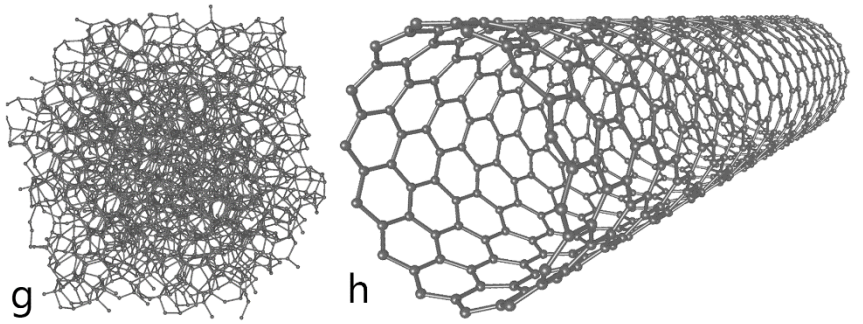
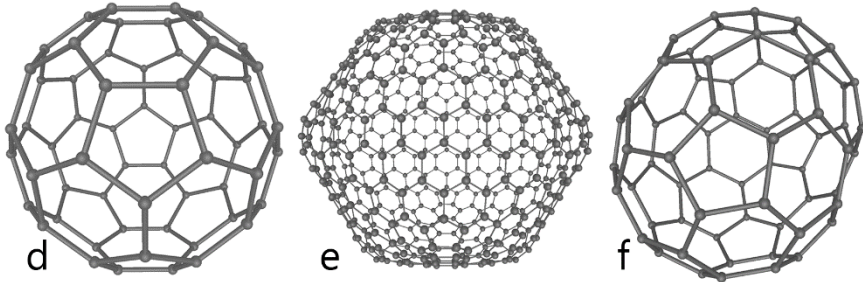
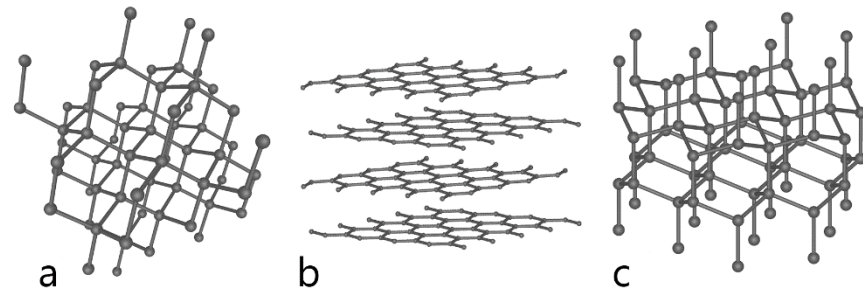


The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov *"for groundbreaking experiments regarding the two-dimensional material graphene"*

NATURE | EDITORIAL  
INTERNATIONAL YEAR OF CHEMISTRY



**2011: YEAR OF  
CHEMISTRY**  
Celebrating the  
central science



- a) Diamante
- b) Grafite
- c) Losdaleite
- d) Forme fullereniche
- e) Forme fullereniche
- f) Forme fullereniche
- g) Carbone amorfo
- h) Nanoptubi di carbonio
- i) Nano cipolle

# Fullerene



$C_{60}$

1 nm



# Nanotubi di carbonio



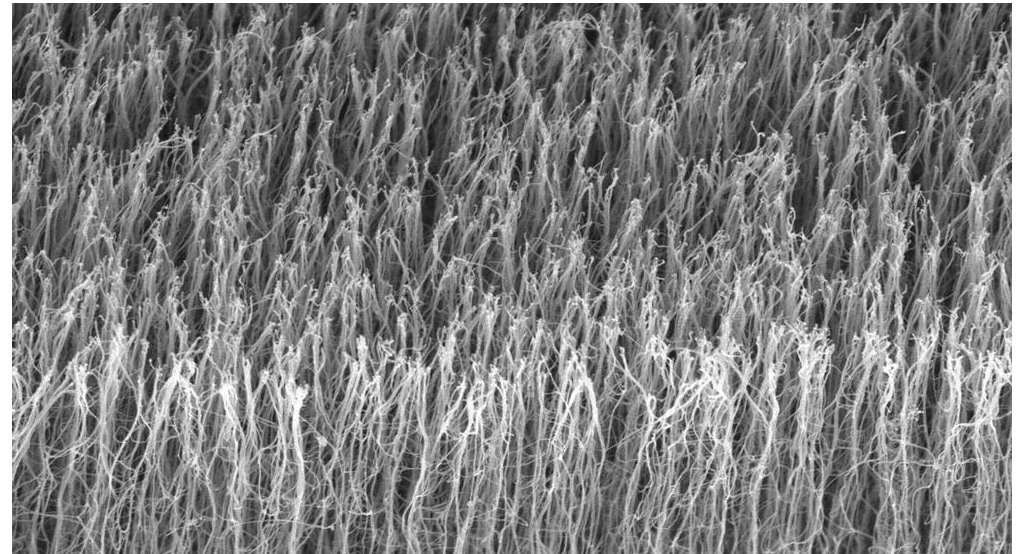
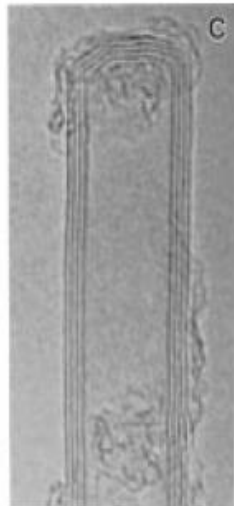
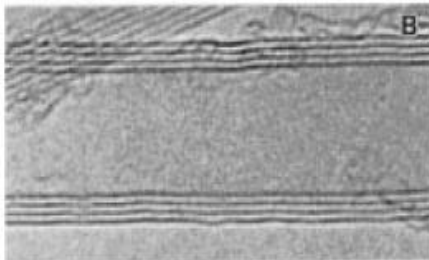
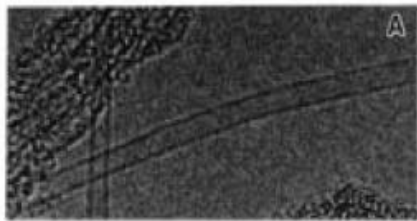
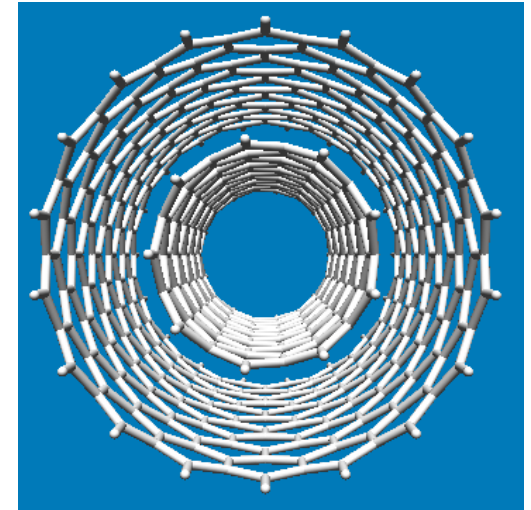
armchair



zigzag



chiral





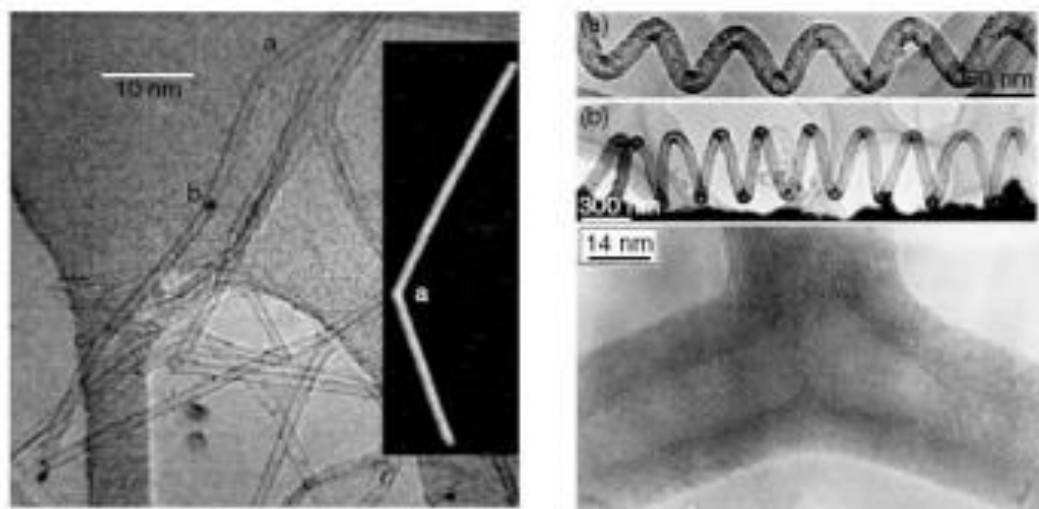
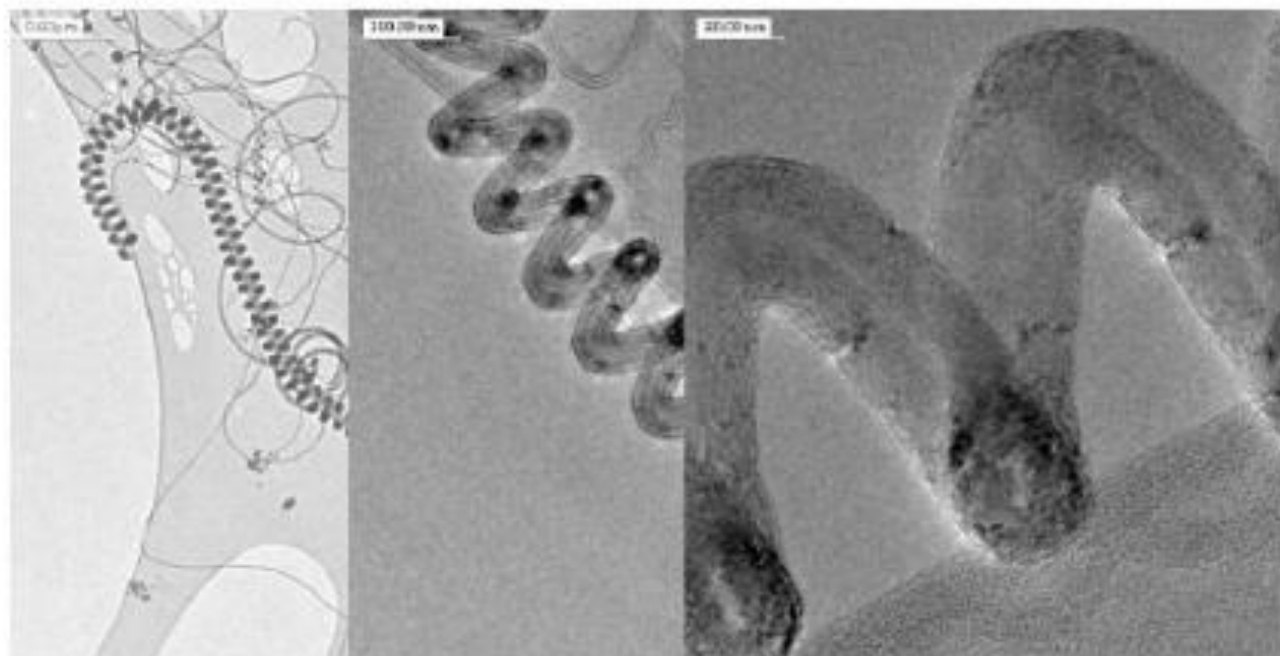
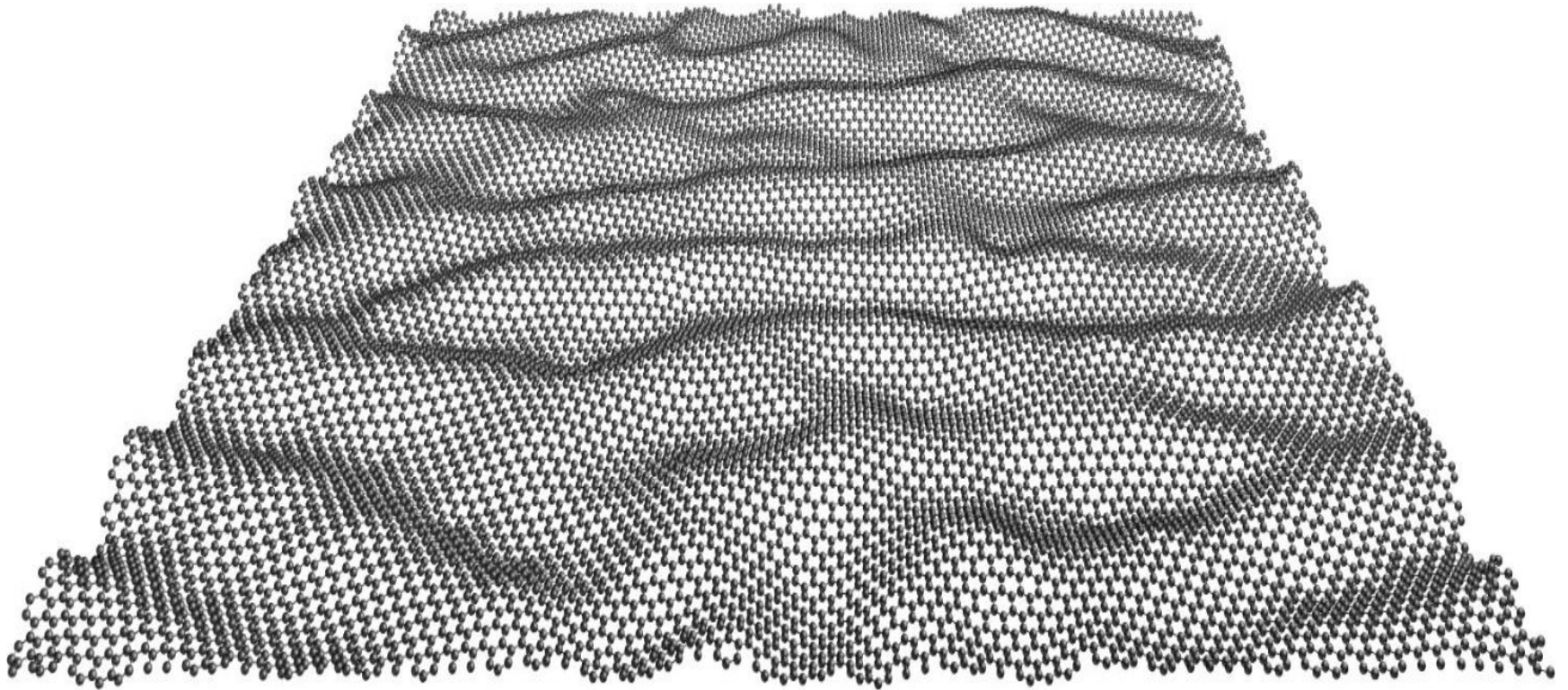


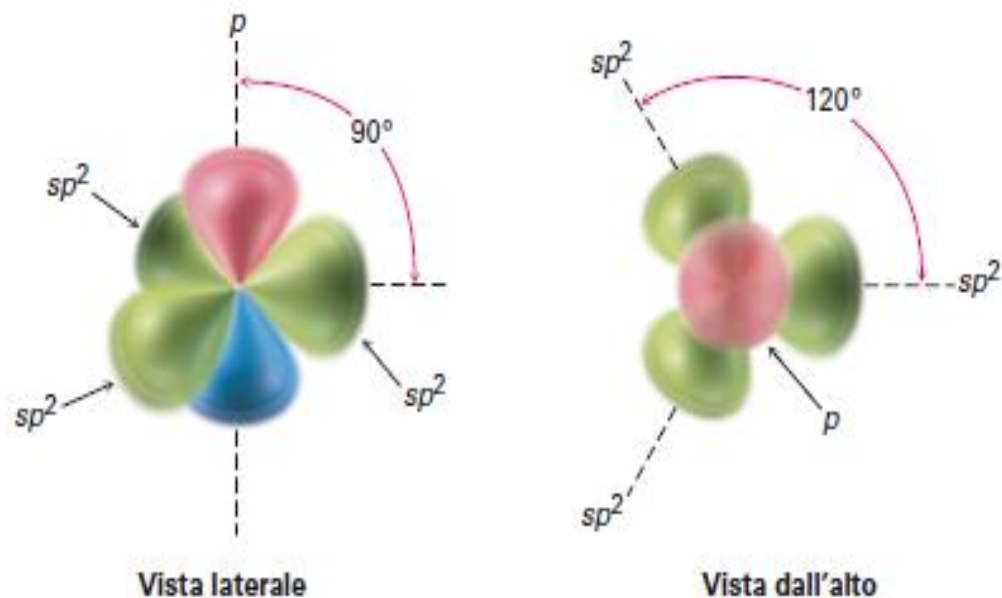
FIGURE 1.5 Representative TEM and AFM (insert) images of the individual SWNT bends. (a), (b) and (c) denote three typical bend angles of  $34^\circ$ ,  $26^\circ$ , and  $18^\circ$  [18], MWNT coils [17], and Y branches [16]. (Figure 1.5a from Zhang et al., *Appl. Phys. Lett.*, 83, 423, 2003; Figure 1.5c from Satishkumar et al., *Appl. Phys. Lett.*, 77, 2530, 2000.)



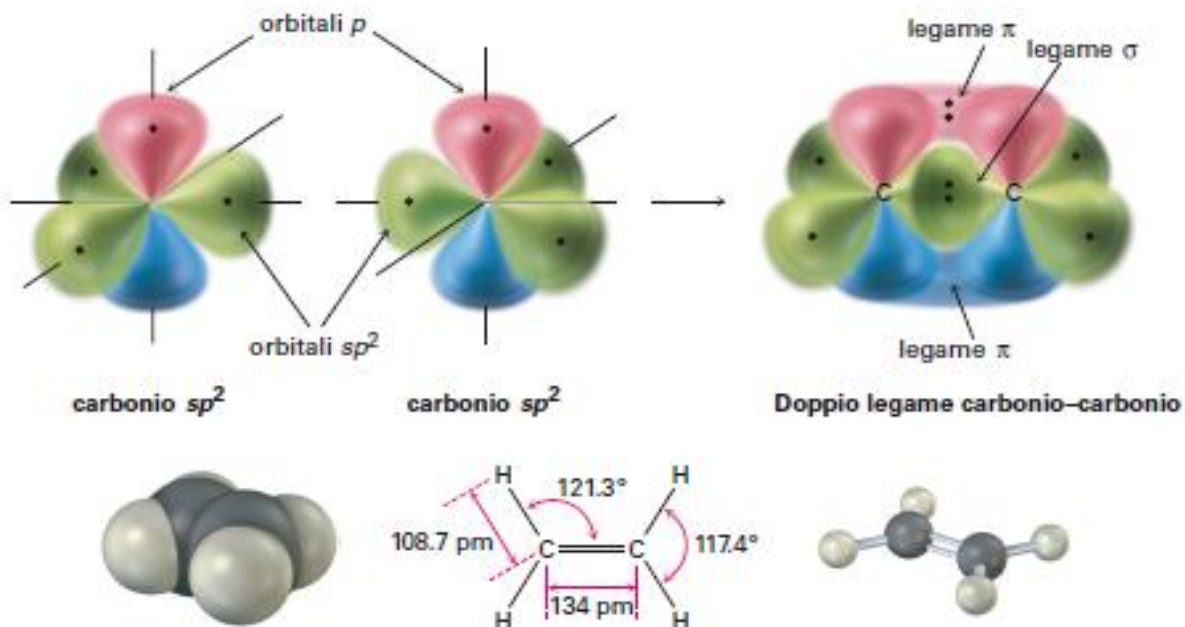
# Grafene

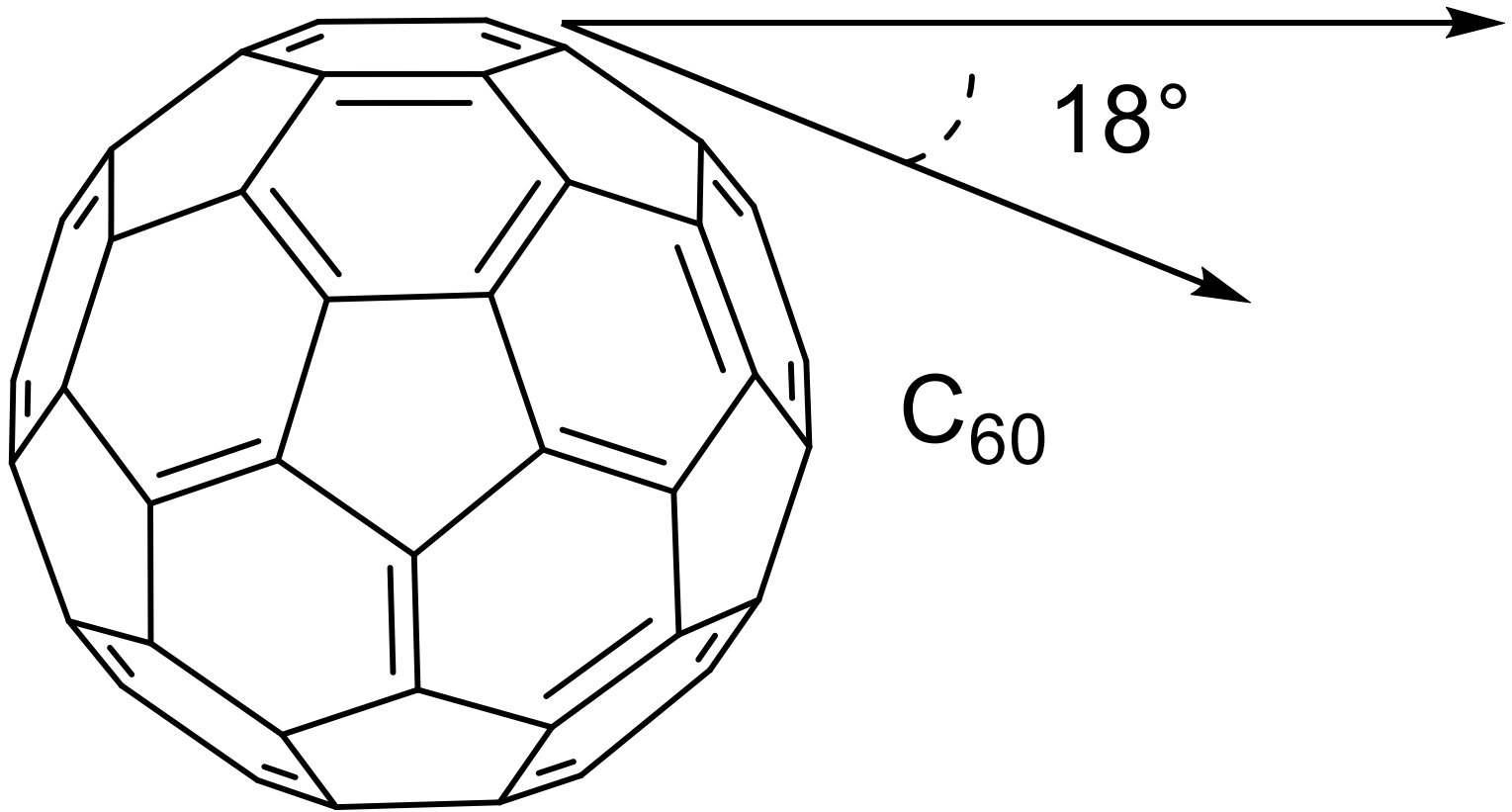


**Figura 1.13** Un carbonio ibridizzato  $sp^2$ . I tre orbitali ibridi  $sp^2$  equivalenti (verde) giacciono in un piano ad un angolo di  $120^\circ$  l'uno rispetto all'altro, ed un singolo orbitale  $p$  non ibridizzato (rosso/blu) è perpendicolare al piano  $sp^2$ .



**Figura 1.14** Struttura dell'etilene. Sovrapposizione degli orbitali di due atomi di carbonio ibridizzati  $sp^2$  a formare un doppio legame carbonio-carbonio. Una parte del doppio legame deriva dalla sovrapposizione  $\sigma$  (testa-testa) degli orbitali  $sp^2$ , e l'altra parte deriva dalla sovrapposizione  $\pi$  (laterale) degli orbitali  $p$  non ibridizzati (rosso/blu). Il legame  $\pi$  ha regioni di densità elettronica su ciascun lato di una linea tracciata tra i nuclei.

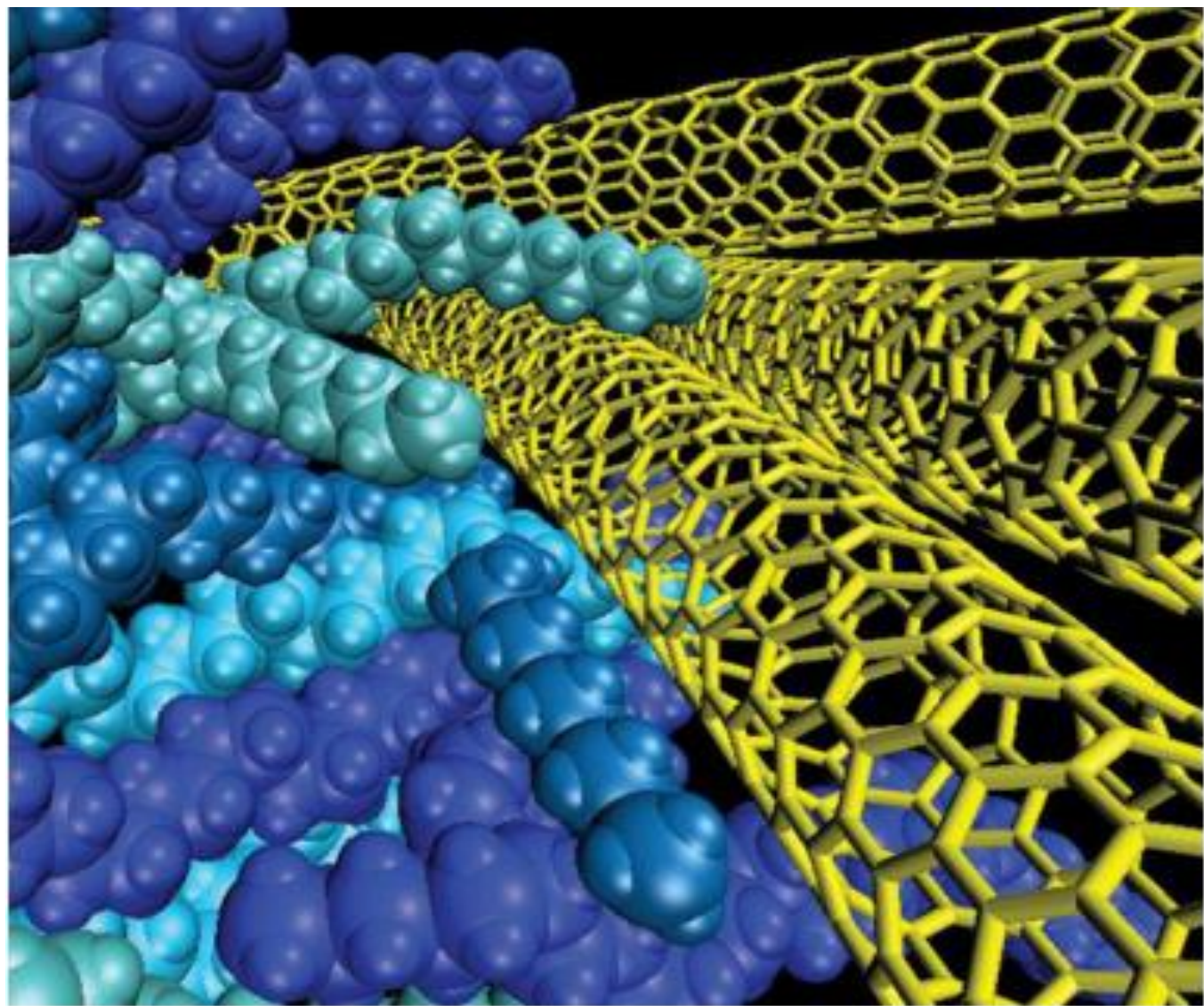




TI VUOI SCIUGLIERE  
• • • O NO!

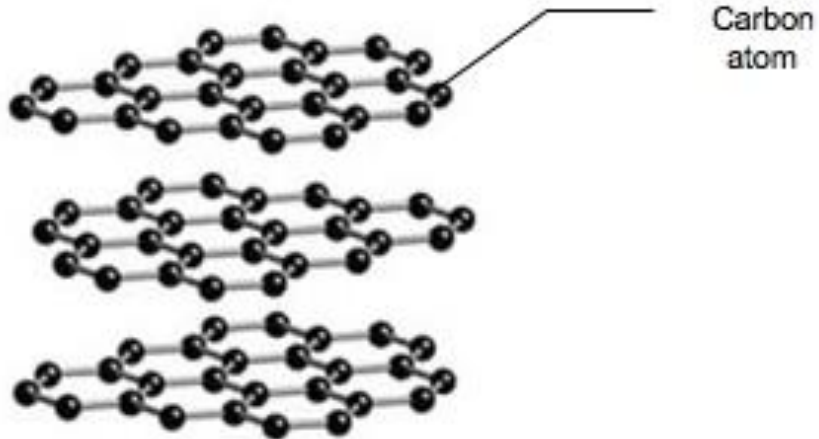


<i>Solvente</i>	<i>Solubilità C<sub>60</sub> (mg/mL)</i>
n-pentano	0.005
decalina	4.6
dodecano	0.091
cicloesano	0.036
CCl <sub>4</sub>	0.32
CH <sub>2</sub> Cl <sub>2</sub>	0.254
metanolo	0
etanolo	0.001
benzene	1.7
toluene	2.8
xileni	5.2
bromo benzene	3.3
1,2-diclorobenzene	27.0
1-cloronaftalene	51
Disolfuro di carbonio	7.9
2-metiltiofene	6.8
tetraidrofurano	0





## Structure of Graphite







Graphene.mp4

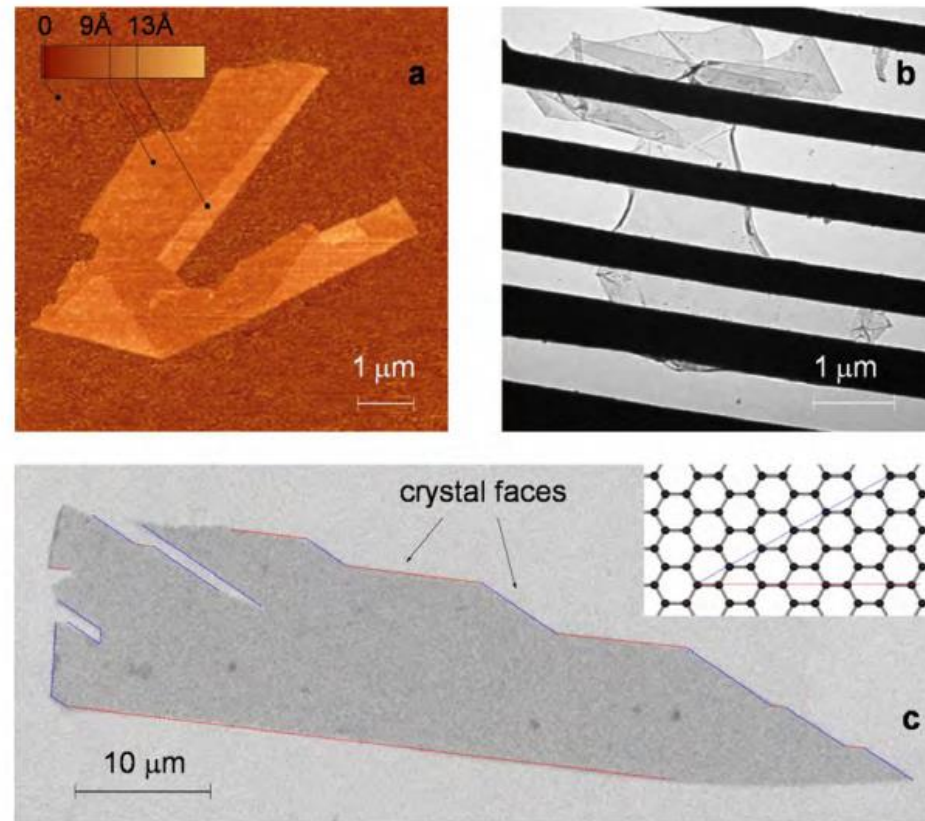


Figure 2. **One-atom-thick single crystals: the thinnest material you will ever see.** **a**, Graphene visualized by atomic-force microscopy (adapted from ref. 8). The folded region exhibiting a relative height of  $\approx 4\text{\AA}$  clearly indicates that it is a single layer. **b**, A graphene sheet freely suspended on a micron-size metallic scaffold. The transmission-electron-microscopy image is adapted from ref. 18. **c**, scanning-electron micrograph of a relatively large graphene crystal, which shows that most of the crystal's faces are zigzag and armchair edges as indicated by blue and red lines and illustrated in the inset (*T.J. Booth, K.S.N, P. Blake & A.K.G. unpublished*). 1D transport along zigzag edges and edge-related magnetism are expected to attract significant attention.

Sigma Aldrich 1 cm X 1 cm  
singolo strato su supporto di Cu  
178 euro

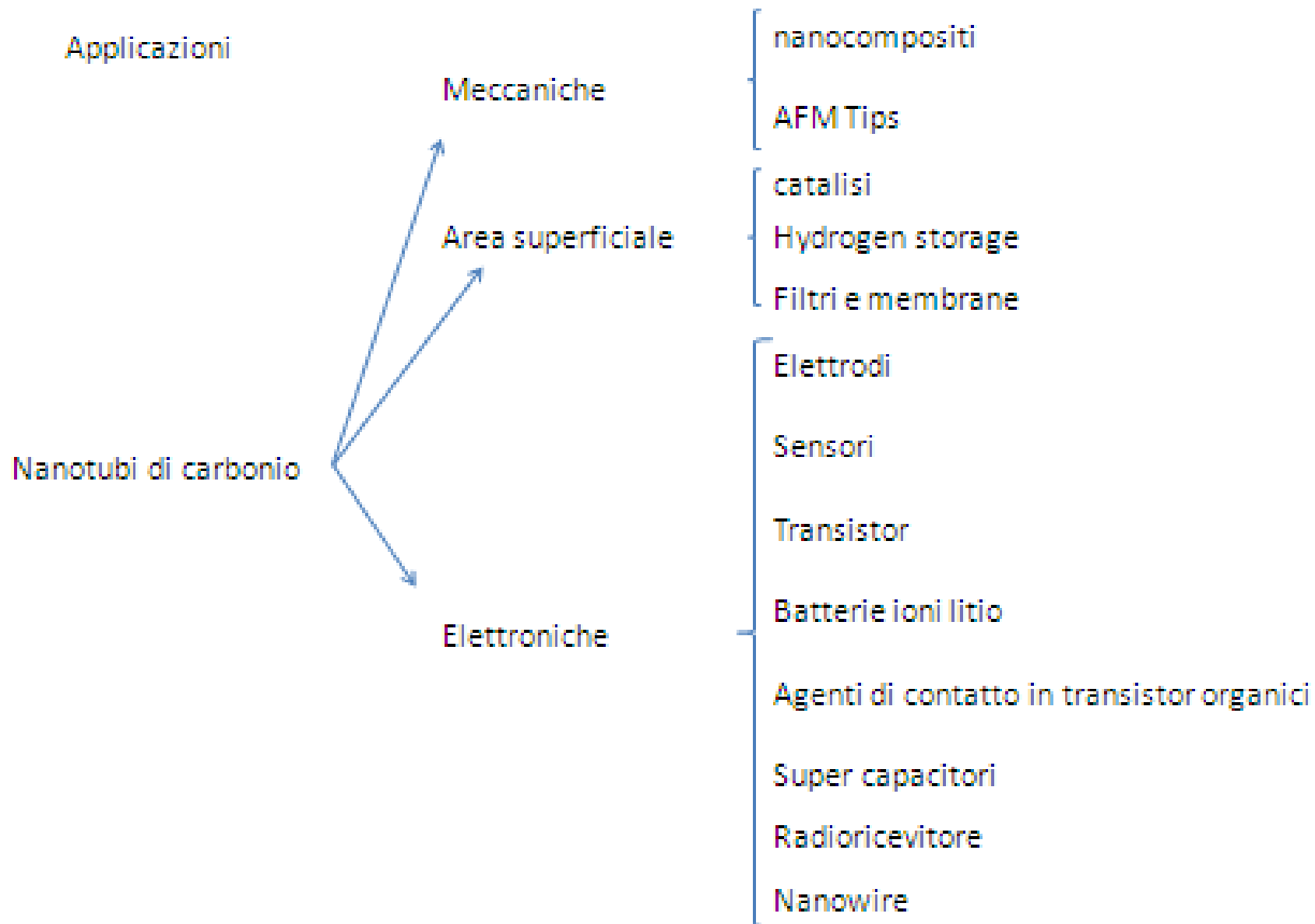


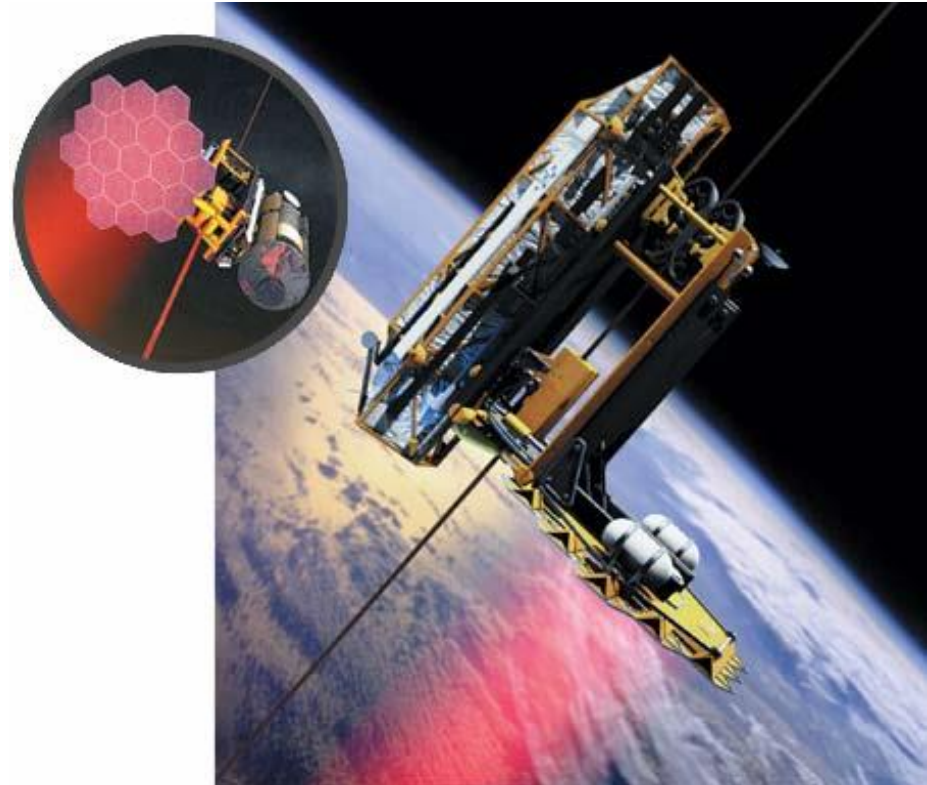
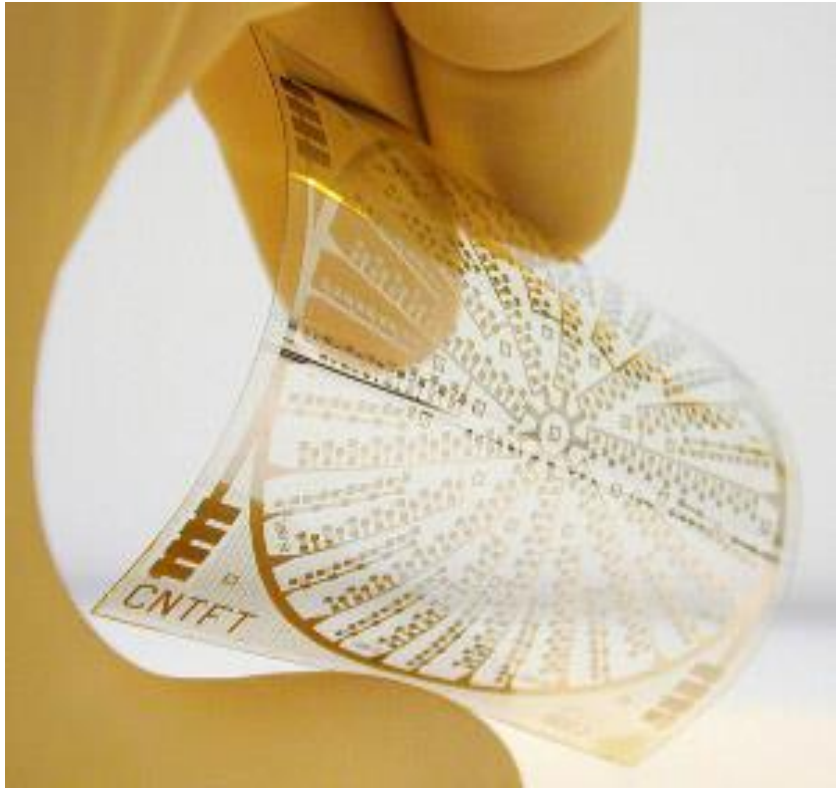
Fullerene C<sub>60</sub> (98%) 1 g, 161 euro

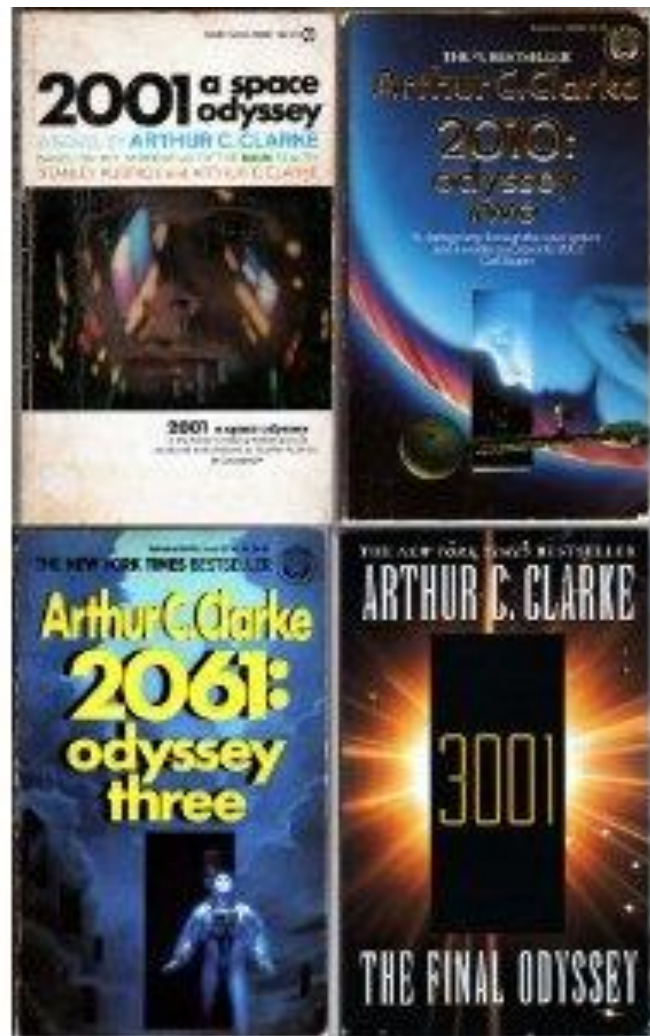
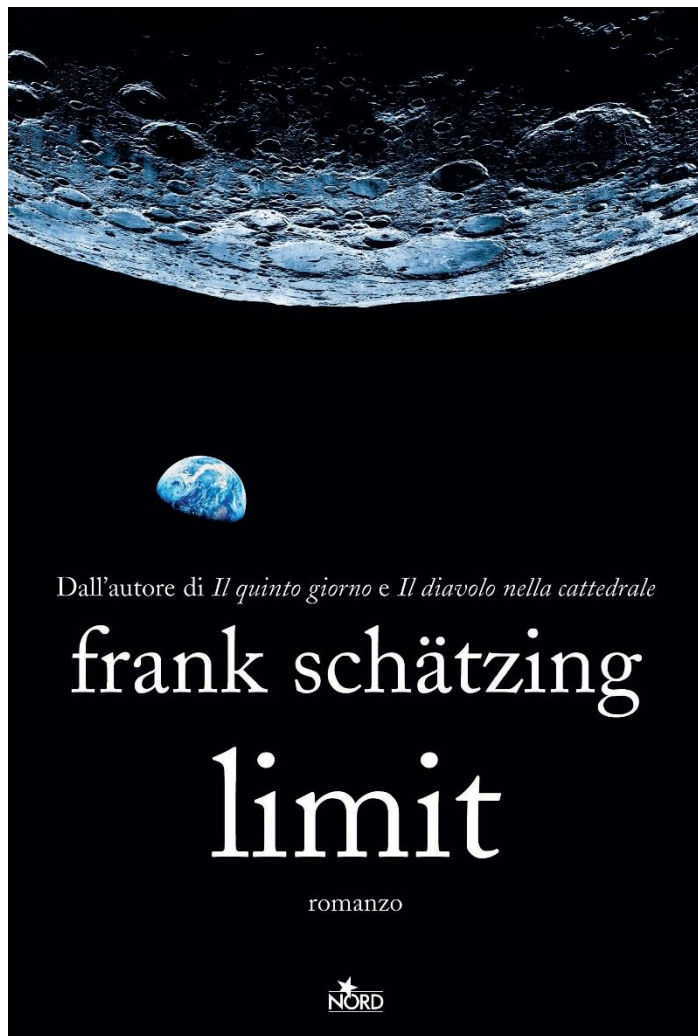
Nanotubi di carbonio SW 250 mg, 290 euro

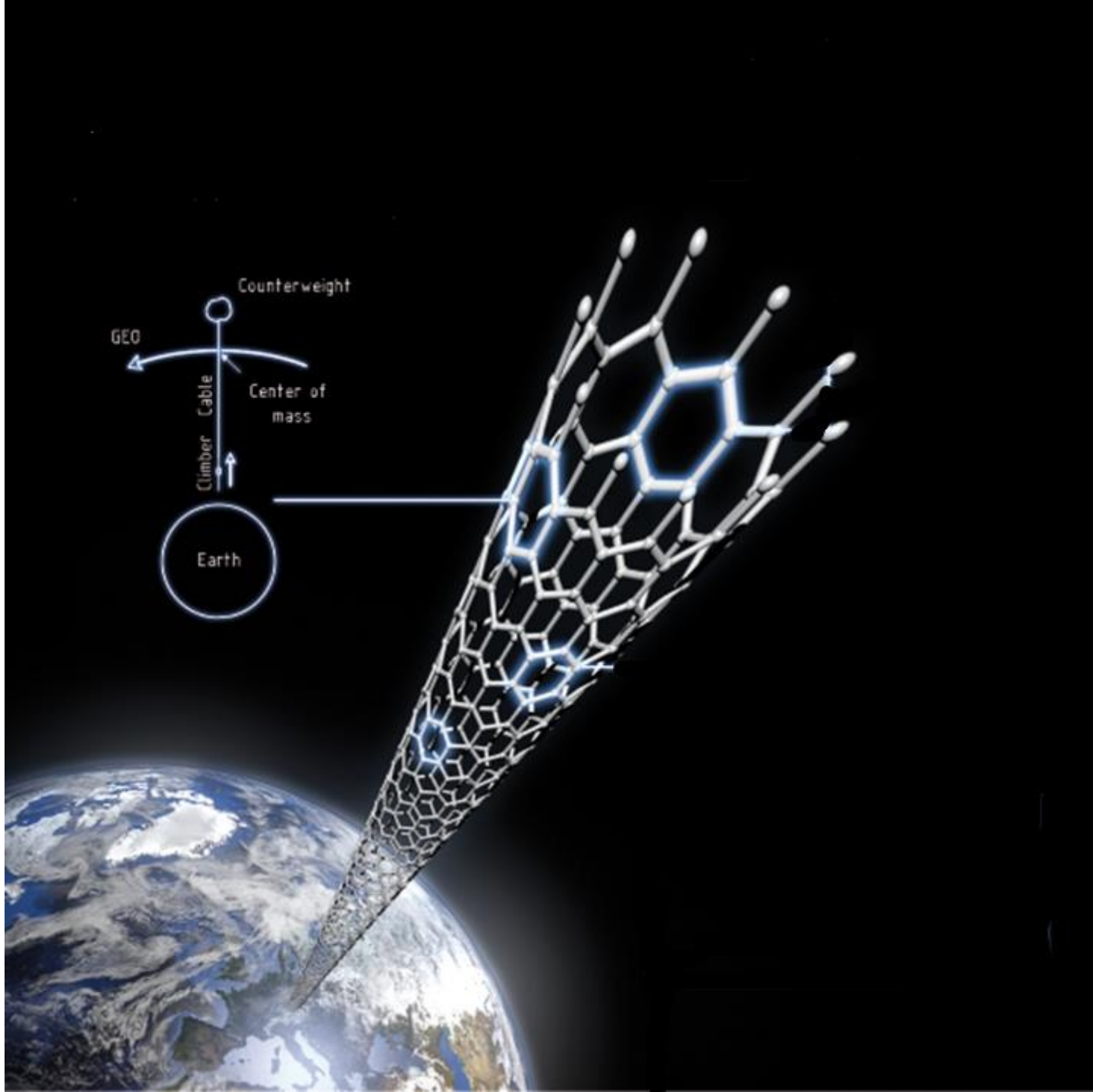
Nanotubi di carbonio MW 25 g, 170 euro



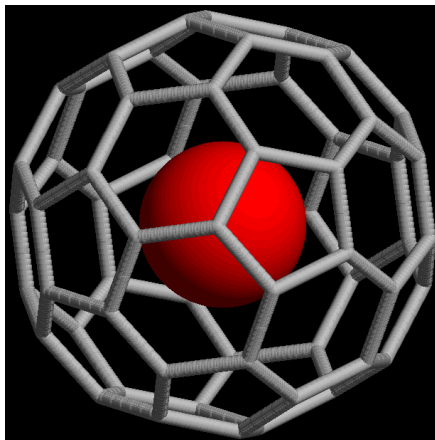








@Fullerene



hydrogen 1 <b>H</b> 1.0079																	helium 2 <b>He</b> 4.0026				
lithium 3 <b>Li</b> 6.941	beryllium 4 <b>Be</b> 9.0122															boron 5 <b>B</b> 10.811	carbon 6 <b>C</b> 12.011	nitrogen 7 <b>N</b> 14.007	oxygen 8 <b>O</b> 15.999	fluorine 9 <b>F</b> 18.998	neon 10 <b>Ne</b> 20.180
sodium 11 <b>Na</b> 22.990	magnesium 12 <b>Mg</b> 24.305															aluminum 13 <b>Al</b> 26.982	silicon 14 <b>Si</b> 28.086	phosphorus 15 <b>P</b> 30.974	sulfur 16 <b>S</b> 32.065	chlorine 17 <b>Cl</b> 35.453	argon 18 <b>Ar</b> 39.948
potassium 19 <b>K</b> 39.098	calcium 20 <b>Ca</b> 40.078	scandium 21 <b>Sc</b> 44.956	titanium 22 <b>Ti</b> 47.867	vanadium 23 <b>V</b> 50.942	chromium 24 <b>Cr</b> 51.996	manganese 25 <b>Mn</b> 54.938	iron 26 <b>Fe</b> 55.845	cobalt 27 <b>Co</b> 58.933	nickel 28 <b>Ni</b> 58.693	copper 29 <b>Cu</b> 63.546	zinc 30 <b>Zn</b> 65.39	gallium 31 <b>Ga</b> 69.723	germanium 32 <b>Ge</b> 72.61	arsenic 33 <b>As</b> 74.922	selenium 34 <b>Se</b> 78.96	bronine 35 <b>Br</b> 79.904	krypton 36 <b>Kr</b> 83.80				
rubidium 37 <b>Rb</b> 85.468	strontium 38 <b>Sr</b> 87.62	yttrium 39 <b>Y</b> 88.906	zirconium 40 <b>Zr</b> 91.224	niobium 41 <b>Nb</b> 92.906	molybdenum 42 <b>Mo</b> 95.94	technetium 43 <b>Tc</b> [98]	ruthenium 44 <b>Ru</b> 101.07	rhodium 45 <b>Rh</b> 102.91	palladium 46 <b>Pd</b> 106.42	silver 47 <b>Ag</b> 107.87	cadmium 48 <b>Cd</b> 112.41	indium 49 <b>In</b> 114.82	tin 50 <b>Sn</b> 118.71	antimony 51 <b>Sb</b> 121.76	tellurium 52 <b>Te</b> 127.60	iodine 53 <b>I</b> 126.90	xenon 54 <b>Xe</b> 131.29				
caesium 55 <b>Cs</b> 132.91	barium 56 <b>Ba</b> 137.33	57-70 *	lutetium 71 <b>Lu</b> 174.97	hafnium 72 <b>Hf</b> 178.49	tantalum 73 <b>Ta</b> 180.95	tungsten 74 <b>W</b> 183.84	rhenium 75 <b>Re</b> 186.21	osmium 76 <b>Os</b> 190.23	iridium 77 <b>Ir</b> 192.22	platinum 78 <b>Pt</b> 195.08	gold 79 <b>Au</b> 196.97	mercury 80 <b>Hg</b> 200.59	thallium 81 <b>Tl</b> 204.38	lead 82 <b>Pb</b> 207.2	bismuth 83 <b>Bi</b> 208.98	polonium 84 <b>Po</b> [209]	astatine 85 <b>At</b> [210]	radon 86 <b>Rn</b> [222]			
francium 87 <b>Fr</b> [223]	radium 88 <b>Ra</b> [226]	89-102 **	lawrencium 103 <b>Lr</b> [262]	rutherfordium 104 <b>Rf</b> [261]	dubnium 105 <b>Db</b> [262]	seaborgium 106 <b>Sg</b> [266]	bohrium 107 <b>Bh</b> [264]	hassium 108 <b>Hs</b> [269]	meitnerium 109 <b>Mt</b> [268]	unnilium 110 <b>Uun</b> [271]	ununium 111 <b>Uuu</b> [272]	unbibium 112 <b>Uub</b> [277]	ununquadium 114 <b>Uuq</b> [289]								

\* Lanthanide series

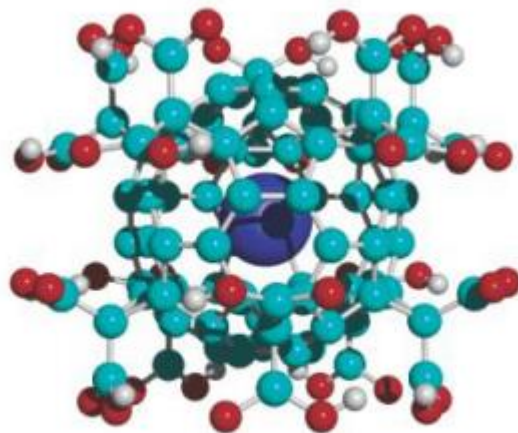
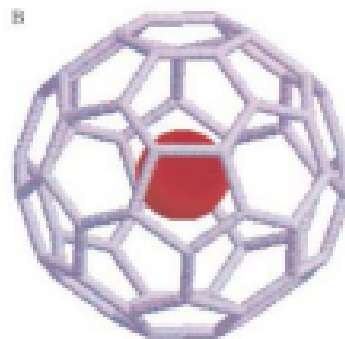
\*\* Actinide series

lanthanum 57 <b>La</b> 138.91	cerium 58 <b>Ce</b> 140.12	praseodymium 59 <b>Pr</b> 140.91	neodymium 60 <b>Nd</b> 144.24	promethium 61 <b>Pm</b> [145]	samarium 62 <b>Sm</b> 150.36	europium 63 <b>Eu</b> 151.96	gadolinium 64 <b>Gd</b> 157.25	terbium 65 <b>Tb</b> 158.93	dysprosium 66 <b>Dy</b> 162.50	holmium 67 <b>Ho</b> 164.93	erbium 68 <b>Er</b> 167.26	thulium 69 <b>Tm</b> 168.93	ytterbium 70 <b>Yb</b> 173.04
actinium 89 <b>Ac</b> [227]	thorium 90 <b>Th</b> 232.04	protactinium 91 <b>Pa</b> 231.04	uranium 92 <b>U</b> 238.03	neptunium 93 <b>Np</b> [237]	plutonium 94 <b>Pu</b> [244]	americium 95 <b>Am</b> [243]	curium 96 <b>Cm</b> [247]	berkelium 97 <b>Bk</b> [247]	californium 98 <b>Cf</b> [251]	einsteinium 99 <b>Es</b> [252]	fermium 100 <b>Fm</b> [257]	mendelevium 101 <b>Md</b> [258]	nobelium 102 <b>No</b> [259]



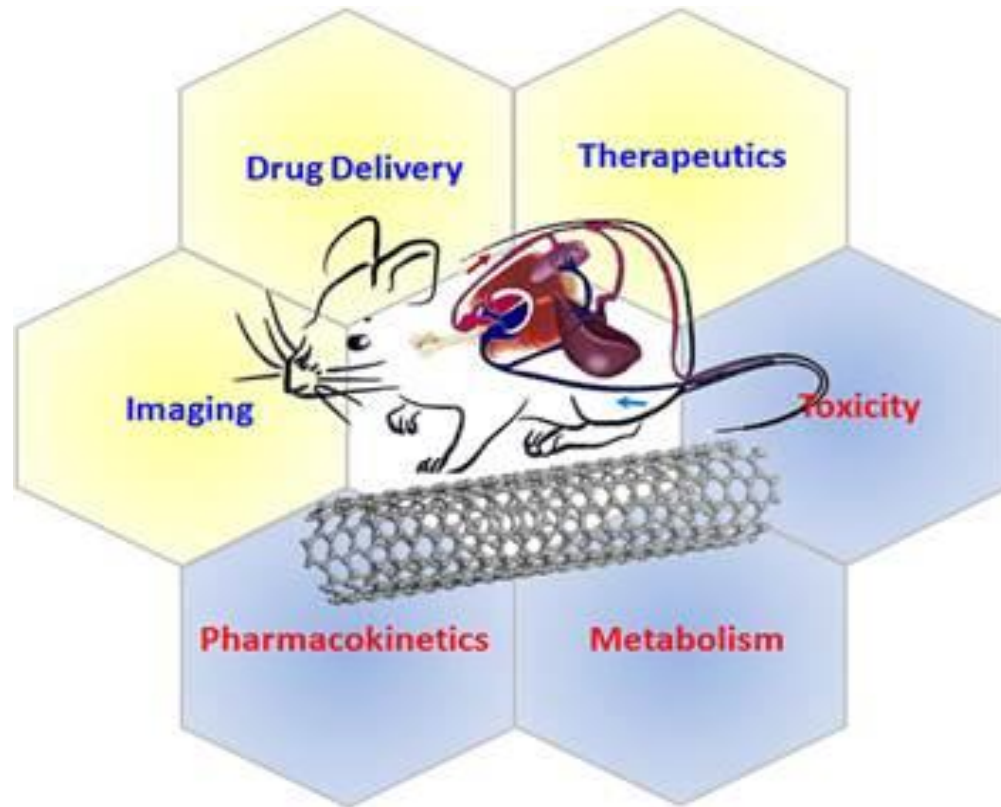


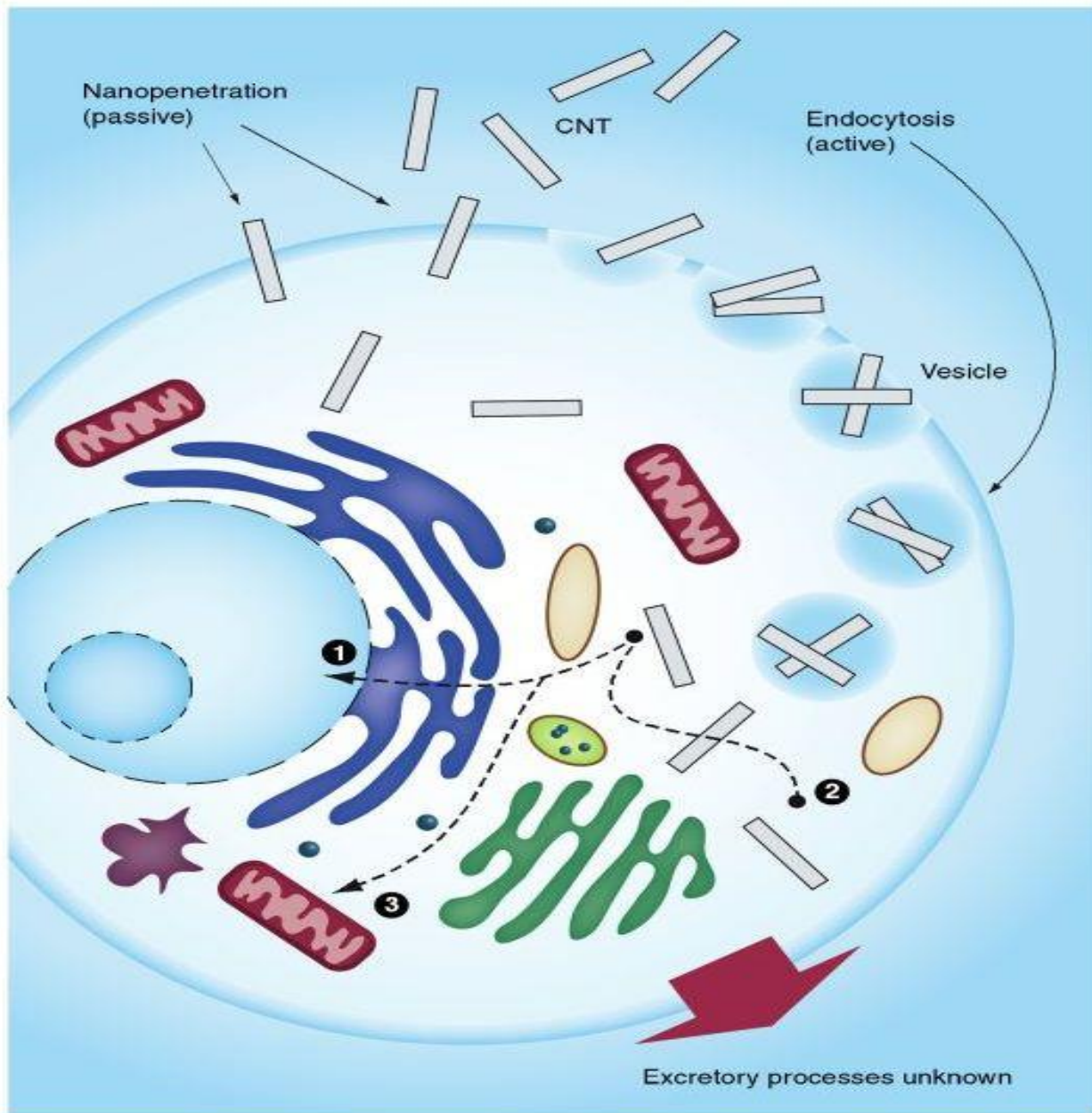
# Gd@Fullerene

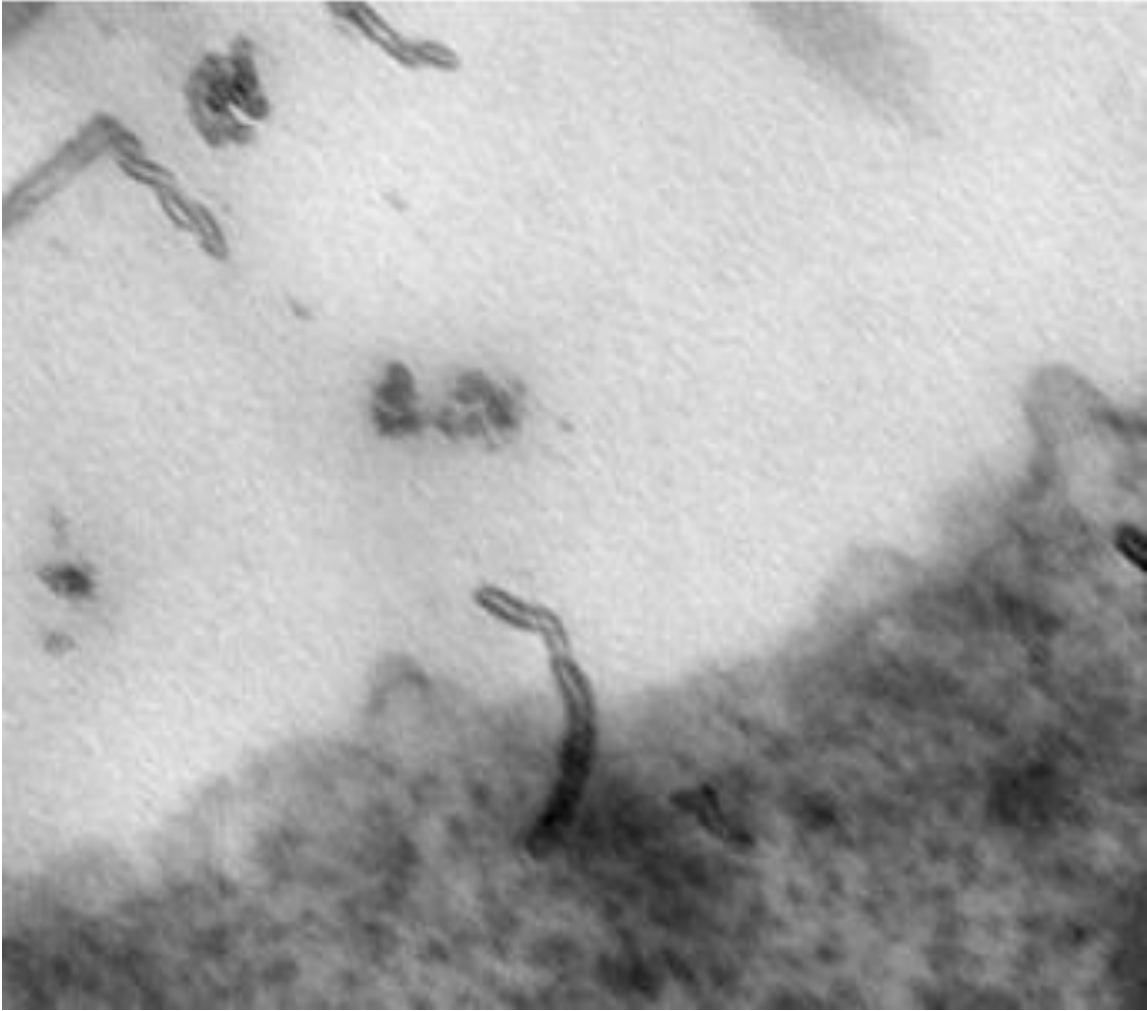


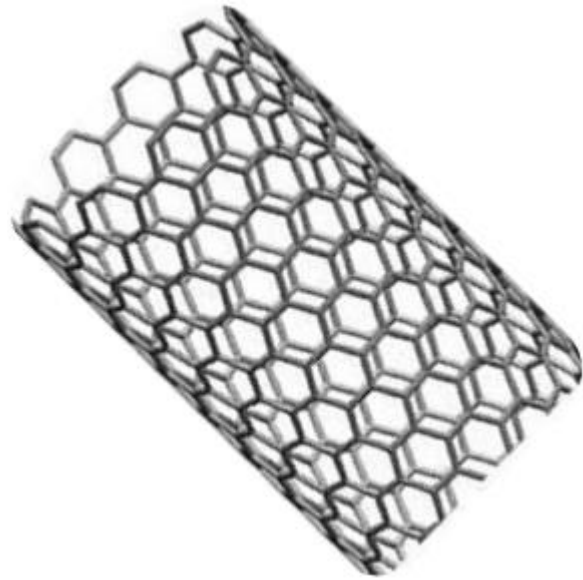
**Figure 3.** Ball-and-stick depiction of  $\text{Gd}@C_{60}[\text{C}(\text{COOH})_2]_{10}$ , illustrating a possible arrangement of 10  $\text{C}(\text{COOH})_2$  addends on a single  $C_{60}$  cage (light blue, C; red, O; white, H; dark blue, Gd).

# Nanoaghi?

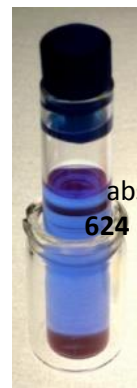
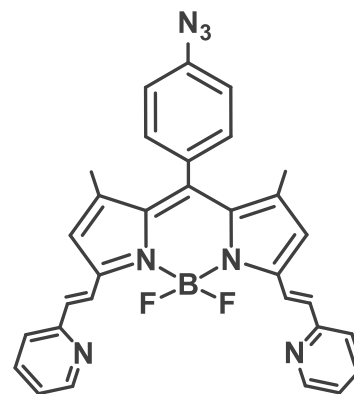
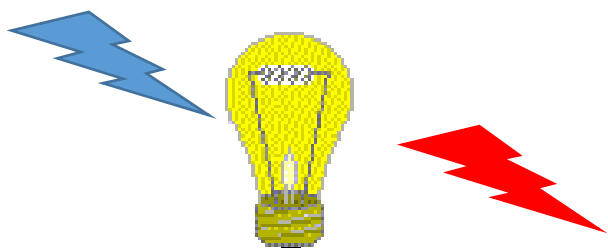




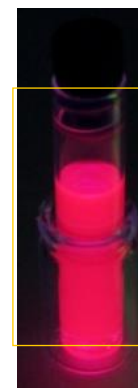






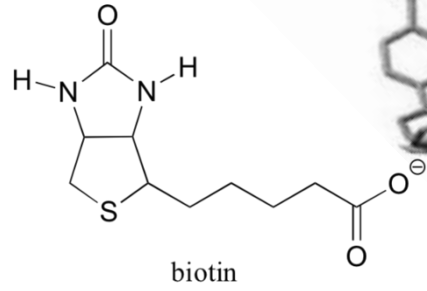
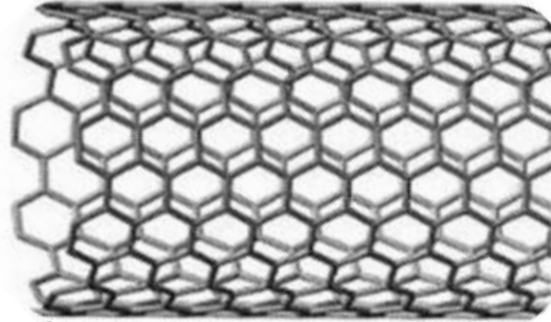
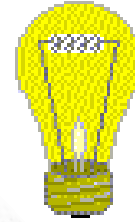


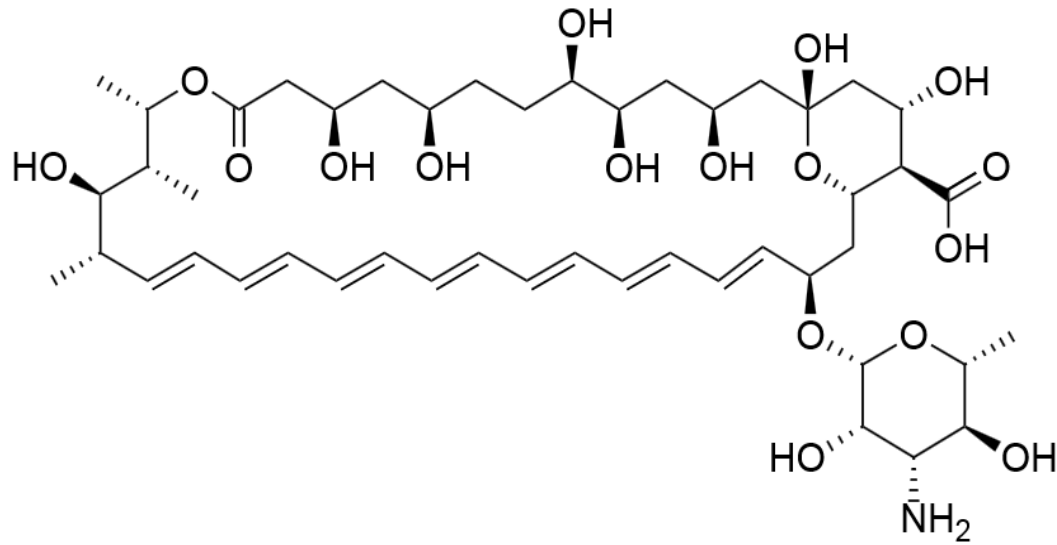
abs  
624 nm



fluo  
643 nm



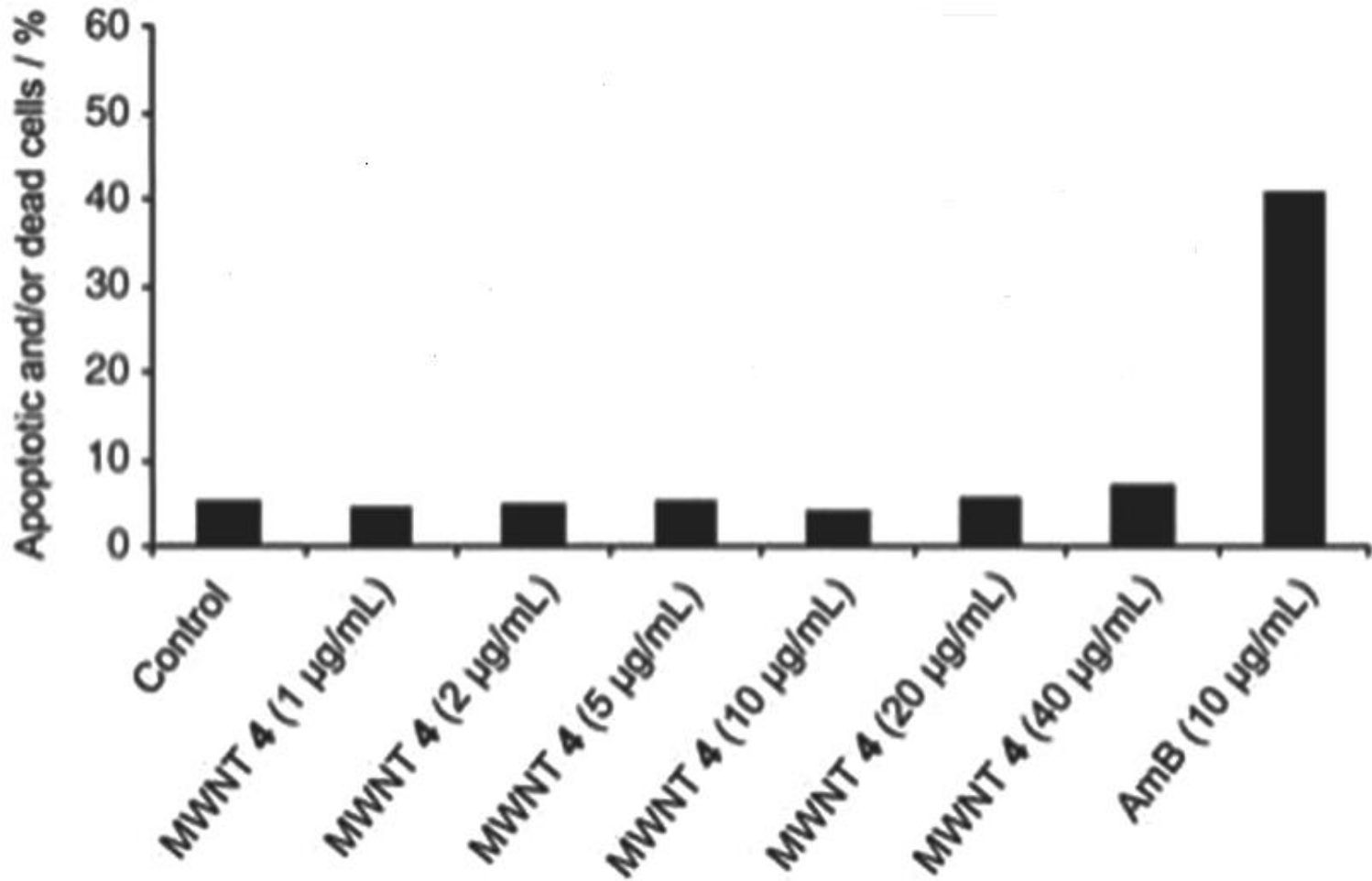


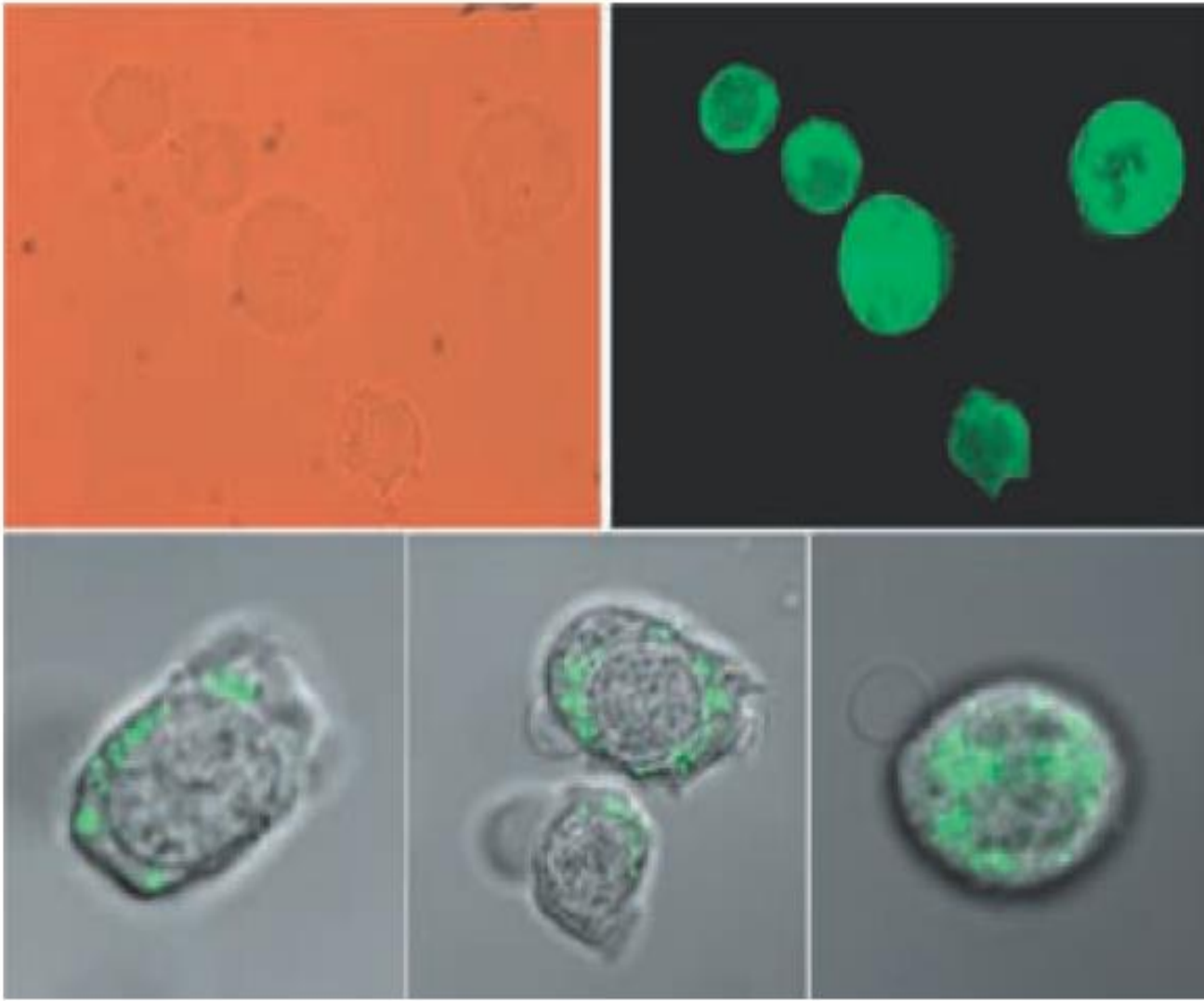


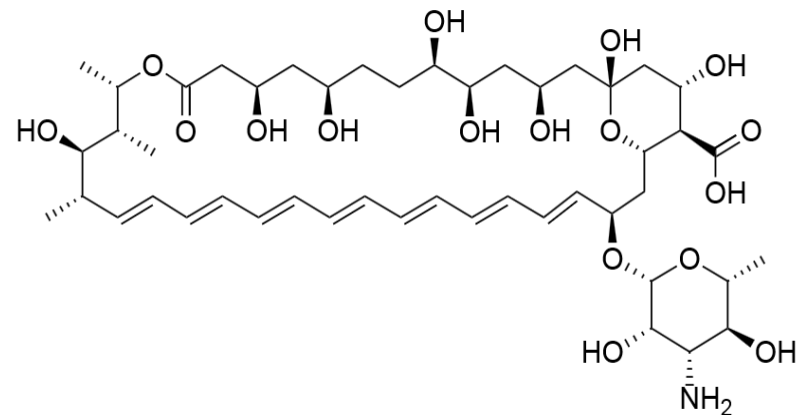
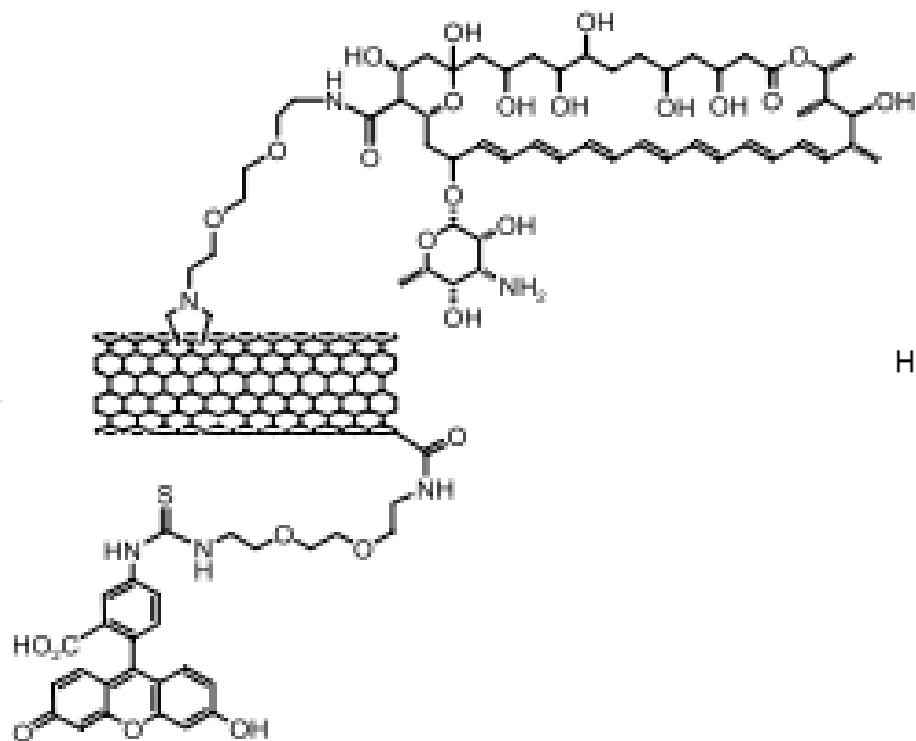
# Amfotericina B



# Tossicità verso cellule umane







**Table 2:** Antifungal activity of CNT–AmB conjugates.

CNT	Minimum inhibitory concentration (MIC) <sup>[a]</sup> [ $\mu\text{g mL}^{-1}$ ]		
	<i>C. parapsilosis</i> ATCC 90118	<i>C. albicans</i> (c.i.) <sup>[b]</sup>	<i>C. neoformans</i> ATCC 90112
AmB	20	> 80	5
SWNT–NH <sub>3</sub> <sup>+</sup>	> 80	> 80	> 80
MWNT–AmB <sup>[c]</sup> <b>18</b>	1.6	6.4	0.8
SWNT–AmB <sup>[c]</sup> <b>19</b>	1.6	13.8	0.8

# ACCOUNTS

of chemical research

## Oh, the Places You'll Go with Graphene

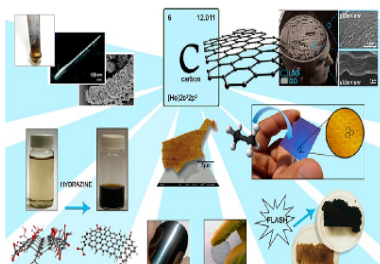
JONATHAN K. WASSEI<sup>†</sup> AND RICHARD B. KANER<sup>\*,†,‡</sup>

<sup>†</sup>Department of Chemistry & Biochemistry and California Nano Systems Institute,  
University of California, Los Angeles, California, 90095, United States, and

<sup>‡</sup>Department of Materials Science and Engineering and California Nano Systems  
Institute, University of California, Los Angeles, California, 90095, United States

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### CONSPECTUS



# Dr. Seuss

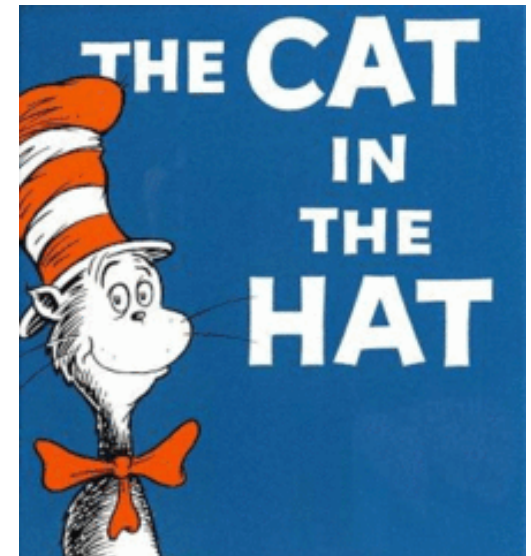




# • OH, THE PLACES YOU'LL SEE!

- Congratulations!
- Today is your day.
- You're off to Great Places!
- You're off and away!
- 
- You have brains in your head.
- You have feet in your shoes.
- You can steer yourself
- any direction you choose.
- You're on your own. And you know what you know.
- And YOU are the guy who'll decide where to go.

- And will you succeed?
- Yes! You will, indeed!
- (98 and 3/4 percent guaranteed.)



In bocca al lupo !

Dipartimento  
di Chimica



**Scuola di Scienze Matematiche, Fisiche e Naturali**  
**Corsi di Laurea in Chimica**

# Scuola di Scienze Matematiche, Fisiche e Naturali



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Biblioteca

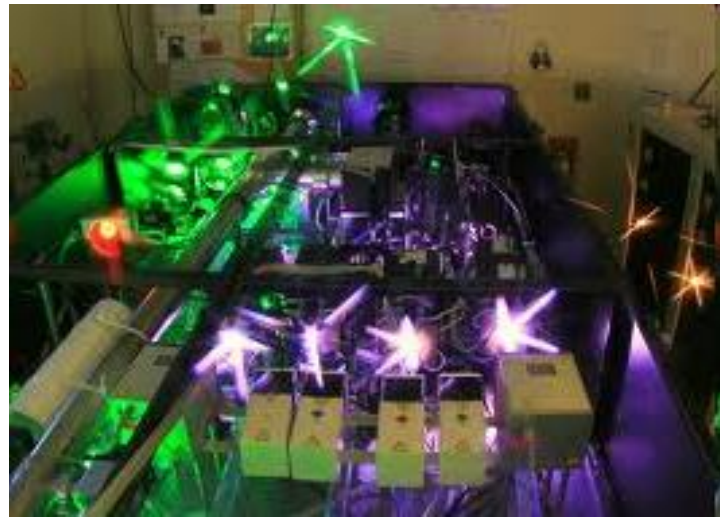
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Europeo  
Risonanza  
magnetica

Laboratorio  
europeo  
Spettroscopi  
e non-lineari

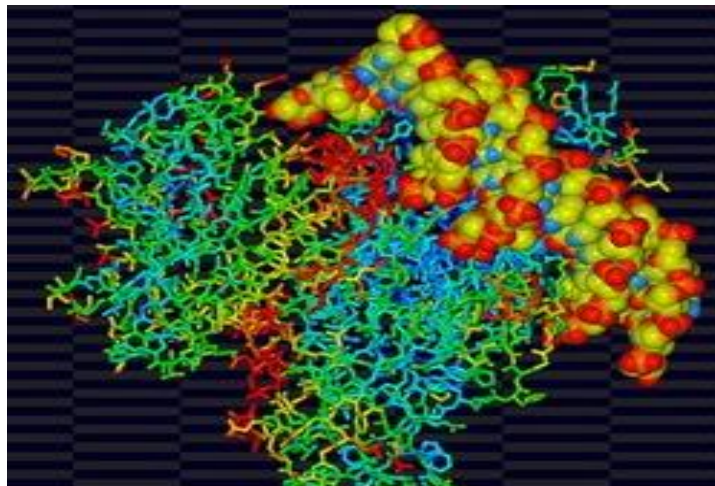
# Scuola di Scienze Matematiche, Fisiche e Naturali



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**CHIMICA**



# Scuola di Scienze Matematiche, Fisiche e Naturali

*Laurea primo livello: due curricula*

*Scienze Chimiche*

*Tecnologie Chimiche*

*Immatricolati 2014-2015: 114 (70% Licei, 25% Istituti  
Tecnici)*



# Scuola di Scienze Matematiche, Fisiche e Naturali

*Laurea di secondo livello (Magistrale): cinque curricula*

*Struttura dinamica e reattività*

*Chimica supramolecolare dei materiali e dei nanosistemi*

*Chimica dell'ambiente e dei beni culturali*

*Chimica delle molecole biologiche*

*Sintesi, struttura e proprietà dei composti organici*

*Possibilità di Erasmus presso molte sedi europee*

**Gradimento Studenti 8.24/10**

**Laureati entro 1 anno di ritardo 70%**



- ***SBOCCHI PROFESSIONALI***

- Il laureato in Chimica rappresenta una qualificata figura professionale che può trovare facilmente una collocazione nel mondo del lavoro e in particolare nel settore industriale, dalla piccola e media impresa locale alle multinazionali chimiche e farmaceutiche, negli enti pubblici e privati nei settori socio-sanitario, del controllo ambientale e del territorio, della conservazione dei beni culturali e della sicurezza alimentare nonché nel campo dell' insegnamento, della ricerca di base ed applicata.

- ***Industria chimica e farmaceutica***
- ***Laboratori di ricerca/analisi pubblici e privati***
- ***Libera professione***
- ***Scuola***

***Tasso di Occupazione: un anno-97%; tre anni-96%; cinque anni-100%***