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Graphene 2010

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Abstract The first production of graphene was awarded the 2010 Nobel Prize in Physics. This discovery has implications for chemistry and within it for structural chemistry as well.

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"Science does not need to be boring to be good."
Andre Geim in 2006 [1]

On October 5, 2010, the Royal Swedish Academy of Sciences in Stockholm awarded the 2010 Nobel Prize in Physics jointly to Andre Geim and Konstantin Novoselov "for groundbreaking experiments regarding the two-dimensional material graphene" [2]. By happy coincidence, earlier on the same day, our editorial office had accepted a manuscript for publication, "Remarkable diversity of carbon–carbon bonds: Structures and properties of fullerenes, carbon nanotubes, and graphene," in which T. C. Dinadayalane and Jerzy Leszczynski reviewed, among others, the results of computational studies on graphene [2]. The manuscript had been submitted in July, however, due to the summer vacations, its reviewing process took a little longer than it normally would have.

The Nobel Prize in Physics in 2010 was among those rather rare cases when the Nobel recognition followed relatively quickly the discovery. Geim and his co-authors communicated the production of graphene in 2004 for the first time. Graphene is a single sheet of carbon atoms. It was a fortunate circumstance that they gave the easy and appealing name of graphene to the new material. Coining a name—and an easy and attractive one at that—is arguably one of the most important, if not the most important component of a scientific discovery [4]. The new material is extremely strong along with many other favorable properties promising a plethora of applications. It may well be that the speedy Nobel recognition was a consequence of the anticipation of an avalanche of studies in the foreseeable future in this area of research after which it might be more difficult to single out up to three awardees.

Here graphene is symbolized by an obviously strong window fence in the Topkapi Sarayi, Istanbul, which could be taken as a model of graphene (Fig 1).

The principal discoverer, Andre Geim was born in 1958 in Sochi, Russia, which is on the Eastern shore of the Black Sea. When he was six years old, the family moved to Nalchik, further East, on the Northern slopes of the Caucasian Mountains, approximately midway between the Black Sea and The Caspian Sea.There he graduated from a high school specializing in the English language. He continued his studies in Moscow and did his Diploma work (Master’s degree equivalent) in 1982 at Moscow Institute of Physics and Technology. He earned his Candidate’s degree (PhD equivalent) in 1987 at the Institute of Solid State Physics of the Soviet Academy of Sciences (now Russian Academy of Sciences). Geim came from a family of Jewish-German origin and as being Jewish was considered to be a nationality his identity documents carried this designation causing barriers in his receiving higher education. He always felt he had to outperform others to survive in the Soviet system. Following his doctorate, Geim did research at the Institute of Microelectronics Technology of the Soviet (then, Russian) Academy of Sciences in Chernogolovka, near Moscow. With the crumbling and then collapse of the Soviet Union, travel became easier and Geim continued as postdoctoral fellow at the University of Nottingham, University of Bath, and University of Copenhagen. Finally, he got his appointment as associate professor at the Radboud University in Nijmegen, Holland. In 2001, he became Langworthy Professor of Physics at the University of Manchester and he has directed its Center for Mesoscience and Nanotechnology. He is now a Dutch citizen.

Konstantin S. Novoselov was born in 1974 in Nizhny Tagil, Russia, in the Southern region of the Ural Mountains. He did his Diploma work at the Moscow Institute of Physics and Technology and in the early 1990s he moved to Nijmegen where he started his PhD work with Geim as his mentor. Novoselov moved to Manchester along with Geim in 2001. He holds both Russian and British citizenships.

Geim (while still in Nijmegen) and his colleagues communicated a photograph in April 1997 displaying a levitating frog [5]. It was taken as an April Fool’s joke. In reality, however, Geim and his colleagues suspended the frog, among many other similar experiments with non-magnetic objects, by creating an upward magnetic force from a powerful magnet and thus they succeeded in compensating for the effect of gravity. Soon a British scientist Michael Berry developed a theory to interpret the phenomenon. When it was realized that Geim’s experiment was not meant to be a joke; rather, the frog was truly levitated in Geim’s experiment, this piece of research was deemed so outrageous that he and Berry were awarded the 2000 Ig Nobel Prize “for using magnets to levitate a frog.”

The Ig Nobel Prize is a joke—taken seriously—which had been created to recognize scientific contributions that should not have been made. Ridiculing the experiment of frog levitation was a severe misunderstanding on the part of the organizers of the very popular Ig Nobel award. Apparently, they did not realize that using a frog was merely a device to attract attention, but the science behind it was serious pioneering achievement. The initiation of the Ig Nobel Prize was a sign of a great sense of humor and it was ironic that the awarders of the Ig Nobel Prize did not recognize humor when others practiced it. Thus, Geim has become the only scientist so far who has received both an Ig Nobel and a real Nobel Prize. Incidentally, the Ig Nobel Prize did not diminish Geim’s affinity for joking. The following year he published another serious result , this time about the detection of earth rotation using a diamagnetically levitating gyroscope, and he listed as his co-author H. A. M. S. ter Tisha, which is supposed to be his favorite hamster by the name of Tisha [6].

The discovery of graphene and the award for it make one think about the history of the fullerene discovery. The surprise in Geim's and Novoselov's discovery in 2004 was that they were able to isolate and stabilize a single-atom-sheet carbon [7]. Prior to their report, many believed that such a two-dimensional atomic crystal simply could not exist. In contrast, back in 1966, David Jones wondered about the possibility of graphite sheets curling up and forming huge balls [8]. When Eiji Osawa decribed the C_{60} molecule of truncated-icosahedron shape in his Japanese-language publication, he based his suggestion on symmetry consideration and did not follow it up neither by computation nor by experiment [9]. This was followed by a computation-based prediction of the stability of truncated icosahedron-shaped C_{60} molecule by DA Bochvar and EG Galpern [10]. This work was not followed up either. Both these reports disappeared in oblivion to be discovered again only after the actual observation and production of buckminsterfullerene in 1985 [11] and 1990 [12], respectively.

The experimental observation of C_{60} was eventually awarded a chemistry Nobel Prize in 1996 to Robert Curl, Harold Kroto, and Richard Smalley. Two physicists pioneered the production of C_{60}, Donald Huffman and Wolfgang Krätschmer, and they might have been recognized by a similar distinction, but they were not. Graphene could be considered at least in principle to be the initial material of all carbon nanotubes and fullerenes. The nanotubes are represented here by a detail of the decorations of the Bangkok Royal Palace (Fig 2) and the fullerenes by a slightly irregular model under the paw of a dragon in the Forbidden City outside Beijing (Fig 3) and a buckminsterfullerene shape from the Topkapi Sarayi in Istanbul (Fig 4).

Geim's and Novoselov's discovery and their Nobel Prize in Physics might also be viewed as the closing act of this beautiful round of discoveries and their ultimate recognition. By this it is not meant that the discoveries might also end; on the contrary, these latest events will undoubtedly contribute to further invigoration of the field and its researchers.

Dedication: The present Editorial is dedicated to the memory of a late friend, David Shoenberg (1911–2004) who was a pioneer in the application of strong magnetic fields, including levitation of type I superconductors [13, 14].

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Figures

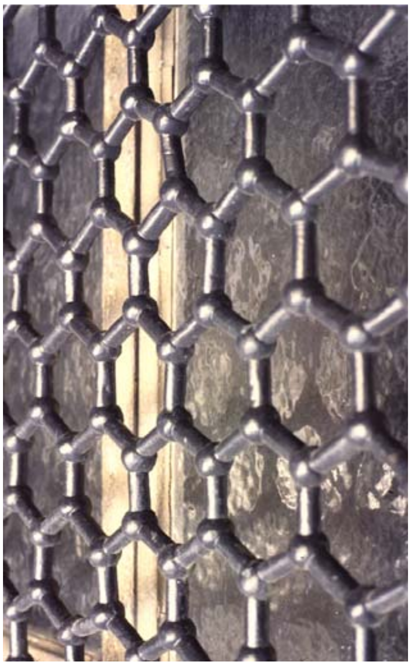

Fig 1 “Graphene model” as a window fence at Topkapi Sarayi in Istanbul (photograph and © by the author)



Fig 2 “Nanotube model” as detail of a decoration at the Royal Palace in Bangkok (photograph and © by the author)
Fig 3 “Slightly irregular fullerene model” under the paw of a dragon at Forbidden City outside Beijing (photograph and © by the author)
Fig 4 “Buckminsterfullerene model” as an entrance decoration at Topkapi Sarayi in Istanbul (photograph and © by the author)