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To: The Nobel Committee,

Class for Physics of the Royal Swedish Academy of Sciences

The Nobel Prize in Physics is the most prestigious scientific achievement award and it is expected that the award be based on diligent and independent investigations. The scientific background document published by the Class for Physics of the Royal Swedish Academy of Sciences that accompanies the 2010 Nobel Prize in Physics is considered to reflect this process and it is therefore presumed to be accurate. I am recognized to be an authoritative source in the research area of the 2010 Nobel Prize in Physics. I can attest to the fact that this document contains serious inaccuracies and inconsistencies, so that the document presents a distorted picture that will be echoed in the community at large if the errors remain uncorrected. I list below several of the more serious errors with suggested changes.

1. Figure 3 is a reproduction of a figure in Novoselov et al's 2004 paper [1]. The figure caption incorrectly states the measurements were made on *graphene* (a single layer of carbon). The 2004 caption states that the measurement was performed on a FLG sample (i.e. ultrathin graphite composed of several graphene layers). In fact Noveoselov's 2004 paper does *not report any electronic transport measurements on graphene*. The band-structure figure accompanying this figure represents graphite and not graphene and the magnetoresistance measurements are explicitly graphitic. The Manchester group published graphene transport measurements in 2005 [2]. Please note also, that the right panel of Fig. 4 is incorrectly labeled and ambiguously credited.

2. Page 2 states: "*It should be mentioned that graphene-like structures were already known of in the 1960's but there were experimental difficulties [13-16] and there were doubts that this was practically possible*." The references all relate to graphene under various conditions. None of the references discuss experimental difficulties nor do they express doubts about the practical possibility (to produce) graphene. For example the respected graphite scientist, H-P Boehm, who later coined the name "graphene", published his 1962 observations of graphene in a most highly regarded journal (Ref. 13) and demonstrated beyond reasonable doubt the existence of freestanding graphene. He certainly showed that the existence of graphene was practically possible. The Nobel committee cites this work and then contradicts its main conclusion without explanation. Boehm's work has stood the test of time and has been reproduced by others. Refs. 14-16 demonstrate that besides freestanding graphene, other forms of graphene are also practically possible. The document must explain how it arrives at the opposite conclusion or replace the sentence with, for example: "*It should be mentioned that graphene structures were already known of before 2004[13-16]"*.

3. Page 1 states: "*It was well known that graphite consists of hexagonal carbon sheets that are stacked on top of each other, but it was believed that a single such sheet could not be produced in isolated form. It, therefore, came as a surprise to the physics community when in 2004, Konstantin Novoselov, Andre Geim and their collaborators [1] showed that such a single layer could be isolated and that it was stable."* This critically important assertion is repeated several times in the document without justification. In fact, the (chemical) stability of graphene did not come as a surprise, even for those who were unaware of Boehm's experiments. Despite Novoselov et al's claim in Ref.1, the chemical stability of graphene did not violate any physical principle and its existence was not doubted in any research paper. Graphene had previously been observed and characterized as a two-dimensional crystal by several research groups [4]. Careful reading of Ref.

1 suggests that Novoselov *et al.* had confused highly stable covalently bonded two-dimensional macromolecules (like micron-sized graphene flakes), with chemically unstable freestanding two-dimensional metal crystals, causing them to presume that theoretically graphene should also be chemically unstable. None of the references cited in Ref. 1 questions the existence of graphene in any circumstance, contradicting the statement in the document that its observation ‘came as a complete surprise’. On the contrary, several references cited in Ref. 1 actually show images of graphene under various conditions. Had graphene’s existence in any form truly violated accepted physical principles, then its observation would have resulted in a flurry of activity to explain the discrepancy. In reality, Ref.1 did not give rise to a single paper reexamining the chemical stability of isolated graphene.

The document must satisfactorily justify the controversial statement quoted above which certainly does not reflect the consensus opinion of experts in the field and it is overwhelmingly contradicted by facts as pointed out in item 2, above. The sentence might be replaced with “*It was well known that graphite consists of hexagonal carbon sheets that are stacked on top of each other and researchers were developing methods to deposit single sheets on substrates. In 2005, Konstantin Novoselov, Andre Geim and their collaborators demonstrated a simple method to deposit and to identify a single graphene sheet on an oxidized silicon carbide wafer. [2].*with a reference to their 2005 PNAS article[2], and not their 2004 Science article Ref[1], as explained in item 5.

4. Page 7 states*: The mobility of graphene is very high which makes the material very interesting for electronic high frequency applications [37]. Recently it has become possible to fabricate large sheets of graphene. Using near-industrial methods, sheets with a width of 70 cm have been produced.[38,39]*

Geim and Novoselov’s method obviously cannot be used for electronic applications; for such purposes, other, previously established graphene production methods are used. The large graphene sheets were made by a CVD method (first described in the 1990’s) developed by Ruoff et al. The first actual high frequency transistors were made with epitaxial graphene on silicon carbide at Hughes Research Laboratories in 2009 and at IBM in 2010 using concepts and methods (first described in the 1970’s) developed by de Heer et al. [3] Earlier in the document, epitaxial graphene is referred to as “carbon layers” on silicon carbide as if it were somehow different than graphene. Well before 2004, epitaxial graphene on silicon carbide had been described as a 2-dimensional crystal that is free floating above the substrate (cf Ref. 15 of the document). It has been shown to exhibit every essential graphene property and photoemission measurements have become icons for graphene’s bandstructure. De Heer’s research *preceded*, and, most importantly, developed entirely independently from Geim and Novoselov’s research. (In 2004 he performed the first graphene transport measurements: the incorrect thickness measurement in Ref. 3a was corrected in Ref. 3b.) The document gives the impression that de Heer’s research on graphene-based electronics (initiated in 2001) was contingent, stimulated or in some other way motivated by Geim and Novoselov. This is not the case, and the document should clarify this.

5. The Summary paragraph, page 7 states: *The development of this new material opens new exiting possibilities. It is the first crystalline 2D-material and it has unique properties, which makes it interesting both for fundamental science and for future applications. The breakthrough was done by Geim, Novoselov and their co-workers; it was their paper from 2004 which ignited the development. For this they are awarded the Nobel Prize in Physics 2010*.

Geim and Novoselov developed a very simple method to produce and observe microscopic graphene slivers on oxidized, degenerately doped silicon wafers. This method was copied by many and provides an ideal method to produce graphene samples for two-dimensional transport studies. The development of this experimental technique was very important for the field of mesoscopic physics, and as pointed out in the document, this was Geim and Novoselov’s most important contribution.

However this method and its application to graphene by Novoselov et al. was *not* reported in 2004 [1] but in 2005 [2]. In Ref. 1 the ultrathin graphite flakes (FLG) whose transport properties were measured, were produced by a more cumbersome method that certainly would not have attracted so much attention [cf supporting on-line material for Ref. 1]. In fact Ref. 1 does not report measurements nor characterization of graphene: instead, it presents evidence of a microscopic sliver of graphene protruding from an ultrathin graphitic flake, not unlike those observed earlier by others (i.e. Shioyama op cit. Ref. 1). It is relevant that Ref. 1 is often wrongly cited for “the discovery of graphene” and for the “Scotch tape method”, even by the authors of Ref.1. This misrepresentation of Ref. 1 should be corrected in the document.

Further note that de facto isolated graphene had been identified and characterized as a 2D-crystalline material in many reports prior to 2004 (see for example [4] for a review). The characterization of graphene as a *new* 2D material is incorrect. This might be corrected in the document along the lines of the second paragraph in this item.

The authors of the Scientific Background document misquoted essential facts pertaining to Ref. 1. An independent review of this document would be helpful to assure that the statements are clear, unambiguous, and factually correct.

We hope that the committee reviews these facts, corrects and publishes an erratum to the scientific background document so that it rises to the exacting standards expected of it.

Sincerely yours,

Walt de Heer

Regents Professor of Physics
Georgia Institute of Technology

1. K. Novoselov et al., “Electric Field Effect in Atomically Thin Carbon Films” *Science* **306**, 666-669 (2004).
2. K. Novoselov et al., “Two-dimensional atomic crystals”, Proc. Nat. Acc. Sci. **102**, 10451 (2005)
3. a. C. Berger et al., J. Phys. Chem. “Ultrathin Epitaxial Graphite: 2D Electron Gas Properties and a Route toward Graphene-based Nanoelectronics” **108**, 19912 (2004). b. W.A. de Heer “Epitaxial graphene”, Sol. St. Comm. **43** 92 (2007)
4. N.R. Gall et al, “Two dimensional graphite films on metals and their intercalation”, Int. J. Mod. Phys. B **11** 1865 (1997)