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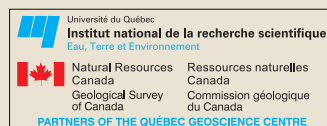
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GREAT SCIENCE OR GREY GOO?



David J. Vaughan

In the spring of 2003, “*Prince Fears Grey Goo Nightmare*” banner headlines appeared in the popular press in Britain and elsewhere. The Prince referred to was HRH Prince Charles, heir to the British throne, who was warning about the possible risks of nanotechnology. The “grey goo” concerned a hypothetical end-of-the-world scenario in which out-of-control self-replicating nanoscale robots consume all matter on Earth in order to build more of themselves. The resulting mass of nanomachines, lacking large-scale structure, would be goo-like. This picture has far more in common with science fiction than with science. Indeed, a grey goo catastrophe is the subject of the novel *Prey* by Michael Crichton, bestselling author of *Jurassic Park*.

As scientists, our reaction to headlines like this is often a mixture of horror and amusement, along, perhaps, with a measure of scorn for the sensationalist nature of such writing. But we would do well to remember that millions of our fellow citizens rely on these reports for their knowledge of the issues associated with technological development. So what might we learn from media phenomena like this one?

It is worth pointing out that Prince Charles never actually used the expression “grey goo”. To quote from his comments following on from the headline news, he does “not believe that self-replicating robots, smaller than viruses, will one day multiply uncontrollably and devour our planet”. Indeed, he went on in these later remarks to say much positive about the possible benefits of nanotechnology to society. However, it comes as little surprise that some journalists are happy to “embellish” a story in order to get the eye-catching headline – and this is something we all need to keep in mind when engaging with the media.

What Prince Charles actually did draw attention to are the potential risks of nanotechnology for human health. An uncomfortable parallel was made with the disastrous story of the drug thalidomide, prescribed for use by pregnant women in the nineteen sixties. The taking of this inadequately tested pharmaceutical led to the birth of many children with serious deformities.

So, should we be concerned about the “dangers” of nanotechnology? The simple answer is “yes”, but as with so many radical new developments, it is not a situation suited to simple answers. The applications of nanotechnology in new materials, electronics and healthcare, to name but a few areas, represent an industrial revolution that is

already well underway (as noted in the first article in this issue, corporate investment in nanotechnology had already exceeded \$4 billion worldwide by 2006 and is projected to reach \$3 trillion by 2015). Whether desirable or not, it is very difficult to see how we could stop, or even slow down, these developments.

The way forward must be to learn much more about the behaviour of nanomaterials in the environment, in the food chain, and in living organisms including humans. This urgently needed research would form the basis upon which *risk* to the environment and to human health from particular types of nanotechnologies could be assessed. This, in turn, would lead to appropriate legislation and regulation. Nanomaterials present new challenges in this regard because it is not only their chemical composition and structure, but also their particle size that gives them their particular properties (which could include toxicity to humans or other life forms). Some work in the

evaluation of the potential toxicity of nanoparticles has already been done; much of this has involved collating and evaluating existing information. For example, see reports by the UK’s Royal Society and Royal Academy of Engineering (www.nanotec.org.uk), as well as (and I admit to personal involvement here) a project funded by the European Commission (www.impart-nanotox.org). The articles in this issue of *Elements* are also eloquent testimony to the role that Earth scientists (*sensu lato*) can play in this task. We have the tools and expertise to characterise nanomaterials, and we know of numerous

example systems in nature – these can surely be harnessed to help in tackling this formidable challenge.

I began this editorial by talking about the popular press, and in returning again to consider the question of whether we should be concerned about the impact of nanotechnology on human health, I want to draw attention to the concept of *risk*. Communicating this concept has always proved difficult: people like to have “black and white” answers; to be given 100% assurance that they could never be harmed by nanotechnology. We cannot do that – or even totally eliminate the grey goo nightmare – any more than we could say that life on Earth could never be destroyed by a large meteorite impact. But with a sound knowledge base, we can estimate the risks and take measures to reduce them to the absolute minimum. We can then try to communicate this information, and provide a balanced view of the hazards of nanotechnology, comparing them, for example, with the relatively high risks we all take as drivers or pedestrians on our roads.

Cont'd on page 364

THIS ISSUE

"Nano" has become a very fashionable word, and as guest editor Mike Hochella points out in his lead article, nanotechnology is now a multibillion-dollar business. This issue brings to the fore the fact that nanoparticles have always been part of our environment, hence the importance of studying natural nanoparticles and their impact on our health and environment in order to illuminate the potential impact of engineered nanoparticles. This issue also makes clear that every crystal goes through a "nano" phase in its growth. One can also be awed by the fact that we are on the verge of acquiring the technological capability to image the structure of single nanoparticles.

FOUR YEARS OLD!

With this issue, we close our fourth year of publication. We have now explored 23 widely ranging topics of relevance to our scientific community and beyond, and the list of potential topics seems to get longer and longer. This is a reminder that we are always looking for proposals for future topics. If you have an idea, contact one of the principal editors. We are now booking themes for 2010.

EDITORIAL (Cont'd from page 363)

Finally, to answer the question posed in the headline to this editorial, I do believe that great (nanogeo)science is being done, as the following articles attest. As for our being turned into grey goo, I would put the risks of that at around a zillion to one against – but we certainly do need rigorous studies of the environmental and health risks of nanotechnology.

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Among this year's milestones are a rising impact factor (2.23 in 2007), a print run that has reached 13,000 copies for the last three issues of this year, and an updated website.

OUR 2009 LINEUP

In the following two pages, we proudly present an overview of the topics selected for 2009. All the guest editors and authors for these issues are hard at work already.

THANKS TO THE AUTHORS AND GUEST EDITORS OF VOLUME 4

Once again we are indebted to a multitude of persons who have helped *Elements* along, especially the guest editors and authors who have worked diligently to write at the level we are striving for in the journal. Our thanks go to volume 4 guest editors Jay D. Bass, James M. Brennan, David R. Cole, Michael F. Hochella Jr., Calvin F. Miller, James E. Mungall, Eric H. Oelkers, John B. Parise, David A. Wark, and Eugenia Valsami-Jones.

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