Anniversary of a myth

Richard Feynman's talk anticipating nanotechnology was inspirational, but no blueprint.

Popular accounts of the history of nanotechnology typically begin 50 years ago this month, with Richard Feynman's talk at the meeting of the West Coast division of the American Physical Society, titled 'There's plenty of room at the bottom'[1]. Here, Feynman offered a vision of a technology that involved arranging atoms "one by one, just as we want them". He described encyclopaedias written on the head of a pin, or "all of the information that man has carefully accumulated in all the books in the world… written… in a cube of material one two-hundredth of an inch wide."

It certainly sounds a lot like the dream of ultradense data recording that is one of nanotechnology's tantalizing promises today. And Feynman's notion of atom-by-atom fabrication was realized in 1991 when Don Eigler and Eric Schweizer at IBM's Almaden Research Center wrote their company name using 35 xenon atoms manipulated using a scanning tunnelling microscope[2].

> Part of the discrepancy between Feynman's vision of nanotech and today's is the issue of where the information is stored.

All of this shows how Feynman was both in some ways remarkably prescient, and also, like many at the time, confident in the limitless nature of human creativity. Certainly, one had to be bold or slightly crazy (Feynman may have been both) to imagine such things in 1959, and one account[3] reports that Feynman's talk elicited more laughter than wonder, as if it was just another example of his jocular nature. Yet the idea that Feynman kick-started nanotechnology doesn't stand up. It is not just that his talk, published the following year in Caltech's house magazine *Engineering & Science*, drew scarcely any citations before the 1980s[3]. More importantly, his vision of atomic engineering bears little relation to what most nanotech researchers are aiming to achieve at a practical scale today.

Feynman's view of the molecular world was almost stereotypically that of the physicist, seeming largely to regard molecules and atoms as scaled-down scaffolds and billiard balls. No one is going to accuse Feynman of neglecting quantum mechanics, and indeed in a follow-up talk in 1983 he anticipates quantum computing[4]. But he more or less ignored the laws and principles of chemistry.

As a result, he could never have foreseen the notion of self-assembly: the ability of atoms and molecules to come together in complex structures, guided by their physical and chemical interactions. For Feynman, these nanoscale entities have to be put in place by laborious 'hand-crafting', and he seems to imagine that, quantum mechanics aside, they will interact like so many macroscopic machine parts. It is presumably because this picture fits so well with the Newtonian vision of 'molecular manufacturing' promoted by K. Eric Drexler in his 1986 book *Engines of Creation*[5] that Drexler so enthusiastically supported the idea of Feynman's talk as a founding text of nanotechnology. Drexler's nanoscale cogs and levers made of diamond-like carbon might have pleased Feynman, but they are regarded less favourably by chemists working at the nanoscale.

Nanoscale mechanical manipulation is by no means absent in today's nanotechnology — researchers at IBM, for example, have investigated whether a massively parallel operation of arrays of scanning probe tips can speed up mechanical high-density data recording to practical levels. But some of the core approaches to nanofabrication now owe more to the principles of supramolecular chemistry pioneered by Jean-Marie Lehn, Donald Cram, Fraser Stoddart and others in the 1970s and 1980s, in which molecules (now particularly DNA) are imbued with instructions for their spontaneous self-assembly[6]. In short, part of the discrepancy between Feynman's vision and that of today resides in the issue of where the information is stored: in the nanoscale components or in some external (and probably macroscale) control system.

But let's not be too hard on Feynman; historical revisionism is apt to throw out the baby with the bathwater. One of his most impressive insights, at a time when the structure of DNA had only recently been deduced and the mechanisms of genetic encoding were barely unravelled, was how biology supplies what Harvard chemist George Whitesides has called an "existence proof" of nanotechnology. "Biology is not simply writing information; it is doing something about it," said Feynman. "A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active; they manufacture various substances; they walk around; they wiggle; and they do all kinds of marvelous things — all on a very small scale. Also, they store information." Today the molecular mechanisms of the cell not only point to ways of creating a practical nanotechnology, but also supply some working parts for the job. To Feynman they were largely a black box, and we now know that the mechanisms of, say, motor proteins, work in a way that no mechanical engineer would have designed. But all credit to Feynman for recognizing nature's abundant storehouse.

In the end, Feynman's talk should perhaps be seen not so much as a piece of crystal-ball gazing, still less as a blueprint for nanotechnology, but as an example of the value, even the necessity, of imagination in science. ❐

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Richard Feynman: a visionary with a physicist's view of nanotechnology.

References

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