

Molecular assembler

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A **molecular assembler** as defined by K. Eric Drexler is a "proposed device able to

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Molecular nanotechnology

Molecular assembler

Mechanosynthesis
Nanorobotics • Grey goo
K. Eric Drexler
Engines of Creation

guide chemical reactions by positioning reactive molecules with atomic precision." He also introduced a related term, "molecular manufacturing," which he defined as the programmed "chemical synthesis of complex structures by mechanically positioning reactive molecules, not by manipulating individual atoms."^[1] Some biological molecules such as ribosomes fit this definition, since while working within a cell's environment, it receives instructions from messenger RNA and then assembles specific sequences of amino acids to construct protein molecules. However, the term "molecular assembler" usually refers to theoretical man-made or synthetic devices. They are thought to be highly desirable since they have been theorized to manufacture products with absolute precision and thus without any pollution. However, others have warned that such a powerful technology might escape human control and begin to compete with natural forms of life on earth.

Since synthetic assemblers have never been constructed, there is much controversy as to whether they are possible or simply science fiction. Confusion and controversy has also stemmed from their classification as nanotechnology, which is a broadly defined term. Nanotechnology is an active area of research which has already been applied to the production of real products; however, there are currently no research efforts into the actual construction of "molecular assemblers". A primary criticism of the computational research into "molecular assemblers" is that the structures investigated are thought to be impossible to synthesize. Much as only certain programs can be written for the universal computer, only certain configurations can be constructed with universal assemblers.

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Nanofactories

A **nanofactory** is a proposed system in which nanomachines (resembling molecular assemblers, or industrial robot arms) would combine reactive molecules via mechanosynthesis to build larger atomically precise parts. These, in turn, would be assembled by positioning mechanisms of assorted sizes to build macroscopic (visible) but still atomically-precise products.

A typical nanofactory would fit in a desktop box, in the vision of K. Eric Drexler published in *Nanosystems: Molecular Machinery, Manufacturing and Computation* (<http://www.e-drexler.com/d/06/00/Nanosystems/toc.html>) (1992), a notable work of "exploratory engineering". During the last decade, others have extended the nanofactory concept, including an analysis of nanofactory convergent assembly by Ralph Merkle, a systems design of a replicating nanofactory architecture by J. Storrs Hall, Forrest Bishop's "Universal Assembler", the patented exponential assembly process by Zyvex, and a top-level systems design (<http://www.jetpress.org/volume13/Nanofactory.htm>) for a 'primitive nanofactory' by Chris Phoenix (Director of Research at the Center for Responsible Nanotechnology (<http://crnano.org>)). All of these nanofactory designs (and more) are summarized in Chapter 4 (<http://www.MolecularAssembler.com/KSRM/4.htm>) of *Kinematic Self-Replicating Machines* (2004) by Robert Freitas and Ralph Merkle. The Nanofactory Collaboration^[2], founded by Robert Freitas and Ralph Merkle in 2000, is a focused ongoing effort involving 23 researchers from 10 organizations and 4 countries that is developing a practical research agenda^[3] specifically aimed at positionally-controlled diamond mechanosynthesis and diamondoid nanofactory development.

In 2005, a computer-animated short film (http://www.nanoengineer-1.com/mambo/index.php?option=com_content&task=view&id=33&Itemid=2) of the nanofactory concept was produced by John Burch (<http://www.lizardfire.com>), in collaboration with Drexler. Such visions have been the subject of much debate, on several intellectual levels. No one has discovered an insurmountable problem with the underlying theories and no one has proved that the theories can be translated into practice. However, the debate continues, with some of it being summarized in the Molecular nanotechnology article.

If nanofactories could be built, severe disruption to the world economy would be one of many possible negative impacts (<http://crnano.org/dangers.htm>). Great benefits (<http://crnano.org/benefits.htm>) also would be anticipated. Various works of science fiction have explored these and similar concepts. The potential for such devices was part of the mandate of a major UK study led by mechanical engineering professor Dame Ann Dowling. The report is now complete. (<http://www.nanotec.org.uk/>)

Self-replication

The nanoscale size of a typical science fiction universal molecular assembler requires an extremely large number of such devices in order to produce a practical quantity of a desired product. However, if one were able to construct a single such molecular assembler then it might be programmed to self-replicate, constructing many copies of itself, allowing an exponential rate of production. Then after sufficient quantities of the molecular assemblers were available, they would

then be re-programmed for production of the desired product. However, if self-replication of molecular assemblers were not restrained then it might lead to competition with naturally occurring organisms. This has been called ecophagy or the grey goo problem.[1] (<http://www.crnano.org/BD-Goo.htm>)

One method to building molecular assemblers is to mimic evolutionary processes employed by biological systems. Biological evolution proceeds by random variation combined with culling of the less-successful variants and reproduction of the more-successful variants. Production of complex molecular assemblers might be evolved from simpler systems since "A complex system that works is invariably found to have evolved from a simple system that worked. . . . A complex system designed from scratch never works and can not be patched up to make it work. You have to start over, beginning with a system that works."^[4]

However, most published safety guidelines include "recommendations against developing ... replicator designs which permit surviving mutation or undergoing evolution".^[2] (<http://www.foresight.org/guidelines/current.html>)

Most assembler designs keep the "source code" external to the physical assembler. At each step of a manufacturing process, that step is read from an ordinary computer file and "broadcast" to all the assemblers. If any assembler gets out of range of that computer, or when the link between that computer and the assemblers is broken, or when that computer is unplugged, the assemblers stop replicating. Such a "broadcast architecture" is one of the safety features recommended by the "Foresight Guidelines on Molecular Nanotechnology" (<http://www.foresight.org/guidelines/current.html>) , and a map of the 137-dimensional replicator design space^[5]

recently published by Freitas and Merkle provides numerous practical methods by which replicators can be safely controlled by good design.

Drexler and Smalley debate

A major influence in the discussion of molecular assemblers is K. Eric Drexler, founder of the Foresight Institute. In his book *Engines of Creation: The Coming Era of Nanotechnology*, Drexler advocated the position that the introduction of molecular assemblers would transform the world.

He believes that they would be capable of building anything allowed by the laws that govern the universe with absolute precision and thus without any pollution. He has also stressed that there are great potential dangers from such technology, such as the destruction of life on earth. He asserts that such general assemblers are inevitable and that we need to develop protocols to ensure that their implementation remains benevolent.

Since artificial molecular assemblers remain strictly theoretical Drexler's position is quite controversial. One of the most outspoken critics of Drexler's futuristic vision of molecular assemblers was Professor Richard Smalley (1943-2005) who won the Nobel prize for his contributions to the field of nanotechnology. Smalley believed that such assemblers were not physically possible and introduced scientific objections to them. His two principal technical objections were termed the "fat fingers problem" and the "sticky fingers problem" that he believed would exclude the possibility of precision picking and placing of individual atoms. Drexler and coworkers have responded to these two issues^[6] in a 2001 publication.

Smalley also believed that Drexler's speculations about apocalyptic dangers of molecular assemblers threaten the public support for development of nanotechnology. To address the debate between Drexler and Smalley regarding molecular assemblers *Chemical & Engineering News*

published a point-counterpoint consisting of an exchange of letters that addressed the issues.^[1]

Regulation

Speculation on the power of artificial molecular assemblers has sparked a wider political discussion on the implication of nanotechnology. This is in part due to the fact that nanotechnology is a very broad term and could include "molecular assemblers." Discussion of the possible implications of fantastic molecular assemblers has prompted calls for regulation of current and future nanotechnology. There are very real concerns with the potential health and ecological impact of nanotechnology that is being integrated in manufactured products. Greenpeace for instance commissioned a report

concerning nanotechnology in which they express concern into the toxicity of nanomaterials that have been introduced in the environment.^[7] However, it makes only passing references to “assembler” technology. The UK Royal Society and UK Royal Academy of Engineering also commissioned a report entitled “Nanoscience and nanotechnologies: opportunities and uncertainties”[3] (<http://www.nanotec.org.uk/finalReport.htm>) regarding the larger social and ecological implications on nanotechnology. This report does not discuss the threat posed by potential “molecular assemblers.”

Grey goo

Speculation about the potential dangers of artificial molecular assemblers has led some to envision apocalyptic scenarios. Drexler of the Foresight Institute and others state that artificially created molecular assemblers could represent a competitive threat to all natural life. One scenario suggested danger to life could arise in the form of grey goo which consumes carbon to make more of itself. If unchecked such mechanical replication could potentially consume whole ecoregions or the whole Earth (ecophagy), or it could simply outcompete other natural lifeforms for necessary resources such as carbon, ATP, or UV light (which some nanomotor examples run on). It is worth noting that the ecophagy and 'grey goo' scenarios, like synthetic molecular assemblers, are based upon still-theoretical technologies that have not yet been demonstrated experimentally.

In fiction

Molecular assemblers are a popular topic in science fiction. See e.g. the matter compiler in *The Diamond Age*. The replicator in *Star Trek* might also be considered a molecular assembler. A molecular assembler is also a key element of the plot of the computer game *Deus Ex* (called a "universal constructor" in the game).

See also

- Bioethics
- Biosafety
- Biosecurity
- Biotechnology
- Ecocide
- Ecophagy
- Molecular machine
- Nanofactory
- Nanosocialism
- Nanotechnology
- Santa Claus machine
- Technological singularity

References

- ^a ^b <http://pubs.acs.org/cen/coverstory/8148/8148counterpoint.html>
- [^] <http://www.MolecularAssembler.com/Nanofactory>
- [^] <http://www.MolecularAssembler.com/Nanofactory/Challenges.htm>
- [^] Gall, John, (1986) *Systemantics: How Systems Really Work and How They Fail*, 2nd ed. Ann Arbor, MI : The General Systemantics Press.
- [^] <http://www.MolecularAssembler.com/KSRM/5.1.9.htm>
- [^] <http://www.imm.org/SciAmDebate2/smalley.html>

- [^] <http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/5886.pdf>

External links

- Nano-Hive: Nanospace Simulator (<http://www.nano-hive.org/>) free software for modeling nanotech entities
- Foresight Institute (<http://www.foresight.org/>) proposes guidelines for responsible development (<http://www.foresight.org/guidelines/current.html>) of molecular manufacturing technologies
- Center for Responsible Nanotechnology (<http://CRNano.org>)
- Molecular Assembler website (<http://www.MolecularAssembler.com>)
- Rage Against the (Green) Machine (<http://www.mindfully.org/Technology/2003/Nanotechnology-Rage-Against19jun03.htm>) article originally in Wired
- Government launches nano study (<http://education.guardian.co.uk/higher/research/story/0,9865,975190,00.html>) UK EducationGuardian, 11 June 2003
- Disinfopedia: dangerous technology (http://disinfopedia.org/wiki.phtml?title=dangerous_technology)
- Disinfopedia: pro-technology propaganda (http://disinfopedia.org/wiki.phtml?title=pro-technology_propaganda)
- "Unraveling the Big Debate over Small Machines" (<http://www.betterhumans.com/Features/Reports/report.aspx?articleID=2004-08-16-1>)
- Paper on assembly (<http://www.zyvex.com/nanotech/nano4/merklePaper.html>)
- <http://www.zyvex.com/nanotech/nano4/merklePaper.html>
- Kinematic Self-Replicating Machines (<http://www.MolecularAssembler.com/KSRM.htm>) online technical book: first comprehensive survey of molecular assemblers (2004) by Robert Freitas and Ralph Merkle
- Design of a Primitive Nanofactory (<http://www.jetpress.org/volume13/Nanofactory.htm>)
- Video - Nanofactory in Action (http://www.lizardfire.com/html_nano/themovies.html)
- Nanofactory technology (<http://www.articleworld.org/index.php/Nanofactory>)

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