A conversation with Adam Marblestone on August 27, 2014

Participants

- Adam Marblestone – Director of Scientific Architecting, Massachusetts Institute of Technology Synthetic Neurobiology Group (scientific advisor to GiveWell)
- Nick Beckstead – Research Analyst, Open Philanthropy Project; Research Fellow, Future of Humanity Institute, Oxford University

Note: This set of notes was compiled by the Open Philanthropy Project and gives an overview of the major points made by Dr. Marblestone.

Summary

The Open Philanthropy Project spoke with Dr. Marblestone as part of its investigation of nanotechnology as a global catastrophic risk. Conversation topics included: the plausibility of molecular manufacturing, the extent to which progress in the field can be tracked, and areas that might have room for more funding.

Feasibility of molecular manufacturing

Molecular manufacturing appears to be compatible, in principle, with the known laws of physics. Biological molecular machines provide a proof of concept for roughly analogous, although not completely analogous, types of capabilities. Many specific aspects of the visions outlined by Drexler and others may turn out to be wrong, but the basic idea of the long-term possibility of some form of programmable atomically precise manufacturing has not been disproved.

History of molecular manufacturing

Early interest

Dr. Marblestone was quick to point out that he is not an expert on the history, but was willing to offer some general impressions: As first outlined in the 1980s, the potential benefits of molecular manufacturing generated interest among scientists, the public, and policymakers, but the potential risks generated fear. This was one of the first debates around science that played out on the then-novel world wide web, and the “signal-to-noise ratio” was low. Public perceptions and expectations do not appear to have been well understood or managed. In a changing political climate at the end of the cold war, the government’s response to large-scale technology proposals may also have been hard to anticipate. Futurist rhetoric made advances that could produce catastrophic risks seem closer than they really were, jeopardizing the near-term advances that many scientists were eager to attempt. The magnitude of the challenges and uncertainties involved undermined the credibility of the vision. Many scientists shunned the field because association with speculation, dogmatism and alarm could have damaged their careers.

National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI), a federal research program, was created in the US in the early 2000’s. It appears to have initially been inspired by the vision of early proponents of general-purpose molecular manufacturing. In the face of alarm around “nano-bots”, “grey goo” and other fears, it instead focused on a range of immediately-accessible small-scale projects at the “nano” length scale (e.g., new material properties due to small size scale), primarily funding isolated, incremental iterations on existing chemistry and materials science disciplines, such as new types of nanoparticles – rather than systems engineering. NNI’s timing may have contributed to this shift: basic tools, knowledge and principles necessary for pursuing advances in molecular manufacturing had not been developed by 2003, and prevailing public controversy about molecular manufacturing motivated many researchers to work in other areas.

The slowness and randomness of early-stage technological development
Scientists have incentives to pursue short-term, publishable results; in biomolecular disciplines, this has been particularly driven towards novel scientific rather than engineering results. The government has incentives to fund solutions to short-term issues faced by its citizens. These pressures have led more design-driven approaches to nanotechnology, such as in DNA nanotechnology, to develop almost at random through the piecemeal achievements of decentralized researchers rather than through a systematic initiative mapped by working backwards from a vision about a final goal.

Paths of nanotechnology development

The open route
Dr. Marblestone thinks that technologies which could ultimately contribute to something like molecular manufacturing will develop openly within the scientific community, that a few years will pass between meaningful advances, and that many types and stages of development will be necessary for maturation into some form of general-purpose, atomically precise manufacturing.

Currently, there is no focused effort towards molecular manufacturing as such, but rather a range of academic research on improving programmable nanoscale spatial and chemical control, aimed at a variety of near-term applied and fundamental science goals.

In the past, researchers in fields related to biomolecular machinery and biomolecular design have made major contributions to the types of tools that could ultimately contribute to developing early prototype forms of molecular manufacturing. He thinks biomolecular approaches are the most promising routes for advancing the technology, at the present time, as well as integration of biomolecular approaches with top-down lithography.

Open publication would make monitoring ongoing advances in these broad areas relatively easy and would provide guidance and reality-checks for those evaluating risks. It would also allow discoveries along the way to benefit the public immediately.

The secret route
Chris Phoenix and some others have proposed that molecular manufacturing could develop secretly, through a government research effort comparable to the Manhattan Project. Dr. Marblestone thinks this is unlikely in the present climate because molecular manufacturing is not a known priority of any government. Still early in its development, molecular

manufacturing as such is not considered a near-term solution to urgent issues, and there are still many uncertainties associated with the relevant engineering problems, so it does not fit the current funding habits of the US government.

It might be difficult to keep a “Manhattan project” type nanotechnology effort secret. The gaps in chemical shipments, funding allocations, and researcher time would be noticeable.

A secret, centralized project with significant funding would likely be inefficient because of the serendipity necessary for early scientific progress in a field. A centralized route might stymie experiments that do not obviously fit into the research agenda. DNA origami is an example of a serendipitous discovery that might have been unlikely to occur in a centralized, secret molecular manufacturing initiative, but that accelerates the entire field.

Possible signs of progress

Several aspects of nascent molecular manufacturing precursor disciplines could be monitored for signs of progress:

Number of dimensions in which it is done

Computer chips can already be manufactured at the nanoscale in two dimensions. Manufacture in three dimensions would be a major innovation.

Range and cost of raw materials

DNA is currently an essential raw material for work in “soft” nanotechnology. It is very expensive to produce, even in small amounts.

Recently, scientists began experimenting with RNA as a raw manufacturing material.

Progress in this area would likely involve using an increasingly broad range of materials, such as proteins, as raw materials.

Current manufacturing relies on pure, highly processed feedstock. The ability to use general, impure feedstocks would be a major challenge. There is no reason to even attempt this at this point. Down the line, any efforts in this direction would be worth closely monitoring.

Usefulness of biomolecular scaffolding

The scaffolding used in synthetic biology may become more reliable and easier to use in manufacturing processes.

Size of building blocks and finished products

Right now work is done at the scale of a few tens of nanometers. Being able to build things that are a little larger, with the same level of precision, would add flexibility and utility to the technology.

Range of products that can be made

In the near term, this could include targeted drug delivery vehicles and products that can spatially organize catalysts, for example.

Ability to program miniature factories

"Nano-factories" would be able to build a range of objects of different sizes and compositions.

Commercial production

Possible early commercial products:

- Computer chips built using general-purpose self-assembly
    - Improved scaffolding would benefit manufacturing processes in this area, including those involving lithography patterning systems.
- Medicines containing synthetic biological components

Early commercial products may jumpstart the field and produce the most rapid progress towards the long-term possibility of a general-purpose, exponential molecular manufacturing system.

Risks

Risks from molecular manufacturing seem relatively improbable and distant, although evaluating them can be difficult because the future of the technology is so uncertain.

It is extremely unlikely that risks from molecular manufacturing as such, such as "grey goo" and international instability, will arise in the next 10 years.

Grey goo

"Grey goo" is a doomsday scenario in which self-replicating nanofactories consume all the earth's resources. Dr. Marblestone thinks grey goo is unlikely to be a risk for at least decades because self-replication and use of general feedstock – both essential for grey goo – are distant technologies, which need not ever be developed. If molecular manufacturing were to develop gradually and openly, policymakers could monitor emerging threats and establish regulations when necessary.

International instability

If one country develops advanced molecular manufacturing before others, global economic and political disparities could result, leading to instability. Dr. Marblestone does not think this is a major threat in the near term, because the intellectual basis for future molecular manufacturing is currently being developed in a widely distributed public literature. If this continues to be the case, it will be difficult for one country to develop a technological edge. However, if a secret arms race occurs, technological advances in molecular manufacturing could be unevenly distributed.

Remembering possible benefits

Dr. Marblestone is worried about molecular manufacturing and related nanoscale technologies developing too slowly through neglect of possible short-term benefits. He thinks scientists in the near-term should attempt to develop applicable nanofabrication capabilities for near-term use in computing and medicine, among other industries.

What foundations could do

Dr. Marblestone suggests monitoring developments and periodically:

- Assessing the state of the relevant science and technology
- Assessing potential risks and benefits
- Evaluating whether a centralized or decentralized approach would be most efficient at any given time
- Assessing the level of commercial interest in related technologies, and commercial tolerance for systematic long-term research in this area, which could lead to more focused and more secretive projects
- Assessing the level of interest of governments in this type of technology
- Deciding whether to fund research or policy, or just to keep monitoring progress
- Conceptualizing what progress could look like in the short and long term

Monitoring this topic as a case study would also allow foundations to develop an understanding of how people and governments think about and respond to ongoing and future technological change.

Other people to talk to

- Mihail Roco of the NSF
- Mainstream scientists who were involved in molecular manufacturing ideas from the start such as participants in and speakers at the Foresight Institute from the 1980s onward
- Other people who engaged in discussions with Eric Drexler and his peers
- Feynman prize winners who were involved in molecular manufacturing
- Those who took part in the Technology Roadmap for Productive Nanosystems conference in 2007