A conversation with Richard Jones on September 30, 2014

Participants

- Richard Jones – Pro-Vice-Chancellor for Research and Innovation, Professor of Physics, University of Sheffield
- Nick Beckstead – Research Fellow, Future of Humanity Institute, Oxford University; Research Analyst, Open Philanthropy Project

Note: This set of notes was compiled by GiveWell and gives an overview of the major points made by Prof. Jones.

Summary

GiveWell spoke with Richard Jones as part of an Open Philanthropy Project investigation of nanotechnology as a potential global catastrophic risk. Conversation topics included: what might be possible with molecular manufacturing, when advances might take place, and what a philanthropist could fund in the field.

The potential of nanotechnology

Prof. Jones believes it is unlikely that atomically precise manufacturing (APM)/molecular manufacturing (synonymous terms) could outperform organisms at their own tasks. At the same time, he believes organisms are proof that it is possible to build machines that can convert energy into movement, perform chemical synthesis, and process information (among other abilities) on the nanoscale, because organisms do just those things on the subcellular level.

Soft nanotechnology

The phrase “soft nanotechnology” is used to refer to nanoscale objects designed with the principles at work in subcellular biological systems in mind. This contrasts with “hard nanotechnology,” in which researchers attempt to extrapolate from the principles of mechanical engineering to design nanoscale objects.

Biological nanomachines operate very differently from machines designed using principles of mechanical engineering. For example, biological systems organize themselves through self-assembly and Brownian motors, which function by principles very different from the principles typically operative in mechanical engineering. Prof. Jones is therefore more optimistic about “soft” development pathways for nanomachines (such as DNA nanotechnology) in comparison with “hard” development pathways (such as atomic force miscroscopy).

In this respect, he is an agreement with Dr. Eric Drexler. The soft route has been more popular in the past because it has seemed likely to yield applications periodically. Examples of component technologies where work might be done include:

- The development of sequenced copolymers
- Computer simulation of docking mechanisms in artificial materials similar to DNA

Unlike Dr. Drexler, however, Prof. Jones is skeptical of the potential to develop “hard” nanomachines from “soft” nanomachines. In Prof. Jones view, it’s completely unclear how we would make that transition, but also impossible to rule it out on specific technical grounds.

Possible applications

Advances in soft nanomachines could potentially improve our capability to control electrons and light. This could improve the performance of computers and advance quantum information processing over the next 20 years. John Pendry’s work on metamaterials at Imperial College London fits into this area of research, in which combinations of electrical conductors and insulators allow researchers to direct light in matter.

Prof. Jones believes there may be applications of APM to medicine. Since basic biological processes happen at the nanoscale, it might be very valuable to be able to intervene at that scale. This kind of work requires an understanding of the information processing that takes place at the cellular level. If he were setting priorities for the next 50 years of the field, Prof. Jones would probably focus on developing this soft nanotechnology to allow for precise interventions in biological processes.

Unlike Dr. Drexler, Prof. Jones does not believe that advanced nanotechnology would be capable of making most structures consistent with physical law.

Prof. Jones believes APM is unlikely to be part of the development of more efficient solar cells, because he believes technology for solar energy will develop more quickly through other approaches.

Weapons

Prof. Jones believes that it might be possible to use APM to make dangerous weapons, but he is not particularly worried about this because there are already many ways of making weapons that seem more frightening to him. He believes that other terrifying weapons, such as the robot weapons studied by Noel Sharkey of the University of Sheffield, will become a near-term threat before APM-based weapons do. Such robots, for example, could become much cheaper in the next 10 years and may become available to non-state actors in that time. In addition, the cost of nanofactories and products built by nanofactories would have to reflect the cost of development and not just the cost of materials, just as the cost of transistors reflects both the cost of materials and development. Therefore, Prof. Jones is skeptical of the idea that, were general-purpose nanofactories somehow constructed, they could be used to rapidly and cheaply produce large quantities of weapons. He is also not very worried about APM-based weapons now because there are many steps between current technological capacities and self-reproducing nanofactories that could rapidly scale up the supply of weapons, and we have very little sense of how to get from here to there.

Timelines, milestones, and roadmaps

Prof. Jones believes researchers determine the milestones for technologies when choosing goals. It is particularly difficult to outline milestones for APM because researchers lack clear goals and do not understand the science that would make achieving these goals possible.

One soft nanotechnology goal, for example, is to build materials that participate in cell signaling. A couple instances of this have been done using DNA, but researchers are still at an early stage of developing this technology.

One way to estimate timelines for technological development is to study how long it has taken similar technologies to develop in the past. To predict timelines for nanotechnology, the relatively slow development of nanotubes and the relatively fast development of graphene may be useful examples.

Roadmapping

Prof. Jones believes roadmapping is useful when it collects views about the obstacles to developing new technologies. Roadmapping is also useful when it identifies challenges that no one could overcome alone but that might be surmountable by a group.

Prof. Jones does not think it would be useful to put together a very specific roadmap for nanotechnology because so much is still uncertain about it, both in terms of the problems being faced and desired destinations.

Nanotechnology funding

Prof. Jones does not believe that progress toward APM has been held back by opposition from nanobusiness or other nanotechnologists, and that there have been substantial investments in both soft and hard development pathways. He thinks slow progress in the field has resulted primarily from how challenging the science is, not from a concerted effort to limit funding. For example, Don Eigler attracted interest in his atomic force microscopy (AFM) work. People invested in developing the technology, but the research did not produce hoped-for advances, so funding decreased. Prof. Jones does, however, speculate that the competitiveness and specialization of the American scientific community, does work against grand visions like Dr. Drexler's, and this may have contributed to a reluctance in the USA to articulate APM as an explicit goal. In addition, pressure to earn short-term returns limits funding for long-term, highly uncertain projects.

The soft route to APM has likely received more funding than the hard route because it is nearer to commercial applications (such as medicine delivery). There has likely been investment on the order of £1 billion on scanning tunneling microscopy(STM), which is a crucial part of the "hard" pathway toward APM.

In the present climate, venture capitalists and private investors are unlikely to invest in developing nanomachine-based technologies. Even the most long-term investors generally seek a return within five years, and that's currently not possible.

What to fund

DNA nanotechnology is a promising area because it is understood well enough for researchers to begin expanding into new materials and more products. Andrew Turberfield of Oxford is a leading researcher in this area. Foreign DNA is typically rejected by the body, so DNA is not the best material for medical interventions. Prof. Jones believes research on DNA nanotechnology could inform the development of a synthetic, self-assembling polymer programmed to act in desired ways. Over time, researchers could aim to encode more information into these structures. Though work with DNA is increasingly possible, work with proteins and more complex materials is not. RNA is a promising research material because it is intermediate in complexity between DNA and proteins. Developing a mastery of RNA nanotechnology would be a step towards work with synthetic polymers.

In addition to the information-encoding side of research, there is also the machine-related side, in which researchers attempt to make objects capable of completing tasks. In this area, propulsion units (synthetic motors) are an important component technology.

Funding on the order of £10 million per year for 10 years would likely be enough to lead to progress in the field.

If he had £100 million, Prof. Jones would probably first hire Ramin Golestanian of Oxford, the leading theorist and world expert on how to make molecular machines, to develop better theories and models of how to make such machines. He would also hire chemists to investigate possible energy sources, such as an artificial ATP, to fuel molecular machines. He would hire experts in chemical computing such as Andrew Turberfield to advance information processing. He would also consider how to produce something like artificial bacteria, which would be in some ways similar to grey goo.

In terms of policy development, Prof. Jones thinks considering goals for nanotechnology would be more valuable at this stage than protecting against risks. A general, political question is how to align nanotechnology with the kind of society people want. Prof. Jones believes people are most interested in technology that enhances their autonomy rather than technology that reduces their autonomy.

Other people to talk to

George Whitesides, Robert Langer, Angela Belcher, Mark Welland, and Stephen Mann