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Contemplating the social implications of a nanotechnology "revolution"[1]

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Everyone's predicting a nano-"revolution"… but no-one's asking what its social consequences may be

Governments and business leaders world wide suggest that we are on the cusp of a nanotechnology-enabled "revolution" that will transform every sector of industry, bringing far-reaching changes to economic, social and ecological relations. The Asia-Pacific Economic Cooperation (APEC) forum notes that: "If nanotechnology is going to revolutionise manufacturing, health care, energy supply, communications and probably defence, then it will transform labour and the workplace, the medical system, the transportation and power infrastructures and the military. None of these latter will be changed without significant social disruption[1]". The United States National Nanotechnology Initiative predicts: "If present trends in nanoscience and nanotechnology continue, most aspects of everyday life are subject to change"[2]. The Australian National Nanotechnology Strategy Taskforce states that nanotechnology "has the potential to fundamentally alter the way people live[3]". Yet despite the dramatic scope of these predictions, to date there has been a dearth of critical discussion about the important social challenges that nanotechnology presents.

Key questions about nanotechnology's social implications remain not only unanswered, but largely unasked. What would a "post-revolutionary" nanotech world look like? Given that past revolutions have resulted in winners, losers and massive social upheaval is anyone planning to manage this revolution to mitigate its most adverse consequences? Is this even possible? Whose interests are driving nanotechnology research, development and commercialisation? Who bears the risks? Who stands to gain? Who will own nanotechnology's applications? Who will have access? Will nanotechnology overcome global socio-economic disparities and environmental problems or exacerbate them? Given the huge amount of public money invested in nanotechnology research, does the public have a right to be involved in decision making that will help determine nanotechnology's development trajectory?

The macro-economic implications of a nanotechnology revolution have also received little attention. This is perplexing given that nanotechnology's commercial potential is repeatedly cited as a key reason for massive investment of public money in research. Most government communications about nanotechnology's economic implications are based on "blue sky" forecasting; they assume that by driving the next industrial revolution, nanotechnology will make us all fabulously wealthy. But forecasts from nanotechnology analysts suggest that a more sober and critical analysis of nanotechnology's economic implications is warranted. Lux Research Inc has warned that nanomaterials could replace markets for existing commodities, disrupt trade and eliminate jobs in nearly every industry [4]. It predicts that: "Just as the British industrial revolution knocked hand spinners and hand weavers out of business, nanotechnology will disrupt a slew of multi billion dollar companies and industries" [5].

Given predictions that nanotechnology will drive a new industrial revolution, it is surprising that there is not greater reflection on lessons to be learned from the experiences of the 18-19th century industrial revolution. That revolution transformed the industrial base from manual labour to machinery, revolutionising agriculture, transport, manufacturing and communications. It

[1] In questioning the absence of a critical response to claims of nanotechnology-driven revolution, this article builds on ideas advanced by Sparrow R (2008). "Talkin' 'bout a (nanotechnological revolution)". Technol Soc Mag, IEEE 27():37 - 43

underpinned unprecedented economic growth and far greater industrial efficiencies, but led to massive job-shedding, a boom in prison populations and mass emigration of displaced labourers from Europe to its colonies and former colonies, especially to the "New World". Now nanotechnology is predicted to transform our industrial base once again. It seems reasonable to suggest that a nanotechnology-driven revolution could similarly underpin massive economic expansion and greater industrial efficiencies, while also resulting in massive job losses and significant disruptions to international trade. This time there will be no safety valve offered by the possibility of mass emigration of redundant labourers. The economies of many of the world's poorest countries are dependent on the export of commodities that may be vulnerable to displacement by novel nanomaterials. Governments' lack of interest in probing the implications of large-scale nanotechnology-driven socio-economic disruption appears foolhardy.

Why have predictions of nanotechnology "revolution" not been subject to critical questioning?

Australian ethicist Dr Robert Sparrow points out[6] that if a political movement were to announce their plans to initiate a "revolution" that would forever transform the fundamental bases of industry and society, result in large-scale social and economic upheaval, and be carried out with no input from civil society, their plans would be subject to vigorous critique, if not organised resistance.

The absence of a widespread critical response to predictions by nanotechnology's proponents of "revolution" may be largely explained by the very low levels of public awareness of nanotechnology. In a 2006 survey of 1500 individuals that was conducted in the United States, over 60% of respondents said they have never even heard of "nano" or "nanotechnology", 90% said they were unfamiliar with nanotechnology and only 1% could correctly define nanotechnology[7]. Similarly high levels of unfamiliarity with nanotechnology have been found by other recent North American[8] and United Kingdom[9] surveys.

A second reason for the lack of critical response to predictions of nanotechnology revolution is our familiarity with fast-moving technology-driven change. In the last fifteen years alone we have seen mobile phones, vastly increased computer power and the internet transform international trade, and change the way people who have access to these technologies work, shop, share information, access essential services and experience community. For many people, especially people in the Global North who have benefited most from access to information technology, predictions of further, nanotechnology-driven change may appear to offer "business as usual", or even exciting new opportunities. However United States lawyer Joel Rothstein Wolfson cautions that "If the nanotechnology gap [both within and between nations] will be anything like the gap that exists in ownership of computers and usage of the internet, the nanotechnology gap between haves and have-nots will pose real societal issues"[10]. Increasing numbers of authors from the Global South are questioning whether rather than alleviating poverty, the probability of a nano divide means that nanotechnology is more likely to exacerbate existing global socio-economic inequities[11]. Yet given the pressing and immediate threats facing much of the Global South, it is perhaps unsurprising that the future implications of nanotechnology have so far received little public attention.

A third reason for people not responding critically to predictions of nanotechnology "revolution" is that they just don't believe the hype. There is a massive disconnect between the hundreds of first generation "nanoproducts" that are now on sale in supermarkets and the visionary predictions of nanotechnology (for example represented by the images often found in popular science magazines and even government reports of surgical "nanobots" and mini-submarines circulating in our blood stream[12]). Quite simply, the transparent sunscreens, odour-eating socks, longer-lasting paints, anti-bacterial food packaging and germ-killing dishwashers that now incorporate nanomaterials hardly appear to herald the dawning of a new industrial revolution. It is possible that the next 5-10 years will see the commercial release of more sophisticated nanodevices for manufacturing and medicine, and even nanobiotechnology-modified crops and animals, which may raise the level of interest or concern among the general public regarding nanotechnology applications. But it is difficult to predict which aspects of nanotechnology's potential will be realised and which will never pass the speculative phase. It may well be that dramatic predictions of nanotechnology-driven "revolution" are simply never realised.

A fourth reason for the failure to grapple with the longer term social implications of next generation nanotechnology is the growing recognition of the immediate risks to health and environment that are posed by first generation nanomaterials. Many civil society organisations have focussed their attention on trying to ensure the safety of nanomaterials that are already present in workplaces and on supermarket shelves, rather than initiating a critical discussion about what social implications nanotechnology may or may not have many years from now.

Perhaps the greatest responsibility to examine nanotechnology's social implications lies with the governments who have invested billions of public dollars into nanotechnology research and development. Yet in the midst of the international race to boost commercial research, secure patents and bring products to market as quickly as possible, government funding for public interest research is tiny in comparison with funding for commercial and military research (see below).

Will a nanotechnology revolution be the solution to our environment and social problems or the source of new ones?

The analysis of the implications of a possible nanotechnology-driven revolution remains sharply divided. Nanotechnology optimists see nanotechnology delivering environmentally benign material abundance for all, by providing: universal clean water supplies; atomically engineered food and crops resulting in greater productivity with less labour requirements; nutritionally enhanced interactive "smart" foods; cheap and powerful energy generation; clean and highly efficient manufacturing; radically improved formulation of drugs, diagnostics and organ replacement; much greater information storage and communication capacities; and personalised interactive "smart" appliances and computers. Some nano-proponents suggest that convergent nanoscale technologies will also enable us to expand human mental, physical and military performance and to dramatically extend life expectancy[13].

Conversely, nanotechnology sceptics suggest that it will exacerbate existing socio-economic inequity and the unequal distribution of power by: creating greater inequities between rich and poor through an inevitable nano-divide; entrenching corporate concentration and enabling its control of even the very building blocks of the natural world; further eroding food sovereignty; distorting international power relations through its military applications and trade impacts; providing the tools for ubiquitous surveillance, with significant implications for civil liberty; introducing serious and poorly understood risks to the health of humans and the environment; and breaking down the barriers between life and non-life, redefining even what it means to be human.

While many nano sceptics acknowledge the potential for nanotechnology to be used for applications which have social or environmental utility, they fear that in reality, the huge costs associated with nanotech research will demand a focus on profitable applications that will deliver a financial return. Groups like Friends of the Earth Australia are concerned that this will result in "smart" medicines, "smart" foods, new cosmetics and "smart" appliances for the rich, rather than an effort to reduce the huge inequities in global food distribution and trade that underpin many of the life-threatening illnesses of the poor.

Existing investment and commercialisation trends show clearly that commercial and military interests are driving nanotechnology's development

As with all new technologies, nanotechnology's development trajectory will be shaped by the political, economic, military and social context in which it emerges. In 2006 the United States government, which is the world's biggest funder of nanotechnology research, spent 33% of the US$1.3billion National Nanotechnology Initiative (NNI) budget on military applications[14]. This disproportionately large funding of military research raises its own obvious problems – not least the potential to spark a new nano arms race. But it also highlights the much lower priority accorded basic research to determine whether or not nanomaterials already found in consumer products and workplaces world-wide pose unacceptable toxicity risks to human health and the environment.

Senior scientists have warned that nanomaterials may pose serious toxicity risks[15]. But the Woodrow Wilson Project on Emerging Nanotechnologies has estimated that highly relevant research into nanotechnology's health and environment risks receives less than 0.85% (US$11 million) of the United States NNI budget[16]. Research into the environment and health risks of nanomaterials received 5% of the European Sixth Framework Programme budget (2002-2006)[17]. World-wide, a tiny 0.4% of nanotechnology research spending is on research into risks for human health and the environment[18].

Funding for research into nanotechnology's broader social implications and challenges is similarly small. The 2006 United States NNI budget included US$43 million for education and research on nanotechnology's social implications, including economic, legal and ethical issues. However it is likely that the bulk of this money was directed to education programs aimed at promoting public acceptance of nanotechnology, rather than inquiry aimed at critical investigation of its social implications. At a nanotechnology workshop held in 2005 by the United Kingdom's Royal Society and the Science Council of Japan[19], representatives from the United States National Science Foundation indicated that they would spend US$28 million on education activities, and only US$7.5 million (0.58% of the 2006 NNI budget) on research into nanotechnology's ethical, legal and social issues.

The first wave of nanoproducts released to market also demonstrates the primacy of the profit motive in guiding nanotechnology's development. Anti-wrinkle cosmetics, display screens for computers, televisions and mobile phones, premium coatings for luxury cars, odour-eating socks and self-cleaning windows and bathrooms are all targeted squarely at wealthy consumers in the Global North. In 2004, the United Kingdom's Royal Society noted that of the nanomaterials then in commercial production, the majority were used by the cosmetics industry[20]. The quest for rapid commercialisation may also mean that many companies do not conduct safety testing. Swiss researchers recently surveyed 138 Swiss and German companies that produce or apply nanomaterials commercially. Of the 40 companies who responded, 65% indicated that they perform no risk assessments[21].

The inevitable development of a "nano divide" and its exacerbation of existing global socio-economic inequity

The consequences of huge global inequities in wealth, power and quality of environment are already starkly evident – poverty, disease and social unrest grip a large proportion of the world's population. Given the current development trajectory of nanotechnology, it appears likely to exacerbate existing social and economic inequities and to create new ones. A nano-divide appears inevitable. This divide will develop firstly between the nano-poor (most of the world's poorest countries) and the nano-enabled nations (the United States, Japan and Europe are the nanotech leaders, although over 60 countries now have national research programs). It will also occur within each nation, as the gap between those who control the new nanotechnologies and those whose products, services or labour are displaced by them, and those whose can afford nano enhanced medicines, materials and goods and those that cannot, becomes ever larger.

The ETC Group observes: "Despite rosy predictions that nanotech will provide a technical fix for hunger, disease and environmental security in the South, the extraordinary pace of nanotech patenting suggests that developing nations will participate via royalty payments… In a world dominated by proprietary science, it is the patent owners and those who can pay license fees who will determine access and price."[22] Vandana Shiva has argued that synthesising nanotechnology alternatives to food will "accelerate existing trends of patent monopolies over life – making a few corporations 'life-lords'."[23] Fearing that the expansion of nanotechnology into agriculture will further erode the ability of peasant, fishing and farming communities to retain local control and ownership of food production, the 2007 international "Nyeleni Forum for Food Sovereignty" resolved to work towards an immediate moratorium on nanotechnology[24].

Nanotechnology-driven commodity obsolescence would have profound disruptive impacts for economies everywhere, but it would have the most devastating impact on people in the Global South. 95 out of 141 developing countries depend on commodities such as cotton, rubber, copper or platinum for at least 50% of their export earnings[25]. South Africa's Minister of Science

and Technology, Mosibudi Mangena has warned that: "With the increased investment in nanotechnology research and innovation, most traditional materials in specialised applications will, over time, be replaced by cheaper, functionally rich and stronger nano-materials. It is important to ensure that our natural resources do not become redundant, especially because our economy is still very much dependant on them."[26]

Converging nanoscale technologies and the controversial field of human enhancement

Nanotechnology may not only reshape every sector of our economies, but it may also redefine our understanding of what it means to be human. To an unprecedented degree, converging nanoscale technologies promise to blur the boundaries between medical treatment and human "enhancement". The 2002 report "Converging Technologies for Improving Human Performance: Nanotechnology, biotechnology, information technology and cognitive science [NBIC]"[27] records the proceedings of a high level workshop sponsored by the United States National Science Foundation and the Department of Commerce. The workshop participants envisioned breakthroughs in NBIC-related areas that they thought could be possible in the next 10 to 20 years. Their grandiose vision included the following:

- "Fast, broadband interfaces directly between the human brain and machines will transform work in factories, control automobiles, ensure military superiority, and enable new sports, art forms and modes of interaction between people…
- The ability to control the genetics of humans, animals, and agricultural plants will greatly benefit human welfare; widespread consensus about ethical, legal, and moral issues will be built in the process;
- Factories of tomorrow will be organized around converging technologies and increased human-machine capabilities as "intelligent environments" that achieve the maximum benefits of both mass production and custom design."[28]

These may well be examples of speculative technologies that have no chance of realisation. However, the fact that one of the key conference organisers is the senior advisor for nanotechnology at the United States National Science Foundation suggests that it is worth considering the possibility that they will in fact be successful with this work.

The quest to use NBIC technologies to enhance human physical, cognitive and military performance has drawn strong criticism from disabilities and human rights advocates concerned that it will create new inequities and further marginalise existing disadvantaged groups[29]. It defies credibility to suggest that a "widespread consensus about ethical, legal, and moral issues will be built in the process" of manipulating human genetics and increasing human-machine capabilities. Who will decide which of these applications are ethically acceptable or socially desirable? What limits and safeguards will be established and who will enforce them? What efforts will be made to ensure that inevitably expensive convergent technology-enabled "enhancement" of a small number of people in the Global North will not be at the expense of providing basic medicines to the majority of the world's people who still lack access to basic medicines? Will efforts to enhance humans result in further marginalisation of existing marginalised groups, for example disabled people? At what point will the quest to enhance human performance and extend human life produce an elite minority of wealthy, long-living enhanced people, leaving an un-enhanced majority underclass?

Molecular manufacturing – if it proves possible – could have an unprecedented disruptive impact on labour markets and global trade

Debates continue to rage within the nanotechnology industry about whether or not sophisticated molecular manufacturing is possible and achievable[30]. Wishing to avoid a public backlash against "weird science", most in the industry prefer not to speculate about whether or not atomically precise manufacturing from decentralised desktop nanofactories will ever be possible. However, given the number of nano-analysts and nano-scientists who predict that molecular manufacturing will be achievable in the next 20-50 years (eg see a series of essays commissioned in 2006 by the Center for Responsible Nanotechnology published in the journal

Nanotechnology Perceptions)[31], it is important to give some thought to its potentially enormous implications for human society.

The massive disruptions in agriculture, trade, manufacturing, culture and social relations that would accompany such developments are extremely difficult to conceive or comprehend. Using desktop molecular factories would reduce the need for labour in the manufacturing sector to virtually zero. It would also dramatically reduce the need to transport, warehouse or sell goods and would have flow on effects for labour in many associated industries. Michael Vassar estimated[32] that 60-80% of all work would become unnecessary in the USA within the decade of widespread availability of desktop molecular manufacturing. What sort of society would we have where 70% of the population did not work? How would this vast group of people feed themselves and meet their basic needs? Would a large part of the population be denied a way of earning a living, becoming dependent on the charity of molecular manufacture? Beyond these basic questions of survival, what would a life dependent on charity without work or the means to purchase non-essential goods mean for people's sense of identity, purpose, self-fulfilment and happiness?

Given the scale of potential impacts of molecular manufacturing, it would be reassuring to know that our governments were at least assessing whether or not it could be possible, and what its implications may be, rather than dismissing it as impossible.

The urgent need for a moratorium on the commercial research, development, production and release of nanoproducts

It's hard for us to comprehend just how nanotechnology will change our world and to what extent the dramatic predictions of "revolution" will be realised. But the current development trajectory of nanotechnology suggests that it will exacerbate existing social inequities and create new ones. There is an urgent need for a moratorium on the commercial production and release of nanoproducts while we assess nanotechnology's social implications, create mechanisms to support public participation in the determination of research priorities and the development of governance measures, and plan how best to maximise societal benefits and to mitigate adverse socio-economic impacts. Perhaps most important, given the predictions of a "revolution" being driven by public monies, is the challenge to democratise nanotechnology's development and governance. Rather than nanotechnology's development simply reflecting commercial and military interests, it is time for public participation and public interest priorities to shape its trajectory.

For further information about Friends of the Earth Australia's work on nanotechnology issues please visit http://nano.foe.org.au

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