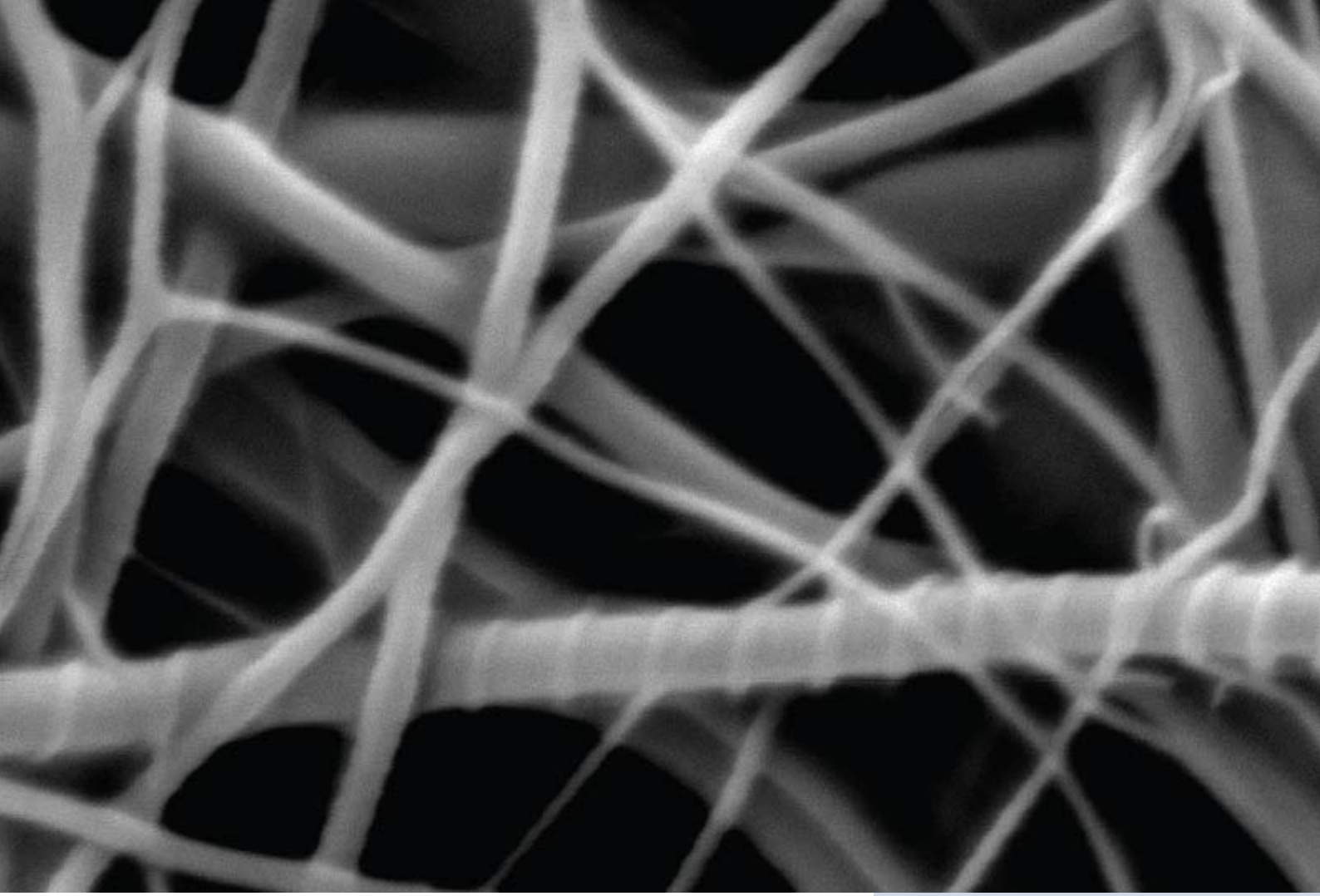

TABAH ANALYTICAL BRIEF | NO. 6 | NOVEMBER 2008

# ETHICAL DIMENSIONS OF NANOTECHNOLOGY

MUSA FURBER

*Contents*



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ETHICAL DIMENSIONS OF NANOTECHNOLOGY



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The *Tabah Analytical Briefs series* aims to empower Tabah clientele – Shari'ah scholars and Muslim leaders – with background information and critical analysis of contemporary events and debates. Each brief is a report of three to five pages, and concisely introduces a concept or topic relating to culture and socio-political change in the global community. The purpose of this series is to provide vital information that will assist scholars and policy makers in formulating a clear conception of the "Shared Public Space", developing an informed discourse, and mediating the challenges facing the Muslim world today.

# Ethical Dimensions of Nanotechnology

**Subject:** Nanotechnology, its dimensions, its potential benefits and harms, and a call for reasoned ethical reflection from the Shari'ah community.

**Significance:** Nanotechnology is one of the most rapidly developing technologies and it could become the most influential force on technology since the rise of the Internet. Ethical reflection must address the potential benefits and harms, as well as assess the goals for which these will be used.

**Executive Summary**: Nanotechnology comprises several fields where matter is viewed and manipulated at the extremely small scale of billionths of a meter. At this scale matter exhibits phenomena and properties that can be used for new applications. Nanotechnology has already made its way into common consumer products such as stain-free cloth, sunscreen, and computer chips. Unfortunately, nothing conclusive is known about the *additional* health and environmental risks of matter at such a small scale. Concern about these risks, and about how nanotechnology will be used and its impact on society have prompted several invitations for public discussions on the ethical dimensions of nanotechnology. Religious perspectives have been requested. Muslim scholars and opinion leaders have yet to respond.

This brief introduces the topic of nanotechnology and its ethical dimensions. It then presents a blueprint of the theological, legal, and ethical issues which Muslim scholars and opinion leaders may need to address, as well as a framework through which scholars can begin working out some of the answers.

Nanotechnology concerns the study and manipulation of physical matter at the extremely tiny scale of nanometers. One nanometer (nm) is one billionth of a meter. To put things in perspective, the width of a human hair is approximately 100,000 nm; atoms, molecules (like DNA), and viruses range between 1 nm and 100 nm; and the unaided eye cannot discern objects smaller than 10,000 nm.

Although scientists began observing and measuring matter at the nanoscale in 1914, they were not able to directly manipulate individual atoms until 1986. Through their studies at the

nanoscale, scientists have found that a number of physical phenomena become pronounced as the size of a system decreases, as do a number of physical properties. For example, gold is chemically inert at normal scales and yellowish orange in color; while at the nanoscale it serves as a catalyst and is red in color.

Two principle factors cause nanoscale matter to behave differently from materials at other scales. The first factor is the increased relative surface area which results in a given mass of nanomaterial being more reactive than the same mass of material made up of larger particles. The second factor is that quantum effects begin to dominate as size is reduced to the nanoscale, which can affect the optical, electrical, magnetic, and mechanical behavior of materials.[1]

Nanotechnology is not just another step in miniaturization. Materials at the nanoscale can exhibit properties different compared to what they show on a macroscale, thus enabling different applications.[2]

**Definition**. There are different definitions for nanotechnology. The US National Nanotechnology Initiative defines it as "research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 to 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size."[3] Some other definitions differentiate between "nanoscience" and "nanotechnology", defining "nanoscience" as " 'the study and manipulation' of nanoscale particles", and "nanotechnology" as the " 'design, characterization and production' of 'structures, devices and systems' at the nanoscale".[4]

**History**. The major milestones in the history of nanotechnology include:

1914 Richard Adolf Zsigmondy used an ultramicroscope to study colloidal gold and other nanomaterials. He is the first to use nanometer for characterizing particle size.

1959 Richard Feynman's lecture "Plenty of Room at the Bottom", in which he proposed direct manipulation of atoms as a more powerful form of synthetic chemistry than the then current forms.[5]

1974 Norio Taniguchi coins the term "nanotechnology".

1982 Gerd Binnig and Heinrich Rohrer invent the Scanning Tunneling Microscope (STM), which enabled researchers to view individual atoms for the first time.

1984 Richard Smalley, Robert Curl and Harold Kroto discover carbon 60 ($C_{60}$, "buckyballs"). Carbon 60 are a molecule of 60 carbon atoms approximately 1nm in diameter, arranged as 20 hexagons and 12 pentagons. It is expected to have applications as lubricants, drug delivery vehicles, and electronic circuits.

1. Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," *The Royal Society and the Royal Academy of Engineering* 29 (2004), 7.
2. UNESCO, *The Ethics and Politics of Nanotechnology* (Paris: UNESCO, 2006), 5.
3. ibid.
4. ibid.
5. Richard P. Feynman, "Plenty of Room At the Bottom," http://www.its.caltech.edu/~feynman/plenty.html (accessed 6 November, 2008).

1986 Gerd Binnig is involved with the invention of the Atomic Force Microscope (AFM), which enabled researches to manipulate individual atoms.

1989 Donald Eigler, a researcher for IBM, uses an AFM to arrange Xenon atoms to spell out "IBM".

1991 S. Iijima discovers nanotubes, which are estimated by some to be the strongest and most flexible material yet discovered.

1990s Discovery and research of nanoparticle semiconductors ("quantum dots") which can be made to absorb or emit specific wavelengths of light and have already found applications in medical imaging, solar cells, and tracing biological molecules.

While the ability to see and directly manipulate individual atoms is recent, researchers have found several centuries' old artifacts which took advantage of nanoscale properties. For example, medieval European stained glass windows use gold nanoparticles which also destroy air-borne pollutants;[6] and the steel found in a 17th century Damascus sword includes carbon nanotubes and cementite nanowires, which may account for the amazing mechanical properties of Damascus steel blades.[7]

**Applications**. There are two main approaches used to apply nanotechnology. In the *bottom-up* approach, materials and devices are built from smaller components (molecules or atoms) which assemble themselves through atomic-level control. In the *top-down* approach, a larger object is reduced to a nano-object, similar to how a sculptor chips away at a slab of rock to reduce it to a sculpture. Thus far, the focus has been on the top-down approach as the bottom-up approach is not yet practical.

A short list of the areas where nanotechnology has applications ready today or under development includes:

- Medicine. Nanoscale silver is currently being used as an antimicrobial agent in the treatment of wounds. Applications under development include new ways to detect and treat cancer, to diagnose infection and disease, and to deliver drugs.

- Air quality. Research is being done to make existing methods of reducing air pollution more effective and economical, as well as to develop new methods for controlling pollution by reducing emissions and removing existing pollution.

- Water management. Nanotechnology is being developed to remove wastes from water; to remove salt and metals from water; and to filter out viruses.

- Energy. Nanotechnology is already being used to reduce the cost and increase the efficiency of fuel cells and solar cells. Batteries are being developed that will charge faster than conventional batteries and can sit in storage for decades. Research is being done to make fossil fuels more efficient to use and produce, and to find alternative sources for energy.

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6. Kenneth Chang, "Tiny is Beautiful: Translating 'Nano' Into Practical," *New York Times*, http://www.nytimes.com/2005/02/22/science/22nano.html (accessed 6 November, 2008). and wire.com, "Air-Purifying Church Windows Early Nanotechnology," http://nanotechwire.com/news.asp?nid=6517&ntid=122&pg=1 (accessed 6 November, 2008).
7. M. Reibold et al., "Materials: Carbon Nanotubes in an Ancient Damascus Sabre," *Nature* 444, no. 7117 (2006): 286-286.

- Electronics. Nanotechnology is already being used to reduce the size, weight, power consumption, and cost of devices.

- Space. Stronger, lighter materials will make space flight and exploration more practical. There has even been discussion of using carbon nanotubes to create a space elevator that would reduce the cost of sending payloads into orbit.

- Food. Nanotechnology is currently being used in food packaging to ensure freshness and safety. Areas of research include packaging materials which can detect bacteria, new methods for delivering vitamins, and food with selectable color and taste.

- Consumer products. Nanotechnology has produced fabrics that are self-cleaning, water and stain resistant, kill the bacteria which cause odors, and insulate better. Nanotechnology is being used in sporting goods to provide stronger rackets and clubs which afford more control, and tennis balls that leak less so they keep their shape and bounce longer. Cleaning products also benefit from nanotechnology: films that make countertops and glass easier to clean and more water repellent, soap that cleans better while being safer for the environment, and cleaners with antibacterial agents. A large number of cosmetic and skin products use nanotechnology.

- Chemical sensors. Nanomaterials can detect very small amounts of chemical vapor with a high degree of specificity, which has applications in health, safety, environmental monitoring, and security.

- Micro-Electromechanical Systems (MEMS). These techniques allow electrical and mechanical devices to be manufactured on a single silicone chip, which is being used in pressure sensors and ink jet nozzles.

Developed and poor nations will both be able to participate in nanotechnology research and to benefit from its applications, though the resources and interests of each country will determine the extent of their participation and in which areas.

Several countries within the Middle East have already taken interest in nanotechnology. Iran has been active in nanotechnology since 2001; it opened its own Iranian Nanotechnology Initiative in 2003,[8] and produced its first nanotechnology product that same year. The Middle East's first conference on nanosciences was the four-day International Conference on Bio-Nanotechnology[9] held in Al Ain, UAE, starting 18 November 2006; a second conference was held in November 2008.[10] Both Saudi Arabia and Egypt have recently opened research centers in partnership with IBM.[11]

The fruits of nanotechnology research have already found their way into many commercial

8. Iranian Nanotechnology Initiative, "The Iranian Nanotechnology Initiative Council," http://www.nano.ir/en/pages.php?Pages_Id=36 (accessed 17 November, 2008).
9. Bionanotechnology is the intersection of biology and nanotechnology.
10. AME Info, "International Conference on Bio-Nanotechnology Opens in Al Ain," *AME Info*, http://www.ameinfo.com/102302.html (accessed 17 November, 2008) and Justin Smith, "Sheikh Nahyan opens International Conference on Bio-Nanotechnology," http://bi-me.com/main.php?c=3&cg=3&t=1&id=27479.
11. Wagdy Sawahel, "Saudi Arabia Boosts Nanotech Research," http://www.scidev.net/en/news/saudi-arabia-boosts-nanotech-research.html (accessed 17 November, 2008) and Wagdy Sawahel, "Egypt to Host First Northern African Nanotech Centre," http://www.scidev.net/en/news/egypt-to-host-first-northern-african-nanotech-cent.html (accessed 17 November, 2008).

consumer items. The Project on Emerging Technologies' Nanotechnology Consumer Products Inventory boasts "807 products, produced by 420 companies, located in 21 countries";[12] 502 of these products are health and fitness products (for example, personal care and cosmetics); 426 of the products originated from the USA, with nanoscale silver being the most common material mentioned in the product.[13] Silver is classified as an environmental hazard because of its toxicity, and very little is known what additional risks nanosilver poses.[14]

**Concerns**. While there is much excitement about nanotechnology, there are also many concerns. These concerns include:

- Inequalities regarding access to nanotechnology research within and between nations leading to a "nanodivide",[15] as well as in the *kinds* and *direction* of research.[16]

- Toxicity and exposure to humans and the environment.[17]

- Determining who will reap the benefits and who will suffer the risks.[18] This is of particular concern in an age where products produced in one locale are used in another, and then disposed of in yet another.

- Nanotechnology research being used for weapons.[19]

- National governments may abuse the threat of terrorism to classify research, or simply dismiss scientific results it finds at odds with its political goals.[20]

- Information collection and the implications for civil liberties.[21] Nano-sized surveillance devices will be able to observe a wider range of phenomena and will be more difficult to detect, and there is fear that they will be abused for genetic profiling or spying.

- Proper labeling of nanotechnology products, consumer awareness of nanotechnology issues, and enforcing compliance with nanotechnology product regulations.[22]

- Intellectual property rights.[23]

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12. The Project on Emerging Technologies, "Nanotechnology Consumer Products Inventory," http://www.nanotechproject.org/inventories/consumer/ (accessed 6 November, 2008).
13. The Project on Emerging Technologies, "Analysis of Consumer Products," http://www.nanotechproject.org/inventories/consumer/analysis_draft/ (accessed 6 November, 2008).
14. Samuel N. Luoma, "Silver Nanotechnologies and the Environment: Old Problems Or New Challenges?," *Project on Emerging Nanotechnologies*, http://www.nanotechproject.org/process/assets/files/7036/nano_pen_15_final.pdf.
15. UNESCO, *The Ethics and Politics of Nanotechnology*, 13, 20; Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 52–53.
16. UNESCO, *The Ethics and Politics of Nanotechnology*, 13, 20.
17. UNESCO, *The Ethics and Politics of Nanotechnology*, 13, 20; Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 35–50.
18. UNESCO, *The Ethics and Politics of Nanotechnology*, 17, 20; Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 52.
19. UNESCO, *The Ethics and Politics of Nanotechnology*, 17, 19; Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 55–56.
20. UNESCO, *The Ethics and Politics of Nanotechnology*, 17, 19.
21. Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 53–54.
22. UNESCO, *The Ethics and Politics of Nanotechnology*, 20.
23. ibid. 17–20.

- Increasing public scrutiny on the research and results of science.[24]

- Human enhancement.[25] An extreme form of this is transhumanism, which advocates using technology to liberate the human race from its biological constraints, thus making it stronger, smarter, healthier, and immortal.[26] Transhumanists even envision a "posthuman" being whose abilities so surpass today's human beings that it must be considered a new species.[27]

- How nanotechnologies will combine with other developments ("convergence").[28]

The relatively narrow technical issues (for example, safety, toxicity, and environmental impact) can be addressed through risk analysis, scientific experimentation, and regulation. The broader political and ethical issues (for example, intellectual property, secrecy and legitimacy of scientific results, and the potential for a knowledge divide based both on funding and on the legal implications of intellectual property) are more difficult to address.

**Nanotechnology and the UN Millennium Development Goals.** In order to address sustainable development issues in developing nations, a panel of 85 nanotechnology experts was formed to identify and rank the ten nanotechnologies that will most benefit these nations. The panel's results were: energy storage, production, and conversion; agricultural productivity enhancement; water treatment and remediation;[29] disease diagnosis and screening; drug delivery systems; food processing and storage; air pollution and remediation; construction; health monitoring; and vector[30] and pest detection and control.[31]

These results were then compared to the UN Millenium Development Goals (MDGs) to determine to what extent pursuing these technologies would work towards meeting these goals. The MDGs are eight goals that the UN aims to achieve by 2015. These goals are:

1. Eradicate extreme hunger and poverty.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria, and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.[32]

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24. ibid.
25. Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 54.
26. Francis Fukuyama, "Transhumanism: The World's Most Dangerous Ideas," *Foreign Policy* September/October (2004).
27. See "The Transhumanist FAQ: A General Introduction," http://www.transhumanism.org/resources/FAQv21.pdf (accessed 18 November, 2008), §1.2.
28. Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties," 54–55.
29. Remediation is the action of remedying something, in particular of reversing or stopping environmental damage.
30. A vector is an organism, typically a biting insect or tick, that transmits a disease or parasite from one animal or plant to another.
31. UN Millenium Project, "UN Millenium Project Goals," http://www.unmillenniumproject.org/goals/index.htm (accessed 18 November, 2008), and UNESCO, *The Ethics and Politics of Nanotechnology*, 14.
32. Fabio Salamanca-Buentello et al., "Nanotechnology and the Developing World," *PLoS Medicine* 2, no. 5 (2005): 383–87.

The results of this comparison are shown in the table below:

| Rank | Applications of nanotechnology | MDGs met |
|---|---|---|
| 1 | Energy storage, production, and conversion | 7 |
| 2 | Agricultural productivity enhancement | 1, 4, 5, 7 |
| 3 | Water treatment and remediation | 1, 4, 5, 7 |
| 4 | Disease diagnosis and screening | 4, 5, 6 |
| 5 | Drug delivery systems | 4, 5, 6 |
| 6 | Food processing and storage | 1, 4, 5 |
| 7 | Air pollution and remediation | 4, 5, 7 |
| 8 | Construction | 7 |
| 9 | Health monitoring | 4, 5, 6 |
| 10 | Vector and pest detection and control. | 4, 5, 6 |

**The ethical dimension.** There have been several attempts to assess the societal implications of nanotechnology with ethics being a common topic. The first major attempt by the United States National Science Foundation at a workshop held for two days in September 2000, with another two day workshop in December 2003. A report was published after each workshop.[33]

In June 2003, the British government commissioned the Royal Society, the UK National Academy of Science, and the Royal Academy of Engineering, and the UK National Academy of Engineering, to conduct an independent study on nanotechnology. They published their findings on 29 July 2004 in a 127 page report.[34]

While the above reports focus on a wide range of nanotechnology topics, UNESCO has focused extensively on the ethical dimensions of nanotechnology from a global perspective. It was a topic of discussion at the 3rd Ordinary Session of COMEST[35] in December 2003. When it came up again at the 4th Session in March 2005, an ad hoc group of experts was formed to explore the issues of nanotechnology. The group presented an outline for a policy document at an Extraordinary Session held in June 2006, with additional consultations in November 2006. These recommendations were taken into consideration in the 5th Ordinary Session in December 2006, resulting in the publication of "COMEST Policy Recommendations on Nanotechnologies and Ethics". The document's introduction states that:

> Nanotechnologies can be used to enhance the lives of the privileged, as well as to address the concerns of the developing world. …From a global perspective, ethical reflection needs to address the potential benefits and harms of nanotechnologies but even more important is assessing and publicly discussing the goals for which these technologies will be used, now that science and technology can be harnessed to solve the most pressing needs of humankind.[36]

33. See Mihail C. Roco, and William Sims Bainbridge, eds. *Societal Implications of Nanoscience and Nanotechnology*, NSET Workshop Report (2001), and Mihail C. Roco, and William Sims Bainbridge, eds. *Nanotechnology: Societal Implications – Maximizing Benefit for Humanity*, National Nanotechnology Initiative Workshop (2003).
34. See Dowling et al., "Nanoscience and Nanotechnologies: Opportunities and Uncertainties."
35. COMEST is the World Commission on the Ethics of Scientific Knowledge and Technology. It is "an advisory body and forum of reflection composed of 18 independent experts. The Commission is mandated to formulate ethical principles that could provide decision-makers with criteria other than purely economic." (See COMEST, "COMEST: UNESCO: SHS," <http://portal.unesco.org/shs/en/ev.php-URL_ID=6193&URL_DO=DO_TOPIC&URL_SECTION=201.html> (accessed 18 November, 2008).)
36. UNESCO, *Nanotechnologies and Ethics: Policies and Actions, COMEST Policy Recommendations* (Paris: UNESCO,

The document identified three categories of stake holders involved in exploring the ethical dimensions and international activities: philosophers and ethicists, scientists, and policy-makers,[37] and it summarized the phases and work done thus far: identification of the moral dimensions (2005), testing the relevance of potential international actions (2006), and enhancing the political feasibility of potential actions (current, future).[38]

The UNESCO document also identifies several peculiarities of nanotechnology that give rise to specific ethical concerns:

- Its extremely tiny scale makes it difficult to control and trace.
- Its relative newness and the pace of development create difficulties in identifying potential impacts and formulating a response – especially long-term impacts.
- Its weapons applications could vey well result in conflicts with human rights.
- The potential risks of nanotechnology are risks even for countries and societies that are not participating in nanotechnology as researchers, producers, or consumers.
- The potential for increasing the inequalities between developing and developed countries (the "nanodivide").[39]

The document stressed the need for awareness-raising and public debate on nanotechnology, and recommended topics including the risks and benefits of nanotechnology; environmental impact and health issues; assessment of health *and* ethical risks; nanomedicine; privacy and confidentiality; and intellectual property.[40]

It also stressed the need for ethics education of scientists and engineers:

> Public engagement and educational strategies for nanotechnologies are necessary. The need for adequate ethics education of scientists and engineers is commonly emphasized. It is a consequence of the ethical demands for interdisciplinarity and a holistic view on science and its implication for society in the broadest sense. The interdisciplinarity of nanotechnologies therefore strengthens the need for explicit ethics teaching at all levels of education for scientists and engineers involved in nanotechnologies…. Attitudes towards nanoethics education may differ according to cultural background. To the extent possible, education to encourage critical thinking should be favoured.[41]

Concerning this last part, they add:

> There is a need to conduct social science research on how different cultures envision, define and problematize nanotechnologies, and consequently how related ethical issues are constructed. In this context, the development of innovative

2007), 3. This document is also available in Arabic.

37. ibid.
38. ibid.
39. ibid. 5.
40. ibid. 8–9.
41. ibid. 10.

> methods in framing nanotechnologies research questions, priorities and policies, as well as methods in conducting research should be encouraged.[42]

The document also warns that nanotechnologies will displace many current technologies:

> Countries whose national resources may be replaced by nano-engineered materials, for example, should rather look for the best use of their resources and for specific nanotechnologies research.[43]

## RELIGION AND NANOTECHNOLOGY RESEARCH

In an article published in January 2008 in *nature nanotechnology*, Chris Toumey voiced concerns that religious writers have said little about the religious implications of nanotechnology. While much has been written about the ethical dimensions of nanotechnology, most of it is written in secular voices by authors without formal credentials in ethics. The small sample of religious literature on nanotechnology thus far falls under three categories:

1. Religious writers presenting nanotechnology and speculating about its possible issues in very general terms. These articles are educational – not religious – and end up being equivalent to the secular statements.

2. Transhumanist writers, such as William Sims Bainbridge (one of the editors for the US NSF reports) and Raymond Kurzweil, who envision nanotechnology saving us from illness, ageing, death and other problems, and even transforming the human species. Toumey writes that Bainbridge "speaks in a secular voice but his writing is a kind of religious literature: a crusade against traditional religion that is tantamount to calling for a new religion that will deliver eternal life and ultimate meaning".[44] Rosalyn Berne of the University of Virginia has shown how "transhumanism makes use of the religious idioms of rebirth, transcending biological form and the transmigration of souls, as well as other common features of religious thought".[45]

3. A small number of writers reacting with values and beliefs explicitly grounded in Christianity. Toumey observes:

> It has been speculated that conservative Christians might react negatively to nanotechnology in much the same way that they oppose stem-cell research, which they equate with abortion. As far as I can tell, with a few exceptions, nanotechnology has not caused such alarm among conservative Christians. However, some nanotechnologies are viewed as 'enhancement', similar to the use of steroids by athletes, which is not compatible with the Christian ideal of 'embodiment' (that is, the belief that Christians should be comfortable with their imperfect bodies, and that bodily death is not something to escape).[46]

As for the "few exceptions" mentioned above, a number of Christian writers have been ap-

42. ibid. 12.
43. ibid. 13.
44. Chris Toumey, "Atom and Eve," *nature nanotechnology* 3 (2008), 2.
45. Rosalyn Berne, "Recognizing Religious Mythology in Visions of New Technology," *IEEE Technology and Society Magazine* 22, no. 1 (2003): 34–39, via Chris Toumey, "Atom and Eve," 3.
46. Chris Toumey, "Atom and Eve," 3.

palled by transhumanist values. These writers are reacting to what they deem to be amoral approaches to using nanotechnology – not nanotechnology itself.

Toumey points out that the transhumanist and religious writers define their approach in terms of the highly-speculative long term life- and body-enhancing possibilities of nanotechnology, instead of focusing on short-term developments and the broader scope. He closes his piece asking whether the religious writers could "address the rights and wrongs of the near-future changes at least as much as the far-future topics?" and points out that "if religious writers think about nanotechnology only in terms of enhancement and immortality, they fall into a trap and become systematically hostile to a very broad technology."[47]

One month after Toumey's article, Dietram Scheufele, a University of Wisconsin-Madison professor, presented survey results for the percentage of people who agree that nanotechnology research is moral. Scheufele found that there was a distinct difference between Americans and Europeans from countries that are key players in nanotechnology research. The survey respondents were well informed on nanotechnology. Of those surveyed, 29.5% of the Americans considered nanotechnology research moral, in stark contrast to 54.1% in the UK, 62.7% in Germany, and 72.1% in France. When asked to explain the cause for the gap between Americans and Europeans, Scheufele replied that it was religion:

> The United States is a country where religion plays an important role in peoples' lives. The importance of religion in these different countries that shows up in data set after data set parallels exactly the differences we're seeing in terms of moral views. European countries have a much more secular perspective.[48]

He further explained that Americans may lump nanotechnology, biotechnology, and stem cell research together, and that researchers are viewed as "playing God" when they create materials that do not occur in nature.

One might wonder whether Scheufele's American respondents read any of the writings by Christian religious authors from Toumey's third category.

## RECOMMENDED AREAS OF REFLECTION

Given the interdisciplinary nature of nanotechnology research and its wide range of applications, it is useful to focus first on general issues related to working with matter at the nanoscale, and to focus next on issues related to particular application areas.

**1. General issues.** Nanotechnology draws on a number of fields which are not themselves limited to studying matter at the nanoscale, such as subatomic physics and cellular biology. It is thus important that we limit ourselves to the issues specific to the study and manipulation of matter at the nanoscale and leave the smaller- and larger- scale issues to their respective fields.

There are several nanotechnology-specific issues for Muslims and Muslim jurists and theologians to consider – bearing in mind that Muslim researchers working in the field are already asking some of these very questions:

47. ibid.
48. Terry Devitt, "Study: Religion Colors Americans' Views of Nanotechnology," http://www.news.wisc.edu/14773 (accessed 16 November, 2008).

- What is the status of nanotechnology with respect to theology? What does theology say about a quantum, non-deterministic, universe?

- What is the legal ruling of manipulating matter at the nanoscale, in particular when it is assembled into configurations which do not otherwise exist in nature?[49]

- How do the Shari'ah's permission to harness the creation and its warning against tampering with God's creation apply to nanotechnology?[50]

- Given the potential health and environmental dangers, and the fear that nanotechnology will be used for weapons – especially in light of the specificity, added capabilities, and difficulty in tracing them – then to what extent will "blocking the means"[51] apply, and how do we weigh them in light of the potential benefits?

**2. Issues related to particular application areas.** While current nanotechnology applications all involve inanimate matter, technologists envision it being applied to humans and other living creatures. Its application to humans and other living creatures prompts many fascinating issues concerning life itself and what it means to be human. It is crucial when thinking about these issues to remember that biological applications are a small subset of the possible applications for nanotechnology.

- It is possible to arrange atoms into configurations which are not already found in creation, such as quasicrystals. Is it permissible?

- Do nano-replicas of natural substances have the same ruling as the natural substance? For example, does a nano-replica of silk, created atom by atom, have the same ruling as natural silk? Could men use it?

- Do nano-particles of natural substances have the same ruling as the non-nano substance? For example, nano-particle gold takes on a different color; is it permissible for men and women to use?

- Nanotechnology can be used to create smaller, more invasive and difficult to detect sensors and surveillance devices. Do individuals have a right to privacy, and to what extent?

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49. Legal ruling (الحكم التكليفي), or "defining law", can be described as the locution or communication from the Lawgiver (God) which demands the legally responsible party to do something, or forbids something, or gives him an option in between the two. See Zakariya al-Ansari, *Ghayat al-Wusul fi Sharh Lubb al-Usul*, 5; Muhammad Abu Zahrah, *Usul al-Fiqh* (Cairo: Dar al-Fikr al-Arabi), §24–26; and Mohammad Hashim Kamali, *Principles of Islamic Jurisprudence*, 3rd ed. (Cambridge: The Islamic Texts Society, 2003), 413.
50. The permission to harness the creation is understood in the verses where God Most High has said: *Allah is Who has subjugated the sea to you, that the ships may sail in it by His command, and that you may seek of His favor, and that you may be thankful; And He has subjected to you everything in the heavens and the earth; it is all from Him. In this are signs for people who reflect* Q45:12–13.

    The warning against tampering with creation is understood in the verses where God Most High describes the Devil: *he [the Devil] said: "I will surely take of your slaves an appointed portion. And I will surely lead them astray, and arouse desires in them, and command them and they will cut the cattle's ears, and I will surely command them and they will change Allah's creation." Whoever chooses the Devil for a friend instead of Allah is assuredly a loser, and his loss is manifest* Q4:118–19.
51. "Blocking the means" (سد الذرائع) is a principle within Islamic jurisprudence that involves blocking the means to an expected end that is likely to materialize if the means towards that end is not obstructed. (See Muhammad Abu Zahrah, *Usul al-Fiqh*, §278–82; and Mohammad Hashim Kamali, *Principles of Islamic Jurisprudence*, 397–409.)

- Who is responsible in cases of nanotechnology-related death, injury, or environmental damage? The extreme tiny size of nanomaterial makes it very difficult to trace and detect.

- Is it permissible to weaponize nanotechnology? If so, what are the guidelines for lawful nanotechnology weapons? What types of weapons would be unacceptable?

- Is it permissible to develop nanotechnology weapons capable of mass devastation with the intention that they be used only as a deterrence?

- Should Muslims support a ban on weaponizing nanotechnology? If scholars were to support such a ban, would it be binding?

- Is it permissible to replicate living cells or tissue to be replicated atom by atom?

  The process here is not identical to cloning since here the replica would be directly assembled atom by atom, while cloning takes advantage of the normal means of cellular reproduction.

  Does the replica have the same ruling as the original? For example, is a replica of human blood considered ritually filthy (*najas*)?

- What is life? Can life be created or caused? Is life merely a material consequence of atoms assembled in a certain way?

- Is it possible to replicate a living creature atom by atom? Will it be living? Is this permissible?

- Is it possible to create a new living creature unprecedented in creation? For example, a griffin, a unicorn, or some other fantasy creature.

- A non-Muslim author raises several issues in his work of science-fiction:

  > A religious college in Cairo is considering issues of nanotechnology: If replicators are used to prepare a copy of a strip of bacon, right down to the molecular level, but without it ever being part of a pig, how is it to be treated? (If the mind of one of the faithful is copied into a computing machine's memory by mapping and simulating all its synapses, is the computer now a Moslem? If not, why not? If so, what are its rights and duties?)[52]

  This is an incredibly insightful question in that it prompts inquiry into the nature of the underlying apparent cause behind the legal rulings concerning pigs and adds a theological dimension. One could add similar questions concerning canine tissue, replicating entire pigs and dogs, and the various legal rulings associated with each type of creature.

- Is it permissible to replicate human tissue or organs (for example, a human heart or brain) through nanotechnology, one atom at a time, and what are its potential repercussions?

- Is it permissible to replicate human tissue and organs for non-medical purposes, for exam-

52. Charles Stross, "Halo," in *Accelerando* (Ace, 2006), 55 PDF version.

ple replicating human brain cells to create a computer, and what are its potential repercussions?

- What does the Shariah say about the possibility of replicating a human being? What does it mean to be human? Would the replication receive the same legal status and sanctity as its original? Is it possible for it to be imbued with a soul?

- To what extent is it permissible to use inanimate matter, or animal or human tissues with human beings as a medical treatment? Is it permissible to replace a natural part with a more capable nanotechnology-based replacement, for example, joints and bones that are stronger and less likely to wear out?

- To what extent is it permissible to use inanimate matter, or animal or human tissues with human beings for the sake of voluntary enhancement? For example, stronger muscles, eyes that can see wavelengths within the infrared band.

- To what extent is it permissible to use technology to modify or enhance human beings? Can it be used to detect and mend flaws within an individual being (for example, genetic birth defects, cancer, the aging of cells), or to make these improvements in such a way that they will be lasting and cross generations through inheritance? Are the flaws of individual humans somehow essential to our identity or survival as a species?

- To what extent is it permissible for humanity to strive to exceed its physical flaws and limitations?

- To what extent is it permissible to detect and modify behavior which has been determined to be genetically influenced?

- Is genetic information private? For example, can someone who has a genetic inclination towards an inheritable disease expect this to be kept secret or is it a matter of public health?

Few of the issues mentioned here are currently possible through nanotechnology. However, the field is moving in these very directions and these are the questions that are coming to the fore. Furthermore, what makes these issues relevant is that many of them are already or nearly possible through other technologies.

While the theological issues are beyond the scope of this brief, it is possible to offer a tentative framework for addressing some of the legal and ethical issues.

The Qur'an and Sunnah do not include texts specific to nanotechnology as a field. Since scholars already approve of physics, chemistry, biology, genetics, and the other fields comprising nanotechnology, it follows that nanotechnology *as a field* is also acceptable. But it is not enough to simply give religious approval to an area of research or to allude to a potential basis for it within source texts without also providing guidelines for how research ought to proceed and how it ought to be applied, and what areas – if any – are verboten. Without religious guidelines, what differentiates Islamic science from, for example, secular science?

Legal maxims might be employed to generate tentative answers to some of these legal and ethical concerns. Although the legal texts of the Shari'ah are silent on the issue, nanotechnol-

ogy *as a field of theoretical and applied research* is permissible since the maxim from the methods of jurisprudence states that permissibility is assumed in the absence of evidence to the contrary.[53]

There remains a need to assess individual areas of research or applications on a case by case basis. Textual evidence and legal precedent covering some of these cases may be found, but most will be novel so scholars can weigh each one against the objectives of the Shari'ah and legal maxims. In cases where a nanotechnology could be used as a means for performing lawful and unlawful actions, the technology remains lawful in accordance to the principle that things which have the potential to be used for unlawful acts remain permissible so long as the unlawful uses can be avoided.[54] However, in cases where a nanotechnology is inextricably linked to performing the unlawful, then it becomes unlawful following the maxim from jurisprudence that when the lawful and the prohibited are linked together, that the unlawful aspects dominate the ruling.[55]

The risks to humans and the environment cannot be ignored. This can be shown by extending the last maxim to cases where harm and benefit are linked (after all, harming oneself or others is itself unlawful, and harming others is punishable). This is confirmed by the maxim which states that warding off harms is more important than obtaining benefits;[56] this maxim also sheds light on possibilities for a Shar'iah-based policy on how nanotechnology should proceed.

Unfortunately, there is not yet conclusive data on what these harms actually are, so scholars need to assess to what degree "blocking the means" should be applied.

Because of the dynamism of Shari'ah based reasoning, Muslim scholars are well placed to provide a religious alternative to ultra-conservative American Christians as well as to set policies where religion fosters scientific inquiry instead of suffocating it. Scholars may want to consider thinking about and preparing answers to Shari'ah issues related to nanotechnology so that curious Muslims – and non-Muslims – can rely upon their answers instead of feeling the need to look elsewhere.

Non-Muslims have already expressed interest in what Muslim scholars have to say about nanotechnology. COMEST has already expressed the need for representatives of all cultures and religions to participate in exploring its ethical and policy dimensions. A basic survey of

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53. The preponderant ruling among the scholars is that when the Shari'ah is silent on an issue which is not repugnant to reason that it will be presumed to be permissible, as God Most High has said, *He created for you all that there is on Earth; then He turned to the sky and fashioned into seven heavens, He has full knowledge of all things*, Q2:29.

    In Arabic, this principle is formulated as (الأصل في الأشياء الإباحة). See Zakariya al-Ansari, *Ghayat al-Wusul fi Sharh Lubb al-Usul*, 6 and 152; and Mohammad Hashim Kamali, *Principles of Islamic Jurisprudence*, 387–88.

54. This principle is cited frequently in the *fatawa* of Dr Ali Gomaa, the current Grand Mufti of Egypt. The Arabic formula for this principle is (الحرمة إذا لم تتعين حلت).

55. The legal maxim states that when the lawful and the prohibited are linked together, that the unlawful aspects dominate the ruling. The evidence for this is the saying of the Prophet (may Allah bless him and give him peace), "Leave that of which you are uncertain for that which you are certain." The formula for this maxim in Arabic is (إذا جمع الحلال والحرام يغلب الحرام على الحلال). See Jalal al-Din al-Suyuti, *Al-Ashbah wa al-Naza'ir*, 117.

56. The maxim that warding off harms is more important than obtaining benefits is based upon the saying of the Prophet (May Allah bless him and give him peace), "That which I have forbidden to you, avoid; that which I have ordered you to perform, do as much of it as you can". This formula for this principle in Arabic is (درء المفاسد أولى من جلب المصالح). See Jalal al-Din al-Suyuti, *Al-Ashbah wa al-Naza'ir*, 74.

the available literature shows that Muslim scholarship has yet to respond in any significant fashion.

## CONCLUSION

There is great need to explore the theological, legal, ethical, and medical aspects of nanotechnology and its application. There have already been several international discussions on these topics. Muslim scholars and policy makers need to represent Islam and the Muslim community in these discussions.

## AREAS FOR FURTHER RESEARCH

- How do the UN MDGs fit within the overall goals of the Shari'ah? Should wealthy Muslim nations consider making them priorities for the global Muslim community, or even consider them an eligible recipient of obligatory alms (*zakat*)?

- Although the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was created in 1989 in response to ships bearing toxic waste offloading their cargo onto poor, unsuspecting nations, this has done little to prevent developed nations "outsourcing" their environmental nightmares. Alang, India, is the world's favorite spot for dumping ships. Africa and Asia are choice locations for post-consumer trash – particularly plastics and computer equipment. These are *existing* environmental disasters.

- What are the guidelines for setting policies for technologies that are being used in unlawful ways or that have negative impacts on society? There is a need to form policies which allow individuals to benefit from these technologies while still protecting society and other individuals. Cameras were added to cell phones in 2000 in Japan, giving users the ability to snap shots anytime, anywhere, and with near anonymity. The most widely reported abuse by 2002 the surreptitious photographing of woman's short dresses from compromising angles. The problem became so large that phone manufacturers were eventually required by law to configure the phones to emit a mandatory sound whenever a picture was taken. Japan also has laws restricting cell phone camera usage in areas where people have an expectation of privacy. Similar laws have been proposed in the USA. Attention should be directed to the fact that secular societies and their attendant authorities are currently taking the lead in setting practical ethical policies where the religious community is conspicuously silent.

- When it comes to dilemmas regarding religion and technology, very often the Muslim public tends to adopt current Christian religious reasoning for lack of an authentic alternative. This is not a sustainable solution because often the Christian solution is not congruent with the way Shari'ah reasoning would frame the issue and prescribe a treatment.

- Are science and technology morally neutral or even free of moral judgment? Does the Shari'ah permit the research or development of a technology that can only be used for unlawful purposes?

- Views of traditional Muslim scholars on technology and ethics remain largely unknown in the West.

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