



postnote

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THE DUAL-USE DILEMMA

Science is primarily used to benefit humanity, but it can be misused, presenting scientists and others with an ethical quandary known as the dual-use dilemma. This note examines three scientific areas posing a significant risk of misuse and considers how to tackle dual-use dilemmas in these and other areas.

Background

Dual-use dilemmas arise when the same scientific work can be used to do good or be misused, and it is unclear how to prevent misuse without foregoing beneficial applications.¹ 'Misuse' can be interpreted differently, but is defined here as any unethical intended use of science, in civilian or military settings. Recent discussion has focussed on terrorist applications of science, prompted by reports of the accidental creation of a vaccine resistant mousepox virus² and synthesis of poliovirus.³

In the wake of the September 11, 2001 attacks, some US commentators argued that reports such as those mentioned above provided a blueprint for bio-weapon development by terrorists and should not have been published. Meetings of scientists and security experts led to a statement from journal editors (Box 1), the publication of a report on dual-use life science by the US National Research Council⁴ and the formation, in 2004, of the US National Science Advisory Board for Biosecurity (NSABB). In the UK, a House of Commons Select Committee examined science and terrorism in 2003; the Royal Society, Wellcome Trust, UK Research Councils, and Society for General Microbiology developed policies on preventing misuse of science; while the Foreign Office has led efforts to strengthen the Biological Weapons Convention.

This note outlines concerns about the misuse of current science with three case studies before examining options open to scientists and policymakers faced with dual-use dilemmas. Attempts to prevent misuse could target:

- scientific practice – influencing what scientific work is conducted, by whom and under what conditions;
- dissemination of scientific information;
- the use of technologies developed through science.

Box 1. Scientific Publication and Security

In 2003, the American Society for Microbiology and the editors of *Science*, *Nature* and *Proceedings of the National Academy of Sciences* published a joint statement. This acknowledged a role for journal editors in reviewing papers raising security issues prior to publication. It emphasised the importance of “publishing manuscripts of high quality, in sufficient detail to permit reproducibility” and pointed out that research raising security issues is also “critical to society in meeting the challenges of defence”. The editors stated that “on occasion an editor may conclude that the potential harm of publication outweighs the potential societal benefits” and that “under such circumstances, the paper should be modified or not be published”.

The Wellcome Trust and UK Research Councils support a risk-benefit assessment approach at all three levels.

Case 1: DNA Synthesis

Advances in DNA synthesis have enabled cheap and rapid synthesis of some viral genomes. There is concern that further advances and improved methods for delivering infectious agents may bring bioweapons production within the capabilities of terrorist groups.⁵ Companies might unwittingly aid terrorists by providing DNA segments that could be joined to create the full genome of an infectious agent. In 2006, a *Guardian* reporter successfully ordered a small DNA segment of the smallpox genome for delivery to his home address.

Many UK scientists and non-proliferation experts believe that the bioterrorism risk from cutting-edge DNA synthesis has been overstated in the US.⁵ They note that:

- engaging in high-tech DNA synthesis would not be a cost-effective strategy for most terrorist groups;
- bioweapons would lack the predictable and dramatic effects of traditional forms of terrorism.

Some also question the assumption that advances in DNA synthesis will inevitably enable the production of effective bioweapons. Many further technical hurdles – for example, relating to dispersal – would need to be cleared. Any attempt to produce ‘designer’ pathogens would also require greater understanding of how various factors combine to make a microbe dangerous. Many

argue that, at present, 'high-tech' bioterrorism poses a lesser threat than either natural disease or 'lower tech' forms of bioterrorism, such as spreading pathogens readily found in the environment. However, government officials and scientists are concerned that further advances or cost reductions will make DNA synthesis more attractive to terrorists in the future and thus see a need for ongoing review. There is also concern about use of DNA synthesis in state bioweapons programmes.

Case 2: Neuroscience

Imaging Psychological States

Developments in brain imaging have provided new research and diagnostic tools for scientists and clinicians. There is speculation that advances in neuro-imaging may enable determination of a person's thoughts or feelings. However, barriers include the complexity of the human brain and relationships between brain and mind states, as well as variation in brain structure over a lifetime and between individuals.⁶ Determining a person's broad psychological state may be more realistic. There is concern that technologies for imaging psychological states may be used in ways that infringe privacy.

Incapacitating Agents

Drugs that reduce consciousness have been used as so-called 'non-lethal' incapacitants. Future arsenals may include agents to induce panic, depression, psychosis, pain or delirium. Though use of incapacitating agents is often defended on humanitarian grounds, in warfare non-lethal agents have been used to make conventional weapons more effective.⁷ For example, the US used CS gas in Vietnam to drive enemy troops from cover to increase their vulnerability.

Performance-enhancing Drugs

There is considerable interest in drugs that enhance attention, memory, alertness or other aspects of cognitive performance. The use of such drugs may have socially beneficial effects such as increasing productivity. However, there are concerns about misuse: for example, performance enhancers may be administered coercively or used to exacerbate socio-economic inequalities.

Personality Manipulation

Recent research into the neural and hormonal bases of complex psychological characteristics such as aggression, patience and trust raises the prospect that it will become possible to manipulate such traits using drugs or other biotechnologies. For instance the hormone oxytocin, involved in birth and breastfeeding, may also mediate trust. Research has shown that subjects who inhaled oxytocin exhibited more trusting behaviour in a co-operative game than those who did not. Voluntary use of personality manipulating technologies might be justified in many cases, but scientists and ethicists have raised concerns about coercive or covert use.

Case 3: Laser Uranium Enrichment

Many nuclear warheads and some power generators use enriched uranium. Uranium enrichment typically requires large gas centrifuge or gaseous diffusion facilities. Several countries have attempted to develop alternative laser-

based enrichment processes. Global Laser Enrichment, a subsidiary of General Electric, is seeking to commercialise the novel SILEX technique developed by Australian scientists. There is scepticism about the potential for SILEX to become a cost-effective way of enriching uranium for power generation, but some worry that it may enable the production of small quantities of highly enriched uranium for use in nuclear weapons.⁸ Concerns are intensified as:

- laser enrichment plants could be smaller, and thus more difficult to detect, than traditional enrichment facilities. Since 2002, laser enrichment programmes have been uncovered in Iran and South Korea;
- most components needed to build laser enrichment apparatus also have non-nuclear uses, making anti-proliferation regulations more difficult to implement;
- techniques and technologies required for laser enrichment could be developed using other elements and then applied to uranium as a final step;
- much research in laser uranium enrichment has taken place within universities, which may not be subject to full nuclear safeguards.

Tackling the Dual-use Dilemma

There is no co-ordinated UK approach to misuse of science, though many individual measures are in place to prevent specific unethical applications. Research suggests that these measures have not significantly impeded science,⁹ but scientists highlight the risk that blunt or poorly implemented regulation will slow scientific progress. The challenge posed by the dual-use dilemma is to determine which preventive measures will optimise the benefit-risk profile of science. Ethicists and funding bodies have identified a need for clear assignments of responsibilities for stopping misuse, and for principles to guide decisions about which measures to introduce, and when (Box 2). There is strong support from UK funders for a co-ordinated approach to misuse that identifies and balances the risks and benefits at all stages of the scientific process.

Box 2. Principles for Tackling Dual-use Dilemmas

Attempts to develop principles for tackling dual-use dilemmas raise many ethical issues including:

- which risks and benefits of science to factor into decisions about preventive measures, for example, whether the production of knowledge should be regarded as a benefit regardless of how it may be used;
- how risks and benefits should be weighed, for example, whether the distribution of risks and benefits across countries and individuals should be taken into account.

The remainder of this note outlines examples of preventive strategies drawn from recent discussions of the misuse of science. These focus on preventing nuclear, biological and chemical weapon proliferation. Not all of these strategies will be appropriate for preventing other types of misuse.

Prevention at the Level of Scientific Practice

Education and awareness raising

Programmes based at the Universities of Exeter, Bradford and Leeds have sought to raise awareness of dual-use

issues among scientists and students. They have frequently encountered low levels of awareness. Advocates of risk reduction support education on misuse at all stages of scientists' careers, including compulsory education for students. Some highlight the role well-informed scientists could play in lobbying for better preventive policies. Others suggest raising awareness will promote debate, create a culture of responsibility and discourage scientists from pursuing or disseminating research posing an unacceptable risk of misuse. Some also advocate public engagement on dual-use issues and awareness-raising among policymakers.

Codes of Conduct

The Royal Society, the NSABB, the International Union of Pure and Applied Chemistry, the InterAcademy Panel¹⁰ and others are promoting codes of conduct outlining scientists' responsibilities for preventing misuse of their work.¹¹ Although there is some scepticism about the direct influence of codes on scientific practice, many believe that they will promote a scientific culture of taking responsibility for how science is used.

Funding Decisions

Science funders routinely assess the likely benefits of proposed research. They could also take into account the risks of misuse, an approach supported by the Royal Society and Research Councils UK. Risk assessments could be factored into decisions about individual projects, or the government's strategic science funding decisions. The Wellcome Trust and two research councils have committed to a risk assessment model, ask applicants to declare risks of misuse, and have review procedures for proposals that raise misuse concerns.¹²

Biosafety and Biosecurity Regulations

UK biosafety regulations cover work involving micro-organisms, genetic modification and animals. They are enforced by the Health and Safety Executive (HSE) and Defra. Projects involving certain micro-organisms and genetic modification activities must undergo a risk assessment and be notified to the HSE. In addition, the Anti-Terrorism, Crime and Security Act 2001, enforced by the Home Office, institutes personnel vetting and notification procedures for laboratories dealing with specified pathogens and toxins. Though these regulations restrict access to dangerous pathogens, they may not cover all scientific work that could subsequently aid, though does not itself involve, the creation of pathogens. The US's National Research Councils recommended the extension of biosafety measures to cover "experiments of concern" in addition to specified pathogens,⁴ though questions have been raised about whether biosafety committees have expertise to fulfil this expanded role.

Prevention at the Level of Information Dissemination

Scientific work relevant to nuclear weapon development has often been carried out in secret state facilities. However, in most scientific disciplines there is a tradition of openness and the dissemination of findings through publication and education is controlled largely by the scientific community. Exceptions in the UK include:

- a new scheme instituting security checks for non-EU nationals seeking to study certain science and engineering subjects in the UK;
- export controls, which restrict the dissemination of some intangible technology, for example information detailing methods for producing explosive nuclear devices. The Export Control Organisation believes that scientists' awareness of controls may be low.

Scientific Self-governance of Information Dissemination

Scientists strongly support self-governance of information dissemination and regard existing peer-review and editorial processes as crucial to scientific progress. Concerns have been raised about self-governance since scientists face a professional imperative to disseminate their work and may lack expertise to assess its security implications. Assessments would ideally incorporate sensitive and potentially classified information about the current capabilities of terrorist groups, for example.¹³ However, the dominant view from the UK scientific community is that existing self-governance is adequate, or would be with greater awareness of dual-use issues. Some advocate greater co-operation between journals in screening papers; smaller journals may lack resources to do this. Some also see a need for greater access to security experts. The US NSABB includes security experts and is available to advise journal editors on dual-use issues, though the impact of its advice is unclear.¹³

Costs and Benefits of Publication

Several journals have procedures to review articles thought to raise security concerns. Experience suggests that such articles are rare. For example, the Nature Publishing Group has received 74,000 biology submissions since 2005. Of these, 28 were flagged for further review due to security concerns, but none was rejected or amended as a result. There is disagreement about when, if ever, scientific information should be withheld because of possible misuse. Concerns are that:

- withholding findings slows the progress of beneficial science. This is true even if only information on method is omitted, as this is necessary for verification and replication of experiments;
- much scientific knowledge that would be useful to malevolent actors is already in the public domain;
- the internet, conferences and informal discussions make limiting information dissemination difficult.

One possibility would be to disseminate sensitive findings only to scientists at approved institutions. However, an international meeting of scientific and biosecurity experts at the Royal Society concluded that "restricting the free flow of information about new scientific and technical advances is highly unlikely to prevent potential misuse".⁵

Prevention at the Level of Technology Applications

Numerous measures to prevent the misuse of technology are in place. These include regulations governing medicine, agriculture and law enforcement. The following examples are measures designed to prevent nuclear, biological and chemical (NBC) weapon proliferation and use. Some of these are required by international arms control agreements (Box 3).

Export Controls

Many countries restrict the export of goods with military applications, though there is some scepticism about effectiveness. The adequacy of controls for dealing with bioweapons is particularly unclear as the life sciences may advance more rapidly than controls can be updated and bioweapon components could be moved covertly.

Other issues are to ensure that controls:

- balance preventing weapon proliferation with allowing access to technologies for peaceful purposes;
- are comprehensive and internationally consistent – in the 1980s Iraq procured chemical weapons materials from countries with weak or no controls.

Box 3. Arms Control Agreements

The **Treaty on the Non-Proliferation of Nuclear Weapons** prohibits acquisition of nuclear weapons by party states that currently lack them, but permits development of nuclear technology for peaceful purposes. Some doubt whether authorities have the capacity to detect clandestine nuclear weapons programmes or black market trading of materials.

The **Biological and Toxin Weapons Convention (BWC)** and **Chemical Weapons Convention (CWC)** prohibit the acquisition, retention or transfer of chemical and biological weapons and control certain materials relevant to their development. The CWC also prohibits the use of chemical weapons. While the CWC includes detailed provisions for verifying compliance and is widely regarded as an effective instrument, the BWC lacks a verification procedure and faces challenges due to rapid progress in the life sciences. Both the USSR and Iraq pursued clandestine bioweapons programmes while party to the convention. The UK government has led efforts to strengthen the BWC and supports a BWC verification protocol. One issue is how to detect non-compliant activities: the “materials accounting” approach used for chemical and nuclear weapons is inappropriate for biological technologies, since micro-organisms can quickly reproduce or be modified. The UK government and the Royal Society argue that a more systematic and regular review of scientific and technological developments relevant to the BWC is needed, and that BWC parties need to find a way of taking these into account when considering options for maintaining the convention's effectiveness.

Monitoring Orders for Dual-use Goods

In 2006, the NSABB recommended that DNA synthesis companies should screen orders to avoid providing terrorists with materials for constructing bioweapons. Some companies now do so, or plan to introduce screening. It is suggested that regulators maintain a list of genetic sequences against which orders can be checked. It has also been suggested that purchases of DNA synthesisers could require a licence or be monitored by manufacturers or safety committees. Screening orders for dual-use goods is regarded as sensible, though scientists emphasise that they should not be prevented from accessing these goods quickly and easily.

Infectious Disease Surveillance and Response

The effects of some biological weapon attacks could be mitigated by the same surveillance and response arrangements used for natural outbreaks of disease. These could also be used to distinguish natural outbreaks from deliberate release. The World Health Organisation

co-ordinates international surveillance, but it would be politically difficult for it to take a role in distinguishing natural from intentional outbreaks. Some have suggested a need for new institutions to deal with this issue. The UN Office for Disarmament Affairs is seeking to revitalise an existing UN mechanism for investigating alleged biological or chemical weapon use.

Counter-terrorism Measures

A UN Security Council Resolution requires all states to prohibit acquisition, possession or use of NBC weapons by non-state parties. UK counter-terrorism measures aim to prevent certain pathogens and chemicals from falling into terrorist hands (for example, through laboratory biosecurity measures) and to challenge terrorist ideologies that justify the use of such weapons.

Overview

- Dual-use dilemmas arise when it is unclear how to prevent misuse of science without foregoing benefits.
- Current discussion of the dual-use dilemma focuses largely on terrorism, though science may also be misused in other settings, including conventional warfare, agriculture and law enforcement.
- Strategies to prevent misuse could operate at the level of scientific practice, information dissemination or technology applications.
- The scientific community is concerned that preventive strategies will cause more harm than good, by impeding scientific progress.
- There is support for a risk-benefit assessment approach to mitigating risks of misuse.

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