Canadian Workshop on Multidisciplinary Research on Nanotechnology: Gaps, Opportunities, and Priorities

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Summary of Key Research Gaps

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Disclaimer:

The contents of this report are a reflection of the comments and opinions expressed by the participants during the workshop. Although every effort has been made to accurately summarize the consensus views of the majority of participants, no guarantees as to the accuracy and completeness of this summary can be made. A full report summarizing all the discussions and outcomes from this workshop will be available shortly. In the interim, this summary provides a list of some of the key research gaps that were highlighted by participants at the meeting. This summary does not necessarily reflect the views of the sponsoring agencies.

I. INTRODUCTION

Through this workshop, the funding agency sponsors brought together experts and interested stakeholders to discuss and identify priorities for research on nanotechnology in Canada, particularly as they relate to NE^{3}LS issues (i.e. nanotechnology ethical, environmental, economic, legal and social issues), health impacts and risks, and the regulatory mechanisms needed to address them. There was a particular focus on the need for interdisciplinary approaches, particularly as it relates to bridging disciplines and perspectives.

The workshop organizing committee had identified a number of general themes or topics to be considered by the meeting participants. These included:

1. Ethics and Related Domains
2. Policy, Regulatory Development and Governance
3. Science, Environmental and Health Risks
4. Social Science and Humanities Perspective

A full report summarizing all the discussions and outcomes from this workshop will be available shortly. In the interim, this summary provides a list of some of the key research gaps that were highlighted by participants at the meeting. This summary has been organized into several categories that span the general themes of the workshop, as a number of common issues and perspectives were raised among the various themes.

II. KEY RESEARCH GAPS AND NEEDS

A. Basic Science Gaps and Research Challenges

- A comprehensive inventory of science and technology expertise in Canada, across all disciplines, is currently lacking. How could such a survey be conducted for nanotechnology research? What areas and aspects would be most relevant for nanotechnology?
- A consistent nomenclature and taxonomy for nanotechnology is currently lacking. What metrological approaches need to be established for detecting and measuring nanoscale materials?
- What are the most pressing instrumentation needs for the study of nanomaterials, including detection, characterization, assessment of exposure, nanotoxicity, and development of predictive models?

- What research is required to gain a clearer understanding of nanomaterial behaviour in the major matrices of water, air, and soil? What are the relevant properties and indicators that would serve as a foundation to an understanding of the physiochemical properties of nanomaterials?
- What process could be developed for evaluating nanomaterial lifecycle assessment, including data against a variety of endpoints that would be relevant to human health and the environment?
- How can we evaluate the relative impacts and risks of nanomaterials in a biological context? What are the potential penetration parameters across natural barriers and defences (e.g. relationship between size/structure and penetration, active vs. passive transport, etc.)? What approach should be taken to understanding behaviour at the cellular level when exposed to nanoscale materials? Would a cellular level understanding help serve to validate current test methods or arrive at new ones?
- Given the limited funding available for assay development in nanotechnology research, how should we rationally prioritize research projects? How can we differentiate between the "need to know" and the "nice to know" research in this emerging area?
- Are current reference sample materials appropriate for nanoscale materials?
- Would it be advantageous to "decouple" the various nanotechnologies – and their related issues and needs - rather than dealing with all the potential aspects of nanotechnology under one term? How could a clear basis for appropriate groupings of technology be established? Are there aspects of nanotechnology that should remain combined for some research purposes?

B. Research Gaps in the Broader Ethical, Legal, Economic, and Social Contexts

- What impacts are emerging technologies like nanotechnology likely to have on the social contract and cultural aspects of our lives, both negative and positive? Could their effects on social cohesion, human security, privacy, health, and perceived well-being be changing, and if so what are the impacts of these changes? For example, what are the implications of technologies that allow some individuals to buy longer life or better health, and are they acceptable to Canadian society? What are the appropriate tools for measuring them and how do we find them?
- Could the study of science and technology innovation as well as how social science has influenced basic science in other fields be relevant for nanotechnology? Are there common research approaches to emerging and converging technologies that could be examined for more specific nanotechnology issues? Are there relevant inventories of current research in other social science fields that may be relevant for nanoscience more broadly?
- What has been learned from the fields of neuroethics (neuroscience and ethics) and

bioethics (including genomics, stem cell research, etc.) that could be relevant for nanoethics? What else could be involved in helping to understand the transferability of this knowledge and experience?

- What place does nanoscience currently occupy within the existing research, ethical, legal, and economic research communities? What research would be required to develop a fuller understanding of what nanoscience currently encompasses, and what it may potentially encompass, in all disciplines?
- Are there studies of the effect of ongoing rapid change on economic and social structures which may be relevant for nanotechnology? What have the impacts of nanotechnology been to date? What should and will influence plans for future re-organization? How can research into economic and business models, including commercialization strategies, be aligned with ethics and related domains? For example, what ethical constructs can be established to cover academic/ government/ industry partnerships?
- Are the emerging intellectual property patterns with nanotechnology consistent with other technology fields, such as biotechnology? Are there lessons about the legal and ethical implications to be taken from biotechnology? What are the current approaches in marketing and labeling of nanotechnologies to the public? What would be the most effective labeling approaches (e.g. informative, not directive)?
- What are the societal acceptance or rejection limits of certain new technologies? Are they regionally or internationally different, and how are they linked to culture? For example, bioengineered foods created a huge outcry in the United Kingdom. However, there was relatively little concern about them in Canada and the United States.
- How does consumer behaviour affect the overall impact of nanotechnology on society? What drives consumer willingness to buy some products but not others? Can we determine which nanoproducts may be acceptable and which may be objectionable?
- Are there ethical issues posed by surveillance in a nano-enabled world? Is it possible to determine the extent to which privacy concerns could be affected by nanotechnology? Are these distinct issues for nanotechnology, or are differences just a matter of degree? What sorts of disclosure requirements should surround nano-surveillance, and what would the role of government be? Is it possible to identify historical mechanisms that have been applied to balance personal or public benefit against real or perceived losses of personal or public privacy or freedom?
- What are the ethical considerations in deciding which aspects of nanotechnology should be publicly funded, who should have input into those decisions, how those decisions should be made, and how the assessment of benefit to the public should take place? Is it appropriate or even possible for current ethical decisions to bind future generations of Canadians? Can ethical decisions be made in contexts that are globally applicable?

C. Health and Environment Issues and Risks

- How can we better understand the intricacies of detecting nanomaterials and their behaviour in complex systems, such as the environment or human bodies?
- Predictive models for human health will require a range of data on chemical properties, physiological functions, pharmacokinetics (distribution in the body, absorption, excretion and metabolism), and toxicological information.
- What degree of exposure to nanomaterials is happening now? Are there any monitoring programs in place? What would be required to develop the appropriate metrology for assessment? What would be appropriate indicator species for nanomaterials? How should these be validated?
- In terms of occupational health, how are those who work with nanomaterials being protected - who is advising researchers in industry, government, and academia who handle nanomaterials? How are decisions about worker protection being made? What are the most appropriate tools to measure the extent of worker risks, including physical tools (metrological) and theoretical modeling tools?
- The traditional industrial hygiene model uses engineering controls, administrative controls, and personal protective equipment to deal with issues of occupational health and safety. Is this approach adequate for dealing with nanomaterials?
- How do we ascertain that models for environmental fate and transport are valid for nanomaterials? How do we ascertain that existing environmental monitoring/detection techniques/programs are valid for nanomaterials?
- Persistence is an issue in regard to toxicity. It is not known what happens when a nanomaterial agglomerates in the environment. Does it continue to be environmentally available and thus a potential human health risk, or is it no longer persistent in terms of bioavailability and toxicity?
- What are the environmental exposures and the health risks of nanomaterials on emergency responders, and what is the risk over the full lifecycle of these materials?
- How can emergency preparedness and contingency planning capacity in the area of nanotechnology safety best be developed, incorporating different disciplines and fields (e.g. information clearinghouses, coordinated outreach strategies, etc.)?
- What should be the role of the various professional societies in Canada in initiating and mediating debate around environmental and health issues? How can they be best engaged?
- What are the potential benefits of nanotechnology in an environmental context? Could water filtration and safe food practices be enhanced by nanotechnology? How do we meaningfully capture not only risks associated with emerging technologies, but also the

benefits?

D. Governance, Regulatory and Policy Gaps

- Who should lead in championing research into the human health and environmental risks of nanotechnology? Within the Canadian context, who should drive policy and governance issues in the near term? Who should drive policy and governance in the next five to ten years as nanoscience and the technologies it spawns continues to accelerate?
- What are the potential risks of not developing a coordinated national nanotechnology strategy for Canada? For example, could integration of nanotechnology into such projects as pollution prevention or mediation capacity be at risk in the absence of any mechanism for assessing their impact?
- Given that there are no well articulated governance rules of engagement for nanotechnology, and the regulatory environment for nanomaterials and products containing them is unclear, how do we guide who will be involved and what the ultimate goals of nanotechnology governance should be? Given the complexity of Canadian governance models, including federal, provincial, municipal and territorial jurisdictional issues - and the complex inter-relationship between government, the private sector, and the not-for-profit sector - what kind of practical modeling of governance structures could or should take place? Would a comprehensive survey of the availability of resources would be useful? How should such a survey be conducted?
- Are there appropriate interim approaches that could be explored and rolled out while broader comprehensive governance and policy is being developed? What regulations and measures must be put in place immediately while waiting for a new regulatory framework for nanoproducts to be developed? Should we prioritize regulations for products that are likely to be before regulators in the very near future (e.g. nanoencapsulated nutrients in foods)?
- What are best measures needed for a risk-benefit analysis in nanotechnology? Some of the specific research gaps could include:
  - Risk tolerance
  - Social acceptance of risk
  - Issues of consumer choice
  - Life-cycle analysis
  - Social and economic consequences from both local and global perspectives
- Would the spectrum of acceptable risks be different in areas where there are significant expected benefits from nanotechnology (e.g., new cancer treatments, pharmaceuticals, etc.)?
- Are there lessons learned in the governance of other emerging technology areas (e.g.

genomics and biotechnology) that would be relevant in the design and implementation of Canadian policy and strategy in nanotechnology?

- At present, a great deal of attention is focused on technologies with large potential economic impacts. What about the interface between government and small and medium-sized enterprises? How can the impetus to insure domestic commercialization of Canadian research and development expertise be reconciled within a governance framework?
- While there is a clear knowledge gap in terms of fundamental research and applied research, there is also a lack of vision about what aspects of nanotechnology policy should address: the cycle of development, individual products, or the process as a whole? Whose job should it be to build an updated policy, in the absence of foundational principles?
- How can the resources—both human and financial—be found for accumulating the necessary baseline scientific data needed for proper assessment of nanomaterials, especially in an environmental or human health context?
- How can we insure that policies are not out of step with what is happening elsewhere in the world, and that there is a thorough understanding of the impact of intervention with various stakeholders? What is the possibility of (and the precedents for) voluntary approaches to nanotechnology regulation? Could voluntary guidelines be put in place more quickly?
- What are the potential parameters needed to govern the scope of monitoring of industrial nanotechnology operations and current products and research? How can we insure appropriate resources are allocated for effective application, once appropriate measures are identified?
- Is there a broader ethical duty to promote Canadian EHS standards and any related risk-assessment models to less advantaged areas of the world?
- Given that research communities and granting agencies often tend to operate in silos, what approaches will allow for truly multidisciplinary research to be integrated both in terms of funding and outcomes? How can the distinct peer review methodology for the social sciences, physical sciences, and biomedical sciences be successfully integrated to accommodate meaningful partnerships?

E. Public Engagement and Communication:

- Can social science communication and knowledge translation (KT) expertise be deployed to help develop communication strategies that are tailored to the intended audience and reflect an appropriate level of complexity? What information does the public need to be able to make good decisions, and is it possible to frame it in a way that allows good decision-making without a highly technical knowledge of the science

implicit in nanotechnology? How do we inform the public of safety issues, without overloading with information to the point where they fail to respond, or respond inadequately?

- What are the significant gaps between public deliberation, level of scientific understanding and public policy? What translational activities could move beyond the gathering of information to the incorporation of that knowledge into policy in the public interest? How do you assess what tools are needed to develop or apply, and how do you measure their effectiveness? What are the best ways to engage the public, decision makers, the media, and other stakeholders in nanoscience research?
- What previous communication campaigns and strategies have been attempted with other new and emerging technologies? Are there important elements in regards to marketing and labeling issues, public response, informed decision-making ability, and the creation of public capacity that could be relevant for nanotechnology?
- How can decision makers be better informed of the state of public opinion and values? How can appropriate avenues for informed communication be built between stakeholders?
- How could the fine arts, drama, and other ways of engaging interest and understanding be used to inform public discussion on nanotechnology? Creative visualization of modest changes in the future can occur through the fine arts. How could current predictive modeling approaches underway in other disciplines be adapted to nanotechnology?
- What are the public concerns about environmental issues, health, and safety aspects of nanotechnology? What are the effects of civic and public management on nanotechnology, including the potential role of NGOs and interest groups and the interface between the general public and research, policy, regulation, and governance communities? How can the critics of nanotechnology be incorporated into governance and policy discussions?
- Once decisions about whether and how to fund nanotechnologies and research are made, based on social priorities, how do you to determine the best way to fairly distribute the benefits of those investments?

F. Challenges for Interdisciplinary Collaborations

- Issues of knowledge translation and communication are crucial in determining how to facilitate multidisciplinary collaboration between disciplines. How do we communicate findings within our own peer groups and to other groups? How are approaches similar and how do they differ between disciplines (e.g. social sciences, physical sciences, biomedical sciences, etc.)? Are there existing models that could be examined to help build such collaborations for nanotechnology research?

- What types of training and mentoring programs are needed to facilitate effective multidisciplinary teams? Who should lead the development of these training programs, and how should they be managed?
- How could interdisciplinary science teams incorporate policy and governance issues, and what are the practical parameters of their collaborative operation?
- Is it feasible to bring together experts from different backgrounds to help develop a common framework for the assessment of environmental and human health risks of nanotechnology? Or do individual technologies need to be assessed separately?
- How can broader perspectives be incorporated into nanoscience education at all levels (i.e. curriculum development)? Can research into what learning styles work at different ages and stages of life lead to a greater commitment to lifelong curriculum development?
- Is there a need for research into cognitive models of how to conduct foresight and forecasting among disciplines? Does our ability to forecast affect our relationship with emerging technology?