

**NANOTECHNOLOGY AND HEALTH: FROM BOUNDARY
OBJECT TO BODILY INTERVENTION**

by

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ABSTRACT

Nanotechnology is commonly understood to involve the manipulation of individual molecules and atoms. Increasingly, healthcare practices in British Columbia are articulated through the nanotechnological in relationship to the body. The hope for better treatment and diagnosis of disease is located in the specificity of nanotechnological applications – the finely tuned targeting of cells and treatments geared towards individual molecular profiles. However, this same specificity also alarms regulators, activists and consumer groups in the potential for increased toxicity. Drawing from participant observation, ethnographic interviews, and theoretical orientations adopted by Susan Leigh Star and Jeffrey Bowker, this thesis explores three questions: 1) How can nanotechnology inhabit multiple contexts at once and have both local and shared meaning; 2) How can people who live in one community draw their meanings from people and objects situated there and communicate with those inhabiting another; and 3) What moral and political consequences attend each of these questions?

Keywords: nanotechnology; medical anthropology; anthropology of the body; science studies; critical theory; feminist theory; ethnography; qualitative research; biomedicine; nanotoxicology; bionanotechnology; British Columbia; Canada; nanomedicine; medical nanotechnology

DEDICATION

To my wife, Andrina Perry.

To my mentor, Jenny Lo.

And to myself at 14 looking up at the feet of college students.

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GLOSSARY

| | |
|----------------|--|
| 4D Labs | 4D Laboratories at Simon Fraser University |
| AI | Artificial Intelligence |
| BC | British Columbia |
| BCCRA | British Columbia Cancer Research Agency |
| CEPA | Canadian Environmental Protection Act |
| CSC | Canadian Safety Council |
| DSF | David Suzuki Foundation |
| GBC | Genome British Columbia |
| GMO | Genetically Modified Organism |
| HOC BC | Health Officers Council of British Columbia |
| ISO | International Organization for Standardization - Note: it is not “IOS” |
| NP | Nanoparticle |
| Nanotech BC | The British Columbia Nanotechnology Alliance |
| NSF | United States National Science Foundation |
| OECD | Organization for Economic Co-operation and Development |
| QD | Quantum Dot |
| R&D | Research and Development |
| SFU | Simon Fraser University |

| | |
|--------|---|
| SPM | Scanning Probe Microscopy |
| STM | Scanning Tunnelling Microscope |
| TC 229 | International Organization for Standardization's Technical Committee 229 on nanotechnological nomenclature and terminology. |
| TJDRC | The British Columbian Cancer Agency's Trev and Joyce Deeley Research Centre |
| UBC | University of British Columbia |
| VCHARI | Vancouver Coastal Health Authority's Research Institute |
| VCP | Virtual Cancer Patient Engine |

1: ORIGIN STORIES AND METHODOLOGIES, INTRODUCTION

1.1 Introduction

Nanotechnology is commonly understood to involve the manipulation of individual molecules and atoms. Increasingly, healthcare practices in British Columbia are articulated through the nanotechnological in relationship to the human body. The hope for better treatment and diagnosis of disease is located in the specificity of nanotechnological applications – the finely tuned targeting of cells and treatments geared towards individual molecular profiles. However, this same specificity also alarms regulators, activists and consumer groups in the potential for increased toxicity.

Prior to the establishment of Canada's National Institute for Nanotechnology in 2001, there was little indication that research scientists, physicians, educators, environmental policy analysts, activists and biotechnology industry leaders in BC understood nanotechnology as a salient practice embedded in day-to-day life. Yet for many British Columbians today nanotechnology, once relegated to science fiction, appears very much a "logical outgrowth[h] of other facts of life" (Yanagisako & Delaney, 1995, p. 12). This thesis explores how that logic is built.

Drawing from participant observation, ethnographic interviews, and theoretical orientations adopted by Susan Leigh Star and Jeffrey Bowker, this thesis explores three questions: 1) How can nanotechnology inhabit multiple contexts at once and have both local and shared meaning; 2) How can people who live in one community draw their

meanings from people and objects situated there and communicate with those inhabiting another; and 3) What moral and political consequences attend each of these questions?

Unlike in the United Kingdom and the United States, very little research has been conducted on nanotechnology by Canadian social scientists, particularly anthropologists. My research questions serve as a guide to explore context that is often erased in formal representations of nanotechnology. As later chapters of this thesis demonstrate, and as previous generations of social scientists have pointed out (Haraway, 1997), tracing nuance proves a potent way to not only think about the body, society, and science, but to bring to light “counter-stories” which may inform and trouble bioethics debates regarding nanotechnology in BC and elsewhere (Solórzano & Yosso, 2002, p. 23).

1.2 Origin Stories

1.2.1 Beginnings

Not everyone agrees on exactly what nanotechnology is. What is clear is that in British Columbia (BC) today a series of practices are articulated through the nanotechnological in relationship to the human body. Whether ingested in a chocolate bar for nutritional enhancement, applied to the skin in moisturizing lotions, utilized in cancer treatment or for in-vivo diagnostics, nanotechnology is understood to be the root of both health and harm.

Chapter 1 of this thesis introduces readers to accounts of nanotechnology’s birth. An in-depth discussion of the methods used in this study is then provided, followed by a characterization of communities of practice currently invested in nanotechnology and the body in BC. Finally, readers are provided with an outline of remaining chapters.

Origin stories have always preoccupied anthropologists. Ethnographers “often include origin stories of the people they study” (Yanagisako & Delaney, 1995, p. 12). The ordering of history and place through narrative allows people to make sense of their identity, classification schemes, relationships and geography (Malinowski, 1954). Like other origin stories the history of nanotechnology is contested. Several scholars, including anthropologists, have traced these narratives. This section introduces readers to origin stories of nanotechnology relevant to BC’s communities of practice. My aim is not to provide a definitive history of nanotechnology or to assess which origin story can make a claim to capital “T” truth; rather, the purpose of this section is to situate practice in relationship to “representations of origins” (Yanagisako & Delaney, 1995, p. 12). This speaks to the story behind the utility and collapsed simplicity of the “boundary object” nanotechnology – a concept explored in more detail in Chapter 2.

1.2.2 Nanotechnology, Richard Feynman and Norio Taniguchi

Articles and reports on nanotechnology, whether in scientific journals, newspapers, magazines, government or social science literature, often begin something like this:

The prefix ‘nano’ comes from the Greek word ‘nanos’ meaning ‘a dwarf’. Hence, ‘nanotechnology’ might well simply mean a technology to do with ‘small’ things. However, nano has also long been used as a prefix in scientific circles to mean 1 billionth (using billion in its American sense of a one followed by nine zeros). So we have the term ‘nanometre’ [nm] meaning 1 billionth of a metre. A nanometre is exceedingly small -- only 10 atoms across (Whatmore, 2006, p. 295).

With etymology firmly in place and an orientation to scale, authors often move on to describe a more detailed understanding of nanotechnology’s origins. Recurrently, physicist and Nobel Laureate, Richard Feynman is cited:

It [nanotechnology] was first put forward by the physicist Richard Feynman, when he gave a lecture in 1959 to the American Physical Society entitled ‘There’s plenty of room at the bottom—an invitation to enter a new field of physics’ [3]. In this lecture—which actually had almost no physics in it but is mainly concerned with the technology of making things—he explored the benefits that might accrue to us if we started manufacturing things on the very small scale. The ideas he put forward were remarkably prescient. For example, he foresaw the techniques that could be used to make large-scale integrated circuits and the revolutionary effects that the use of these circuits would have upon computing. He talked about making machines for sequencing genes by reading DNA molecules. He foresaw the use of electron microscopes for writing massive amounts of information in very small areas...Many of his predictions in that lecture have come true, and are all aspects of what we would now call nanotechnology (Whatmore, 2006, p. 295-296).

In my own research one scientist, Participant A, commented on nanotechnology’s birth in physics, directly referencing Feynman’s famous lecture:

Interviewer: Personally, do you know about the history of the development of nanotechnology?

Participant A: You hear the common popular one about Feynman, his lecture (Participant A, interview, January 17th, 2008).

To a lesser extent the birth of nanotechnology is also attributed to Tokyo Science University professor Norio Taniguchi:

The first use of the term nanotechnology was by Norio Taniguchi who, in 1974, gave a talk describing how the dimensional accuracy with which we make things had improved over time. He studied the developments in machining techniques over the period from 1940 until the early 1970s and predicted (correctly) that by the late 1980s techniques would have evolved to a degree that dimensional accuracies of better than 100 nm would be achievable. He applied the term nanotechnology to this (Whatmore, 2006, p. 295).

Sometimes both researchers are mentioned, with Feynman lending the basic concept and Taniguchi naming it, but Feynman clearly takes centre stage when it comes to the stories told. This could in part be linked to Feynman’s status as a media darling, Nobel Prize

winner and popular science author and autobiographer. The role of Feynman and Taniguchi as scientific visionaries is also emphasized -- each divining a future of nanotechnological revolution.

1.2.3 Competing Origins

Anthropologist Christopher Toumey and historian Cyrus Mody have both embarked on projects to historicize nanotechnology. Both researchers show that the telling of nanotechnology's origins is linked to broader contexts – institutional agendas, government mandates, religion, sci-fiction, politics and struggles over truth, financing and resources.

Toumey asks a critical question in his research: Can we separate the early history of nanotechnology from Feynman's talk, and ask instead whether "Plenty of Room" is retroactively read into the history of nanotechnology (Toumey, 2008, p. 133-150)?

Discussing an interview with Feynman's son Toumey relates:

I presented my ideas to Carl Feynman, son of Richard Feynman. If I had overlooked something about the early influence of "Plenty of Room," and if there was a cadre of scientists who had gone into nanotechnology because of the direct influence Feynman's paper, then perhaps Carl Feynman would know about it and could correct me. In a telephone conversation of 29 March 2005, I summarized my conclusions. Carl Feynman responded, "That seems completely true." I asked him about conversations about "Plenty of Room" with his father. He said "I heard about it from my dad," but "there was no interest in it" in the scientific community in the early years. He added that when he was a freshman at MIT in January 1980, he heard "Eric Drexler was aware of it, and I was stunned" that anyone had heard of it...Were there any scientists who went into nanotech because of reading "Plenty of Room?" "I don't think so, except for Drexler," he answered (2008, p. 159).

Carl Feynman's response destabilizes the story of Richard Feynman as the early father of nanotechnology with researchers rushing to embrace the nanotech revolution upon hearing "Plenty of Room." His mention of Eric Drexler also warrants consideration.

Futurist Eric Drexler, author of Engines of Creation: The Coming Era of Nanotechnology (1986), is another founding father. Note that no founding mothers are invoked in these origin stories - in both narrative and practice, nanotechnology remains highly gendered as a masculinist project. Established in 1986 and located in Palo Alto, California, Drexler's Foresight Institute remains, "dedicated to predicting and planning for the dramatic changes caused by nanotechnology [to this day]," (Mody, 2004). Drexler is most famous for his theory of self-replicating nanotech assemblers and the prospect of "grey goo" – an apocalyptic scenario in which out of control machines absorb all of earth's matter in order to fuel the perpetual creation of robotic replicas, turning everything into grey goo (Drexler, 1986). Drexler has since retracted his theory (Rincon, 2004); however, "grey goo" and the idea of nanobots continues to capture the imagination of media and publics. The idea has also been widely incorporated into science fiction. For example, see sci-fi classics Bloom (1998) and Aristoi (1992) by novelists Will McCarthy and Walter Jon Williams respectively. Responding to the science fiction connection, Participant A also noted that "I think nanotechnology comes with a heavy dose of these misguided nuts that think there are nanobots floating around, and read a book like it's a manuscript and not a novel" (Participant A, interview, January 17th, 2008).

The microscope – particularly the Scanning Tunneling Microscope (STM) and associated Scanning Probe Microscopy (SPM) techniques are predominately featured in

histories of nanotechnology. For example, Toumey explores how STMs capable of manipulating individual atoms and molecules came to be understood as “Feynman Machines” through the poorly acknowledged work of engineering mathematician and inventor Conrad Schneiker (Toumey, 2008). Historian Cyrus Mody also argues that scanning probe microscopists gradually became enrolled in the idea of nanotechnology: “I show how contrary to the standard history, probe microscopists were generally uninterested in “nano” until large pots of money induced them to adopt the label soon after 2000” (Mody, undated, p. 8). Central to Mody’s historicization is the idea that there is plenty about nanotechnology which is not new. “Ion microscopy,” in the 1950s, and “electron microscopy,” in the 1970s, already purported the ability to “see atoms,” and catch phrases for ‘really, really small’ technology have been around for a while. For example, Mody whimsically relates a colleague’s discovery of an early term for the “smallest” technologies in the 1960s - “angstromics.”

Another common story told in this regard is the idea that ‘nature’ was already on to nanotechnology before humans came along (Mody, 2004). Executive Director of Nanotech BC, Darren Frew, touched on this idea in my interview with him:

Interviewer: And how do you define nanotechnology as opposed to something else?

Darren Frew: Okay, it’s a relatively straight forward definition and seems to resonate with most people. It’s the ability to examine and work with materials, any sort of material, at the molecular level or smaller and that’s a great place to start because that’s really what is the heart of all of it.... On a very, very simple and empirical basis, looking right at an element, but you can also do the same thing with compounds or you can get down to the level of being able to examine the molecules and restructure them somehow. That’s where you are going to get your properties changed and so, again, carbon is a really good example of that. I mean this is something that we knew about inherently without really calling it

nanotech...I've got a diamond ring on my finger – well that's a carbon crystal. I've got a pencil in my drawer that's got graphite in it, that's crystal carbon as well – it's two different forms and the atoms of carbon are arranged significantly differently in the diamond than they are in the graphite in the pencil lead. But when that was first explained to me when I was back in high school, they're talking about carbon atoms and they said well, ok, fine, it's the arrangement of the carbon atoms that makes a diamond a hard crystal and it's clear and that makes graphite soft and greasy. When you think about it, well that's nanotech right there. Different forms, different morphologies of the same material and those different morphologies are undertaken at a molecular level and that's nanotech. (D. Frew, interview, January 24th, 2008).

Others credit early use of nanotechnology to the ancient Romans, Greeks and Egyptians (Walter, Welcomme, Hallegot, Zaluzec, Deeb & Castaing., 2006). In “The Lycurgus Cup – A Roman Nanotechnology,” Freestone, Meeks, Sax and Higgitt comment:

The Lycurgus Cup demonstrates a short-lived technology developed in the fourth century A.D. by Roman glass-workers. They discovered that glass could be coloured red and unusual colour change effects generated by the addition of a precious metal bearing material when the glass was molten. We now understand that these effects are due to the development of nanoparticles in the glass (2007, p. 2218).

Walter et al. (2006) also tell the story of nanotechnology and the body in ancient Egypt:

Lead-based chemistry was initiated in ancient Egypt for cosmetic preparation more than 4000 years ago. Here, we study a hair-dyeing recipe using lead salts described in texts since Greco-Roman times. We report direct evidence about the shape and distribution of PbS nanocrystals that form within the hair during blackening. It is remarkable that the composition and supramolecular organization of keratins can control PbS nanocrystal growth inside a hair (p. 2215).

Thus utilizing what is now understood as “nanotechnology,” ancient peoples were able to entice keratins (protein structures) to direct lead sulfide II (PbS) crystal growth within the human hair -- triggering a reaction which turned the hair black (p. 2215). These narratives represent a clear trend: the tendency to reinterpret history through the lens of contemporary understandings of the world. Scientific practice as much as anything else

reflects this. The same scientist who invoked the origin story of Feynman's lecture in my own study may have put it best, "it's like any science, when I say it's a re-branding exercise I mean it" (Participant A, interview, January 17th, 2008).

1.3 Nanotechnology and Bodily Intervention

1.3.1 Anthropology of the Body

Foucault famously argued that there is no such thing as a natural body. Rather, that the body is a script writ large, imbued with ideologies, and disciplined through scientific and medical surveillance and intervention (1975). Anthropologists have long documented an array of understandings of the body -- the body as symbol (Weiss, 1997), social script (Blake, 1994), politic (McCallum, 2005), commodity (Lock, 2001) and location of societal reproduction (Bourdieu, 1984) and resistance (Mitchell, 2001).

1.3.2 Nanotechnology and the Body

Throughout the course of my research -- during interviews, website media review, and while conducting fieldwork at conferences -- I found the idea of the nanotechnologically-mediated body emerged at the juncture of biomedicine and toxicology. Employed in three distinct, yet interrelated, communities of practice (medical research and development (R&D) industry and toxicology and regulation), the nanotechnologically-mediated body was understood to be both vital and damaged. Whether ingested in a chocolate bar for nutritional enhancement, applied to the skin in moisturizing lotions, utilized in cancer treatment or for in-vivo diagnostics, nanotechnology was seen to be the root of both health and harm.

As Chapters 3 and 4 indicate, in BC, technological intervention articulated through the nanotechnological bespeaks a body:

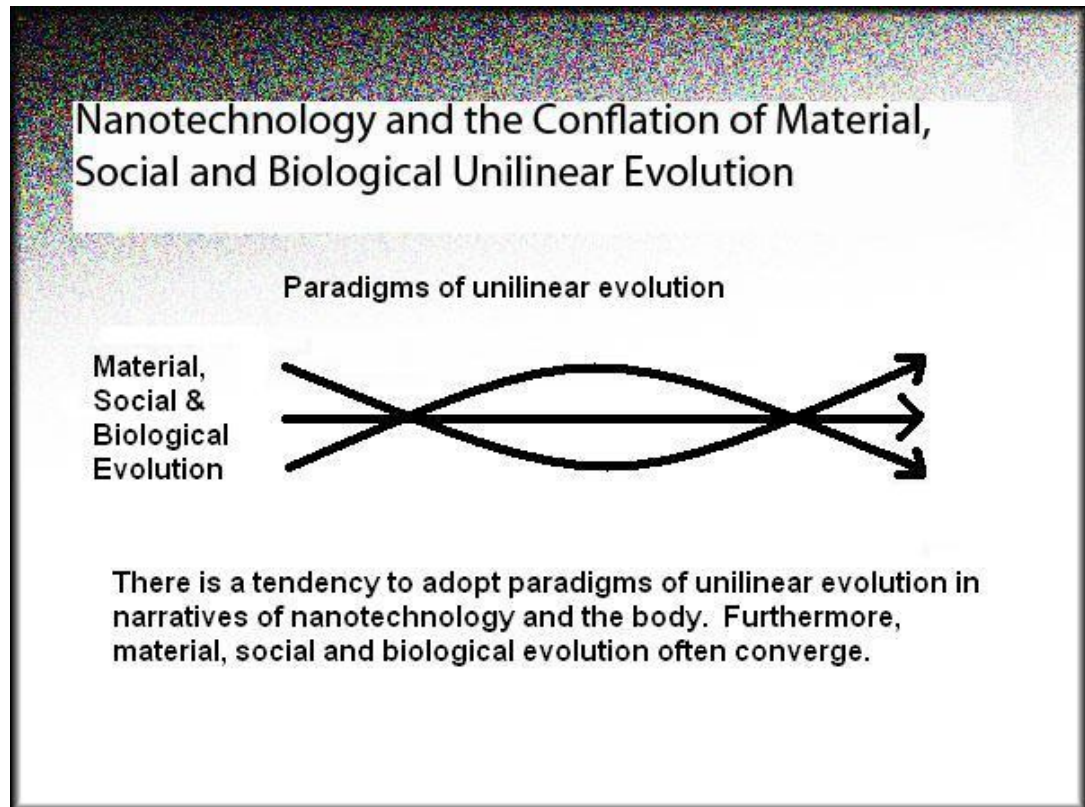
- Bound up in neoliberal material relations and associated ideals of “perfectibility” and “progress” (Taussig et al., 2003, p. 65);
- Subject to highly individualized understandings of healthcare, including the increasing “molecularization” of life itself (Rose, 2008) and, as Mishler has emphasized, the tendency in biomedical practice to negate essential context that shapes the meanings people assign to their everyday lives, including experiences of health and wellness (1978);
- Located in a tense zone, simultaneously bearing the consequence of trust or little trust in corporate and scientific conduct;
- That serves as a potent ground for a political mobilizing -- a rallying point for individuals and groups seeking regulation of nanotechnology. Very often the bodies of animals, particularly the bass, are included in these debates and stand as a symbol and test for the impact of nanotechnology on human health. In juxtaposition, the bodies of animals, for example, mice, are also used in the development of medical applications articulated through the nanotechnological.

The body in this sense stood as map, symbol, social script and location of contested politics. Furthermore, participants expressed diverse embodied perceptions of nanotechnology. For example, Rob McMahon, “former beat reporter” on nanotechnology for Canada’s baking industry, asked, “What if I’m ingesting these food products with nanotechnology and I’m not aware of it? You know, personally, I want to have the choice to not necessarily ingest those kinds of things” (R. McMahon, interview, April 10th, 2008). In contrast, Darren Frew, emphasized nanotechnology and his hope for better cancer treatments; “I’m 47 years old, so 15 years from now I’ll be 62, somewhere between now and then I could conceivably develop cancer...the treatment that will be

available to me 5 years, 10 years, 15 years from now will be significantly different and better than it is now” (D. Frew, interview, January 24th, 2008).

1.3.3 Nanotechnology, the Body and Unilinear Evolution

Figure 1: Nanotechnology and the Conflation of Material, Social and Biological Unilinear Evolution



Nanotechnology is commonly situated as representing the next Industrial Revolution. Applications articulated through the nanotechnological in relationship to the body often merge with understandings of progress and perfectibility, including understandings of material (economic), social and even biological evolution. These understandings emphasize a railway track view of progress (i.e. there is only one way to truly evolve and that is with nanotechnology).

For example, in a 2007 address to the Vancouver, BC Board of Trade, the president of the University of Alberta enthusiastically emphasized:

Unpredictability of seasons, destructive winds and storms, and catastrophic infestations of insects - like that of the pine beetle - that are contained in the past by the long hard freezes that have all but disappeared in recent years - all of these and more are threats to a large economy reliant on agriculture and forestry like BC's. Clearly our strengths hold the potential to be our weaknesses. Both BC and Alberta need to diversify their economies. Let's look at the innovations predicted to lead the economy in 2025. They are resulting from another type of convergence - the convergence of three waves of scientific discoveries and the resulting technologies - ICT [information and communication technologies], molecular biology, and nanotechnology. They are interacting with one another and unleashing innovation on a scale we have not seen in decades. We watch in awe as IT accelerates developments in molecular biology, such as decoding the human genome and, likewise, discoveries in nanotechnology accelerate developments in both IT and molecular biology. These converging waves of innovation are what will produce our advancements in clean technologies, personal security, longevity medicine and eventually human enhancement through neurotechnology. These fields - ICT, biology, nanotechnology and neurotechnology are not easy fields to break into, much less become top competitors in. They require strategic investments in research, development and commercialization - the kind of investments that BC and Alberta are currently positioned to make (Samarasekera, 2007).

In juxtaposition to the chaos of "destructive winds and storms" and the voracious pine beetle with an appetite for trees, nanotechnology, like ICT, biology and neurotechnology, offers a bastion of control and predictability. 'Nature', the wild and dangerous, is subsumed by 'technology' and the predictability and precision it offers. Furthermore, as allies BC and Alberta are poised to take advantage of the nanotech revolution. This speech also echoes a widely circulated American report, sponsored by the United States National Science Foundation and the Department of Commerce, which concludes that the nanotechnologically enabled enhancement of human performance "is vital to the well-being of individuals and to the future economic prosperity of the nation"

(Canton, 2003, p. 71). The demystification of the body enabled through nanotechnology represents a new frontier for science. The nanotechnologically-enabled enhancement of human performance also represents a new economic frontier in the location of such projects as central to financial prosperity.

1.3.4 Nature/Culture

My own characterization of the nanotechnologically-mediated body speaks to previous research conducted by social scientists. More broadly social scientists have documented a shift in people's relationship to biotechnology within the last four decades, particularly in new challenges to what has historically been understood as the nature/culture divide. If we read culture as "technology" and nature as the "foil" to culture (Haraway, 1997) it is apparent that genetically modified fruit, patented life forms, organ transplantation, longevity medicine and genetically altered fetuses pose unique disruptions to tidy boundaries that were always contingent in the first place. As later chapters of this thesis demonstrate, nanotechnology is particularly potent in this regard because of its perceived ability to control, mimic and manipulate molecules and atoms, as the National Research Council of Canada puts it -- "the basic building blocks of nature" (NRCC, 2008).

1.4 Methodologies

1.4.1 Research Questions

Drawing from ethnographic observations, an analysis of websites as information artifacts and qualitative interviews, I examine the following three questions utilizing

theoretical orientations adopted by Susan Leigh Star and Geoffrey Bowker (2000, p. 293):

- How can nanotechnology “inhabit multiple contexts at once and have both local and shared meaning?”
- How can people who live in one community “draw their meanings from people and objects situated there” and “communicate with those inhabiting another?”
- “What moral and political consequences attend” each of these questions?

Ultimately these three questions flow from a central question: What communities of practice in BC articulate their work in relationship to nanotechnology and the body, and how do people negotiate something as complex, ill defined and difficult to standardize in practice as nanotechnology?

1.4.2 Communities of Practice

In 1991, cognitive scholars Jean Lave and Etienne Wenger introduced the concept of “communities of practice” into education studies. Communities of practice reflect a shared engagement with particular activities, knowledge systems, linguistics and subjectivities (Lave & Wenger, 1991). Star elaborates:

We are all in this sense members of various social worlds – communities of practice – that conduct activities together. Membership in such groups is a complex process, varying in speed and ease, with how optional it is and how permanent it may be. One is not born a violinist, but gradually becomes a member of the violin playing community of practice through a long period of lessons, shared conversations, technical exercises, and participation in a range of their related activities (Bowker & Star, 2000, p. 294).

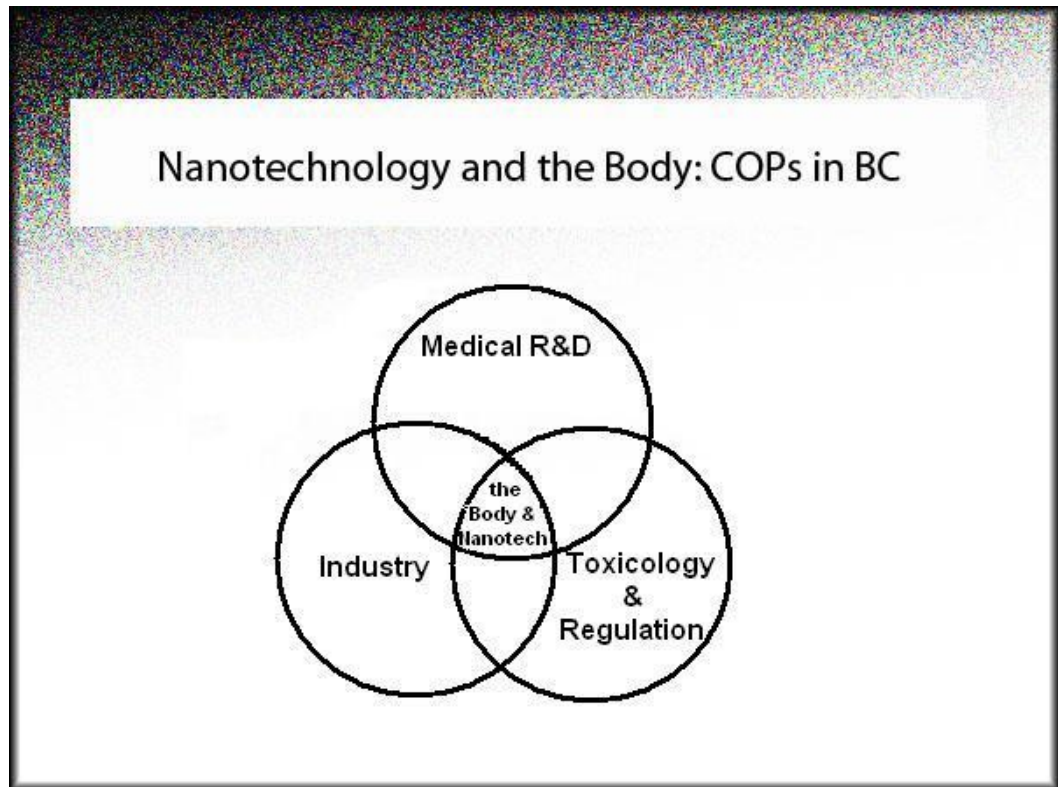
From novice, to expert and gradations in between, communities of practice encompass peripheral and full membership. Star (1991) is also careful to emphasize that we are all members of multiple social worlds and, therefore, multiple communities of practice.

1.4.3 Communities of Practice Invested in Nanotechnology and the Body in BC

Cyprus Mody describes nanotechnology as the “community of communities” – “an overlapping yet mixed bag” of communities of practice (Mody, 2004). Groups invested in nanotechnology in the province share relationships in terms of access to funding for research and development, facilities, tools and networking opportunities. Some work more closely than others.

While communities of practice invested in nanotechnology and the body in BC are intermingled, there is a tendency for organizations to adopt a primary focus on either: 1) industry, 2) medical research and development, or 3) toxicology and regulation. This study is situated against the backdrop of these three distinct, yet interrelated, communities.

Figure 2: BC Communities of Practice Invested in Nanotechnology and the Body



Shared purpose fosters a community of practice and incentives, such as government programs, can encourage collaboration between communities.

1.4.4 Referring Organizations

The BC Nanotechnology Alliance (Nanotech BC): Nanotech BC has received funding from the National Research Council of Canada’s National Industrial Research Assistance Program, the Ministry of Advanced Education and the federally mandated Western Diversification initiative. Offices are located in Vancouver, BC. The organization specializes in fostering BC’s “nanotech business sector,” including education, community building and advocacy for “the BC nanotechnology community, both at home and internationally” (Nanotech BC, 2008). Given the recent economic

downturn, the organization has postponed “all new activities, events and initiatives” in 2009 until funding is secure (Nanotech BC, 2009).

Genome BC (GBC): Genome BC invests capital and develops networking and infrastructure for large scale proteomic and genomic research clusters in the Province of BC. Genome BC is one of six such centres in Canada under the auspices of Genome Canada. The Government of BC and Genome Canada are primary funders of Genome BC, with additional investments from such groups as the Michael Smith Foundation for Health Research and the federally mandated Western Diversification Initiative. Genome BC is located in Vancouver, BC.

The Vancouver Coastal Health Authority’s Research Institute (VCHARI): The Vancouver Coastal Health Authority provides a variety of health-related services, including hospitals, residential care and public health clinics in the municipalities of Richmond, Vancouver, North Vancouver and West Vancouver. In partnership with University of British Columbia (UBC), the VCHARI is engaged in a range of research projects addressing everything from prostate health, to clinical epidemiology, burn treatment, cardiology and diabetes. The institute “is one of Canada’s top funded health sciences research institutes, with nearly \$136-million annually in research funding” (Vancouver Coastal Health Research Institute, 2008). Granting agencies include: the Canada Foundation for Innovation, CDC Atlanta, Genome BC, Genome Canada, National Institutes of Health, the Social Sciences and Humanities Research Council of Canada, the National Sciences and Engineering Research Council of Canada, the National Cancer Institute of Canada and the United States, the Michael Smith Foundation for Health Research, and Canadian Institutes for Health Research. The VCHARI also

works in close partnership with the BC Ministry of Health Services, Health Canada, Vancouver General Hospital, Providence Health Care, BC Children and Women's Hospital and the BC Cancer Research Agency.

The BC Cancer Research Agency's Trev and Joyce Deeley Research Centre (TJDRC): The BC Cancer Research Agency (BCCRA) is an agency of the Provincial Health Services Authority and provides health care services for cancer patients, in addition to cancer research and education. The agency is funded by the provincial government and the BC Cancer Foundation. TJDRC is one of the agency's key research institutes and is located in Victoria, BC. Research at the centre focuses on immunology, cancer prevention and therapeutics. The centre also houses the "Tumor Tissue Repository" which provides researchers with "essential patient specimens for basic and clinical studies" (BCCRA, 2008).

4D Labs at Simon Fraser University (4D Labs): Located at Simon Fraser University (SFU) in Burnaby, BC, 4D Labs recently opened in 2007 with \$7.34 million in funding provided by the Canadian Foundation for Innovation. The lab specializes in the "design, development, demonstration and delivery of advanced materials and nanoscale devices" (4D Labs, 2008). Primary areas of focus include healthcare, information technologies and clean energy initiatives.

The David Suzuki Foundation (DSF): The DSF, a registered non-profit charity in the United States and Canada, specializes in public education and research in the sciences to promote environmental sustainability, clean energy options and conservation. Offices are located in both Vancouver, BC and Eastern Canada. Primary funding is provided by individual private donors, in addition to grants from other charities. The website notes

that “the David Suzuki Foundation does not accept government grants, except in relation to the direct funding of scientific research through the National Sciences and Engineering Research Council of Canada” (David Suzuki Foundation, 2008).

Table 1: Communities of Practice, Nanotechnology and the Body in BC

| Primary area of focus in terms of nanotechnology and the body | |
|--|--|
| Medical Research and Development | - VCHARI - 4D Labs - TJDRC |
| Toxicology and Regulation | - DSF |
| Industry | - Nanotech BC - Genome BC |

1.4.5 Key Funding Agencies

Federally, the National Research Council partnered with the University of Alberta, and the Province of Alberta, established Canada’s National Institute for Nanotechnology in 2001 (NRCC, 2008). The Canadian Institutes for Health Research, various facets of the National Research Council, the Natural Sciences and Engineering Research Council, the Canadian Foundation for Innovation and Natural Resources

Canada also provide funding and resources for nanotechnological initiatives (Health Canada, 2007, p. 1). The following table highlights key funding agencies for organizations that referred participants for this study:

Table 2: Critical Funding Agencies

| Funding Agency | Nanotech BC | GBC | VCHARI | TJDRC | 4D Labs | DSF |
|---|-------------|-----|--------|-------|---------|-----|
| National Research Council of Canada's National Industrial Research Assistance Program | ● | | | | | |
| Ministry of Advanced Education | ● | | | | | |
| Western Diversification initiative | ● | ● | | | | |
| Government of BC (unspecified) | | ● | | ● | | |
| Genome Canada | | ● | ● | | | |
| Michael Smith Foundation for Health Research | | ● | ● | | | |

| | | | | | | |
|---|--|--|---|---|---|---|
| Canada Foundation for Innovation | | | • | | • | |
| CDC Atlanta | | | • | | | |
| Genome BC | | | • | | | |
| National Institute of Health | | | • | | | |
| Social Sciences and Humanities Research Council of Canada | | | • | | | |
| The National Sciences and Engineering Council of Canada | | | • | | | • |
| The National Cancer Institute of Canada | | | • | | | |
| The National Cancer Institute of the United States | | | • | | | |
| Canada Institutes for Health Research | | | • | | | |
| BC Cancer Foundation | | | | • | | |

There are 10 key funders listed, with considerable overlap. For example, the Vancouver Coastal Health Authority's Research Institute (VCHARI) and the David Suzuki Foundation both receive funding from the National Sciences and Engineering Council of Canada. The VCHARI also receives funding from the Canada Foundation for Innovation, as does Simon Fraser University's 4D Labs. Genome BC and the VCHARI are both funded by the Michael Smith Foundation for Health Research and Genome Canada provides funding for Genome BC and the VCHARI. Nanotech BC and Genome BC also receive funding from the Western Diversification Initiative and Genome BC funds the VCHARI.

1.4.6 Websites as Information Artifacts

In selecting organizations and individuals to approach I looked for the convergence of: 1) websites, 2) the boundary object nanotechnology, 3) the body, 4) British Columbian contexts. Websites in this sense were utilized as “information artifacts” – a critical starting point for this research and a valuable resource in terms of contact information, histories of nanotechnology and associated communities of practice in BC. Star, Bowker and Neumann emphasize that:

An information artifact means any of a wide array of tools, systems, interfaces, and devices for storing, tracking, displaying, and retrieving information, whether paper, electronic or other material...Communities of practice and information artifacts converge when use and practice fit design and access...they are difficult to pull apart (2003, p. 244).

Websites simultaneously represent a local and transnational space, albeit powerfully mediated by socioeconomics, the particulars of geographic location and access to computer technologies. One participant noted the concurrent rise of “nanotechnology” and the internet; this represented a benefit to the research itself.

Organizations and researchers articulating their work through the nanotechnological (provincially, nationally and internationally) commonly utilize the internet as a community building tool in the creation of “virtual networks,” in the words of one participant.

The tight or loosely coupled networks that flow between communities of practice were also reflected in websites, particularly the distinction between those groups and individuals primarily invested in toxicology and regulation (Rob McMahon, Stacy Malkin and the David Suzuki Foundation) and those primarily invested in industry and medical research and development (4D Labs, TJDRC, Genome, VCHARI and Nanotech BC). For example, SFU’s “NanoMed Canada” website lists the VCHARI, 4D Labs and Genome BC as key partners. A search within the Nanotech BC website produces a number of ‘hits’ for 4D Labs, the BCCA, and Genome BC. The largely independently funded DSF, which has highlighted the toxic potential of nanotechnology and the inadequacy of current Canadian regulatory paradigms (Boyd, 2007), did not produce a ‘hit’ on either website.

1.4.7 BC as a Research Site

I chose to locate my study in BC for two key reasons. First, my preliminary research revealed that alongside Québec and Alberta, BC has been increasingly situated as a centre for medical nanotechnological research and development in Canada. Early in my study Darren Frew also reported that affiliates from UBC, SFU, BCCA and Nanotech BC had submitted a grant application to Ottawa in the hopes of securing federal funding for a “National Centre of Excellence in Nanomedicine.” Second, like California, the West Coast of BC also has a long history of environmental activism. Environmental

groups in Canada have been overwhelmingly critical of nanotechnology's impact on human health and have actively petitioned the Canadian government to regulate nanotechnology. It became clear to me from the start of this project that communities of practice invested in nanotechnology and the body negotiated vary different agendas while utilizing nanotechnology as a boundary object, something explored in more detail in Chapter 2 of this thesis.

1.4.8 De-centering the Field-site

In his 2004 ethnography of brain scans and biomedical identity, anthropologist Joseph Dumit traces the production and travel of brain imagery from the laboratory into the larger world and back again. Like the nanotechnologies invoked in this study, brain images require millions of dollars in funding, vast interdisciplinary networks and a range of computers, software programs and associated technologies. To speak of a nanotechnologically enabled medical 'application' is an understatement, as a series of applications, relationships and resources are rallied for gold nanoparticles, for example, to do their stuff for the BC Cancer Research Agency. These configurations of technologies, practices and relationships unfold locally while transversing regional and national divides. In recent years anthropologists have traced growing challenges to the notion of the field-site, arguing, rather, for analysis of "global assemblages" or the nuanced ways "global forms" are "articulated in specific situations" (Ong & Collier, 2005, p. 4). In this regard anthropologists Stephen Collier and Aihwa Ong emphasize:

...technoscience, circuits of licit and illicit exchange, systems of administration or governance, and regimes of ethics or values. These phenomena are distinguished by a particular quality we refer to as global. They are abstractable, movable, and dynamic, moving across and reconstituting "society," "culture," and "economy," those classic social

scientific abstractions that, as a range of observers have recently noted, today seem over-vague and under question. As global forms are articulated in specific situations – or territorialized in assemblages – they define new material, collective, and discursive relationships...These “global assemblages” are sites for the formation and reformation of what we will call, following Paul Rabinow, anthropological problems. (2005, p. 4).

In anthropological theory the concept of ‘Culture’ as discrete and bound has been questioned. This re-conceptualization has also been clearly situated by anthropologists as a political and ethical endeavour. For instance, Abu-Lughod famously explained her project in this way:

I explore how feminists and halfies, by the way their anthropological practice unsettles the boundary between self and other, enable us to reflect on the conventional nature and the political effects of this distinction and ultimately to reconsider the vale of the concept of culture on which it depends. I will argue that “culture” operates in anthropological discourse to enforce separations that inevitably carry a sense of hierarchy. Therefore, anthropologists should now pursue, without exaggerated hope for the power of their texts to change the world, a variety of strategies for writing against culture (2006, p. 153).

Scholars engaged in post-colonial/neo-colonial theory also emphasize that homogenization has been integral to the objectification and fragmentation of lives subject to the anthropological gaze (Smith, 1999).

Emerging forms of contemporary ethnography defy the standard ‘unit of analysis’ adopted in disciplines like sociology, political science and psychology, and science, long off limits as the “culture of no culture” (Traweek, 1988, p. 162), has become subject to ethnographic investigation. From websites as information artifacts, to efforts by the International Organization for Standardization to secure a definition of nanotechnology, to interviews with physicians, scientists, researchers and activists, the texture of this ethnographic account is multifaceted – occupying both local and transnational contexts.

1.4.9 Knowledge is Situated

It is difficult to decouple anthropological approaches to knowledge from ethnography as practice. Knowledge, anthropologists argue, is always situated; furthermore, “[t]he knowledge about which thing will be useful at any given moment is embodied in a flow of mundane tasks and practices and many varied social roles (child, boss, friend, employee)” (Bowker & Star, 2000, p. 2). History, politics and social norms shape perspective -- always. Haraway argues that emancipatory approaches to knowledge not only recognize knowledge as situated but embrace diffraction “in the interests of deeper, broader, and more open scientific literacy” (1997, p. 11). In these orientations to knowledge Haraway draws from scholar Karen Barad, who has examined feminist approaches to teaching quantum physics. In her research Barad examines how “objectivity is literally embodied...wholeness is about the inseparability of the material and the cultural. Wholeness requires that delineations, differentiation, distinctions be drawn; differentness is required of wholeness” (Barad cited in Haraway, 1997, p. 116).

Total and complete objectivity – the “gaze from nowhere” is never entirely possible given the limits and promise of our situatedness (Haraway, 1988, p. 581). I challenge a core tenant of positivist knowledge production – total objectivity – while arguing that ethnography has a place in efforts to democratize science. Political scientist Sylvia Noble Tesh emphasizes “[t]his is not so much an unwarranted intrusion of politics into science. There is no science uninfluenced by politics. This is a plea to get the politics out of hiding” (Tesh, 1988, p. 177). “Strong objectivity,” to borrow a term from Sandra Harding (1991, p. 101), “insists that both the objects and the subjects of knowledge-making practices must be located...location is the always partial, always

finite...location is not self-evident or transparent” (Haraway, 1997, p. 37). Racialized bodies, queer bodies, women’s bodies have long been objectified in scientific practice (Haraway, 1997). These orientations to knowledge demonstrate just one way that objects of scientific inquiry have “spoken back” to scientists in calls for more inclusive practices.

1.4.10 Ethnography as Method and Practice

In 2002, I began documenting and following nanotechnology within local contexts as an undergraduate student in preparation for my MA – during my BA I wrote several papers as a consequence of this early research whenever classes allowed. As a graduate student I spent 8 months of immersion in readings in physics, biology, material science and chemistry in preparation for interviews with scientists and physicians. I developed sections of this thesis at previous conferences held by the Society for Social Studies of Science and the Canadian Political Science Association in 2007 and 2008. I conducted participant observation at two conferences sponsored by Nanotech BC -- the Industry Roundtable: Nano-Bio Convergence: Nanotechnology in the Life Sciences (2007) and the Cascadia Nanotech Symposium (2008). I also participated in a clean room tour at 4D Labs. With white body suit in tow, face mask, and gloves I entered deeper and deeper into the world of material scientists, where each subsequent stage of entry into the clean room¹ got cleaner and cleaner – the particles under scrutiny smaller and smaller. I then secured permission to interview a diversity of participants, some at their places of work, some over the phone from the comfort my home office. I read many medical studies – most pointing to the toxicity of nanotechnology, some pointing to a

¹ The lower the class of the clean room the less particles per cubic meter of air. Clean rooms allow for exceptionally sensitive scientific testing and research. Clean rooms are often highlighted as a critical tool for conducting nanotechnological research and development.

benign impact and misrepresentation. I sifted through distinctions between natural, consequential and engineered nanoparticles, purchased a copy of the International Organization for Standardization's tentative definition of "nanotechnologies", and reviewed local reports on nanotechnology in BC. I sifted through statistics in the provincial report "Nanotechnology Asset Map: Activities, Strengths and Opportunities" (Roughley, 2008) to see if the numbers spoke to the gendered distribution of practices articulated through the nanotechnological – they did. In total women accounted for just under 13% of those classified as nanotechnological researchers in the province. I studied images closely, in power point presentations by scientists and on websites and looked for recurring metaphors and orientations to scale. The inclusion of this material was limited in my thesis given copyright restrictions – ownership is a product of economics and society itself. I studied origin stories of nanotechnology tracing contemporary narratives that stretched back to ancient Egypt.

All of this activity was informed by ethnographic methods – the attunement to, and location of meaning in, practice. However, years of immersion in the field, following participants outside of work into other aspects of their day-to-day life, and participating in actual laboratory work, for example, was outside of the scope of this MA project. Longitudinal participant observation – the crux of full blown ethnography many argue (Erickson & Murphy, 2003) – is better suited to a PhD project. Haraway suggests that an "ethnographic attitude" can be adopted in research, including textual research:

...technoscience requires an immersion in worldly material-semiotic practices, where the analysts, as well as the humans and nonhuman studied, are all at risk—morally, politically, technically and epistemologically...an ethnographic attitude is a mode of practical and theoretical attention, a way of remaining mindful and accountable. Such a method is not about "taking sides" in a predetermined way. But it is about

risks, purposes, and hopes—one's own and others'—embedded in knowledge projects (1997, p.199).

Drawing from Haraway, I approach the topics of nanotechnology and the body with an “ethnographic attitude.” My methods are firmly rooted in paradigms in critical research and previous work conducted by feminist scholars tackling technoscience as practice.

1.4.11 Research Participants

Following internet searches for local articulations of nanotechnology and the body in BC, generic letters were distributed to relevant heads of organizations including:

- Nanotech BC,
- Genome BC,
- The Vancouver Coastal Health Research Institute
- The BC Cancer Agency's Trev and Joyce Deeley Research Centre,
- 4D Labs at Simon Fraser University,
- The David Suzuki Foundation.

After securing permission to conduct interviews, organizations then directly referred me to specific individuals. In terms of tightly coupled communities of practice engaged in medical R&D and industry, the same clusters of individuals appeared at (or were discussed) at the two conferences I attended, on websites, particularly Nanotech BC's website and the Nanomed Canada website, and later in participant interviews. For example, during the interview process, research scientist, Participant A, and, contractor, Participant B, referred to several other researchers in my interviews with them -- including each other. Because a component of my interview questions also directly addressed key collaborations and research activities in the province I was able to confirm that I had indeed tapped into, in a modest sense, crucial nanotech activity in the province.

Participants involved in issues pertaining to toxicology and regulation remained peripheral to these groups.

Internet searches for local articulations of nanotechnology and body also produced two additional participants. An interview was conducted with Rob McMahon, a free-lance journalist who wrote an article for the Vancouver publication, the Georgia Straight, on nanotechnology and health and who has worked for BC’s baking industry, reporting on the use of nanotechnology for packaging, flavour and nutritional enhancement. Author, activist and environmental researcher Stacy Malkin, based in Berkeley, CA, was also included in this study after an excerpt from her book Not Just a Pretty Face (2007) appeared in a local magazine Common Ground. Malkin’s book garnered substantial media coverage internationally. Given very few interest groups to work with at the beginning of this study, the later interviews were added to provide more nuanced discussion of nanotechnologies and health (i.e. additional participants, apart from the one secured through the DSF, who address toxicology and regulation).

Table 3: Research Participants

| Participant | Area of Focus, Professional Background | Referring Organization |
|----------------------|---|--|
| Participant A | Research scientist | 4D Labs |
| Participant B | Business sector development | Independent contractor referred from Genome BC |

| | | |
|------------------------|--|--------------|
| Darren Frew | Business sector development | Nanotech BC |
| Dr. Chris Nguan | Surgical Director, Renal Transplant Program at Vancouver General Hospital, Robotic Surgery, Urological Sciences | VCHARI |
| Dr. Xiaobo Duan | Immunological Researcher, Head of Antibody Research Unit | TJDRC |
| Participant C | Environmental Policy Analyst | DSF |
| Stacy Malkin | Environmental activist, cosmetics researcher, author | Not referred |
| Rob McMahon | Journalist, former reporter on nanotechnologies (flavor, nutrition and packaging enhancement) for “Canada’s Baking Industry” | Not referred |

1.4.12 Participant Interviews

Seven semi-structured qualitative interviews were conducted with participants, both over the phone and, where possible, in person. Four of the seven interviews were

conducted on-site in participants' places of work and three were conducted over the phone. The semi-structured pace of the interviews allowed space for participants to elaborate on their understandings of nanotechnology and health. More generally, interview questions emphasized: organizational agendas, research and affiliations (provincial, national, international); understandings of nanotechnology in general, including the history of the development of nanotechnology and defining criteria; and, where relevant, the use of websites by organizations. The interviews, which were recorded for transcription, ranged from 1.5 to 2 hours with an average interview length of 2 hours. I personally transcribed all the interviews in order to gain a greater familiarity with respondent comments. Participants A, B, and C requested to remain anonymous. All participants were provided with the option to remain anonymous on the project consent forms.

1.5 Thesis Outline

Chapter 2 of this thesis situates my research within the context of three central observations. First, drawing from the work of Susan Leigh Star and Jeffery Bowker (2000), that nanotechnology can be understood as a "boundary object." Second, that nanotechnology is a classification of practice moving toward standardization. Third, the collapse of a multiplicity (nanotechnologies) into a singularity (nanotechnology) is resisted in day-to-day scientific and medical practice despite public representations to the contrary.

Chapter 3 introduces readers to healthcare practices articulated through the nanotechnological within tightly coupled communities of practice invested in 1) medical research and development, and 2) industry. Participant understandings of medical

applications are discussed and associated hopes for the treatment and diagnosis of cancer, new platforms for DNA, RNA and protein analysis and surgical innovations. Medical researchers and business interests affiliated with Nanotech BC, Genome BC, the TJDRC, the VCHARI and 4D Labs at SFU are included in this section. Several themes are gleaned from participant interviews, including: understandings of highly individualized healthcare (i.e. specific to individual genetic profiles), the conflation of imaging and treatment, a clinical adoption gap when it comes to applications articulated through the nanotechnological reaching patients, and unique interdisciplinary collaborations in medical research.

Chapter 4 explores communities of practice primary invested in toxicology and regulation and includes interviews with an environmental policy analyst from the DSF, journalist and former “beat reporter” on nanotechnology for Canada’s baking industry, Rob McMahon, and author and environmental activist Stacy Malkin. Central to these interviews were the themes of nanotechnology in consumer products, safety, consumer trust, toxicology, and, recurrently, the idea that “absence of evidence is not evidence of safety” in terms of nanotech regulation (S. Malkin, interview, February 28th, 2008). Finally, Chapter 4 explores intersections of communities of practice; for example, the Canadian Cancer Societies’ involvement in both efforts to regulate nanotechnology and in cancer research articulated through the nanotechnological.

Chapter 5 provides a summary of key research findings and observations, including an exploration of themes regarding both the threatened and vial nanotechnologically-mediated body. Anthropology’s contribution to bioethics is also

discussed, in addition to salient tensions in relationship to nanotechnology and the body in BC today.

2: NANOTECHNOLOGY TRAVELS: SITUATING MY RESEARCH

2.1 Introduction

This chapter situates my research within the context of three central observations: 1) nanotechnology can be understood as a boundary object, 2) nanotechnology is a classification of practice moving toward standardization, and 3) the collapse of a multiplicity (nanotechnologies) into a singularity (nanotechnology) - a process I dub the singularity (re)vision – is resisted in day-to-day scientific and medical practice despite public representations to the contrary. These observations are gleaned from fieldwork, participant interviews and website analysis. Each informs later chapters of this thesis -- where nanotechnology the boundary object and understandings of the body meet.

2.2 Observation 1: Nanotechnology as a Boundary Object

2.2.1 Nanotechnology Can Be Understood as a Boundary Object

In 1989, sociologist Susan Leigh Star, and philosopher James R. Griesemer, introduced the concept of the “boundary object” into social studies of the sciences (1989, p. 387). Boundary objects retain enough stability to translate into multiple social worlds, yet possess enough plasticity to meet the local needs of diverse communities of practice.

In a subsequent publication, Star and science historian Geoffrey Bowker emphasize that:

We define boundary objects as those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. In working practice, they are objects that are able both to travel across borders and maintain some sort of constant identity. They

can be tailored to meet the needs of any one community (they are plastic in this sense, or customizable). At the same time, they have common identities across settings. This is achieved by allowing the objects to be weakly structured in common use, imposing stronger structures in the individual-site tailored use. They are thus both ambiguous and constant; they may be abstract or concrete (2000, p. 16).

Boundary objects are not exclusively applicable to scientific practice, but they do tend to resonate within social studies of the sciences due to the scientist's duty to model truth claims and to tackle the conceptual problems regarding the management, documentation, assessment and creation of classifications and standards (Bowker & Star, 2000).

Scientists also commonly navigate multiple communities of practice throughout the research process - a feat requiring the artful employment of boundary objects (Bowker & Star, 2000). This delicate negotiation of multiple social worlds is particularly pronounced within the context of nanotechnological research and development in B.C. For many scientists part of the intrigue of nanotechnology is the unconventional networks that bloom between seismic scientists, for example, and urologists tackling kidney stone treatment - an issue I elaborate on in Chapter 3.

Boundary objects are also fundamentally pragmatic, "boundary objects do not claim to represent universal, transcendent truth; they are pragmatic constructions that do the job required" (Star, 1989 cited in Bowker & Star, 2000). As later chapters demonstrate, scientists and physicians recognized that understandings of "nanotechnology" are highly mediated by the needs of diverse communities of practice. Nanotechnology, as a concept, was employed specifically to bridge research agendas, to collaborate in terms of facilities, equipment and publications, to garner individual, organizational and joint grants, all the while informing interdisciplinary research practices within the laboratory. Nanotechnology served as the glue which held together a

series of practices dealing with molecules and atoms in a variety of social worlds. These worlds were at times disparate, with practices articulated through the nanotechnological circulating outside of the laboratory, throughout government, industry, media and environmental movements.

In a 1993 study of the crafting of Artificial Intelligence (AI), sociologist Lucy Suchman, and computer scientist Randall Trigg, famously described the “artful” integration of re-representations of information, local constraints, and received standardized applications (Suchman & Trigg, 1993, p. 144-172). Expanding on the idea of artful integration Star and Bowker argue that boundary objects arise when artful integration transitions to: “an ongoing stable relationship between social worlds” and a paradigm where “shared objects are built across community boundaries” (Bowker & Star, 2000, p. 292). Boundary objects arise as a tactic to manage difference across communities of practice.

2.2.2 How Have Other Authors Understood Nanotechnology as a Boundary Object?

While the popularity of the idea of boundary objects in social studies of the sciences has grown within the last two decades, few scholars have applied the concept directly to nanotechnology, with the exception of Professor of Human Technology, Hans Glimell, and, more recently, sociologist Mary Ebeling. Ebeling comments that:

In the effort to build a new technological market out of nanotechnologies, actors make a multiplicity into a singularity—nanotechnologies become “nanotechnology”—and a widely dispersed marketing potential becomes a single market. In this way, the word nanotechnology is constructed and used as a boundary object, a term employed to cross the boundaries of science and business, and to translate the heterogeneity of the science into an investible instrument. Furthermore, not only does the word

nanotechnology operate to draw a boundary around what the technology is; more significantly, the bounded term is utilized to demarcate the nanomarket itself (2008, p. 346-347).

In her writing on the communication of financial risk and nanotechnologies Ebeling explores the ways actors collapse nanotechnologies (a multiplicity) into nanotechnology (a singularity), a feat I call the singularity (re)vision, in order to meet the demands, promises and potential of the market place.

Much like the idea of wave function collapse in quantum mechanics, where wave function (a multiplicity) collapses into a single state upon introduction to the external world, nanotechnologies are reduced to a singularity where they meet the needs, agendas, ideas, histories and contingencies of market places, scientists, regulators and publics. The singularity (re)vision simultaneously collapses a multiplicity into a singularity, a boundary object and a classification. This slip facilitates not only interdisciplinary communication, but contingent politics, institutional needs and educational agendas attuned to the ‘best way’ to present the idea itself.

Building on the work of Bruno Latour (1988), Star additionally introduces the concept of the “open black box” into her discussions of boundary objects (Star, 1992, p. 395). Nanotechnology’s singularity is never universally secure. Star and Bowker point out that:

The sociology of science and technology has emphasized opening the black box of technology, a kind of reverse engineering of the interests and rhetoric inscribed therein. Recent organizational and policy analysis have shown how these black boxes may be opened and closed as circumstances and structural conditions change and rhetorical resources mobilized (see also Yates, 1989). Yet here we have a hybrid of these conditions, where the box, if you will, is neither clearly closed nor black. Perhaps the oxymoronic “open black box” (Star, 1996) would be a fitting name for this

phenomenon, deserving further and urgent investigation in its own right (2000, p. 161).

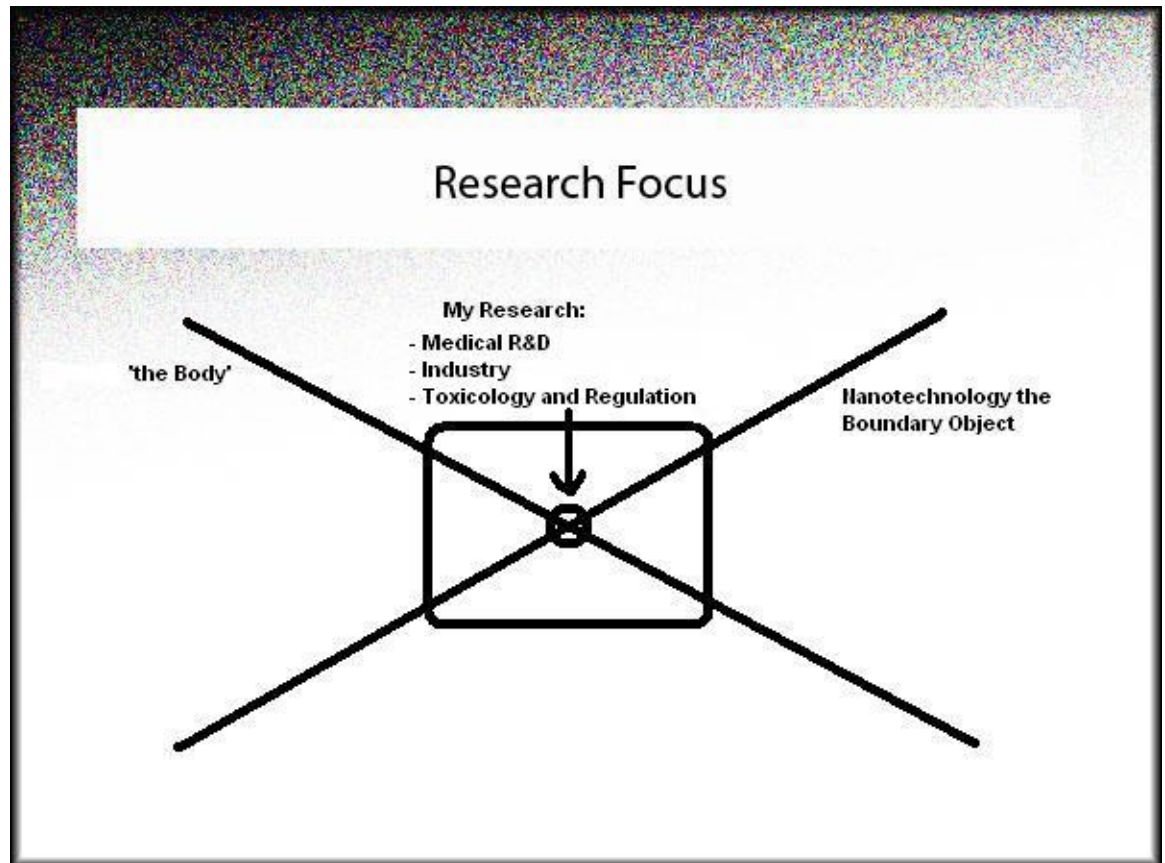
What is it about this open closure that allows a boundary object to work? Hans Glimell emphasizes that, “two parallel general properties are required: plasticity and coherence” (2004). Further developing Star’s idea at the 2004 EuroNanoWorkshop in Brussels, Glimell issued a direct challenge to researchers exploring the ethical, legal and social dimensions of nanotechnology to embrace the idea of the boundary object: “in many studies where the exchange or interactivity between networks or assemblages of actors has been studied, it has proved quite useful. It might, I suggest, prove to be a useful conceptual tool for approaching the task how to communicate about the social or societal dimensions of nanotechnology” (2004). Ultimately this scholarship situates my own observation that nanotechnology itself is utilized as a boundary object within and between particular communities of practice in British Columbia.

2.2.3 Nanotechnology Travels Through Three Distinct, yet Inter-related, Contexts in This Study

Having developed the concept of communities of practice and bodily intervention in Chapter 1, it is clear the boundary object nanotechnology travels through three distinct, yet interrelated contexts: 1) communities of practice primarily invested in medical research and development, 2) communities of practice primarily invested in industry, 3) communities of practice primarily invested in toxicology and regulation. The focus of this research can be understood as the point where diverse communities of practice meet: 1) nanotechnology the boundary object, and 2) the body, including associated understandings of health and harm (*see* Figure 3). This intersection is of course explored

within the specificity of British Columbia, although my findings are useful to scholars developing the idea of nanotechnology and the body within other contexts.

Figure 3: Research Focus



2.3 Observation 2: Nanotechnology as a Classification of Practices Moving Toward Standardization

2.3.1 Standard Setting

Latour once noted that in practice scientific standards are “so inconsistent that the US, according to the National Bureau of Standards, spends 6 per cent of its Gross National Product, that is, three times what is spent on R&D, just to maintain them stable”

(Latour, 1987, p. 251). How is a standard different from a classification? Star and Bowker demonstrate that classifications can be boundary objects and that classifications may later be adopted as formal institutional standards -- they often are. Specifically they characterize the texture of standards as:

- A “set of agreed-upon rules for the production of (textual or material) objects” (13).
- “A standard spans more than one community of practice (or site of activity). It has temporal reach as well in that it persists over time” (p. 13).
- “Standards are deployed in making things work together over distance and heterogeneous metrics” (p. 14).
- “Legal bodies often enforce standards, be these maintained by professional organizations, manufacturers’ organizations, or the state” (p. 14).
- “There is no natural law that the best standard will win” (p. 14).
- “Standards have significant inertia and can be very difficult and expensive to change” (p. 14).

In this sense classifications and standards, although closely related, are not identical. If a classification fails to morph into a standard it is because its use is highly local, temporally limited and impromptu (p. 15). Still, every good standard employs classifications of correct or incorrect ways of doing things and, in practice at least, enough flexibility to work in anomalies (p. 15).

2.3.2 Canada’s Participation in the International Organization for Standardization’s Technical Committee 229: Nanotechnology as a Classification of Practices Moving Toward Standardization

Nanotechnology as a boundary object and classification of practices is in the midst of transition to a standard. Increasingly there have been efforts to standardize nanotechnology, or nanotechnologies (depending on the boundary object chosen), at both

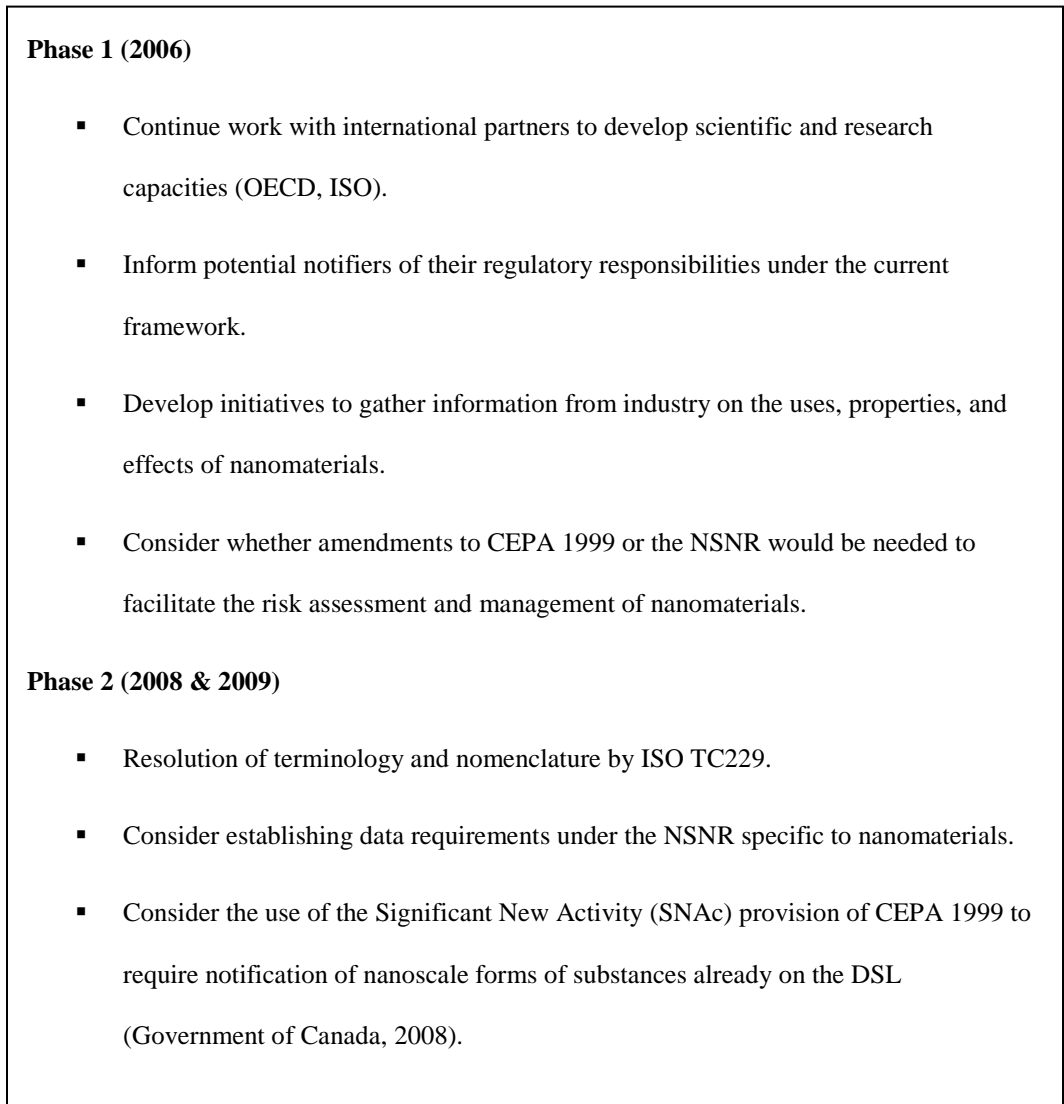
the national and international level. In conjunction with the International Organization for Standardization (ISO) the Government of Canada has played a central role in this push to standardize.

In 2003 a Canadian “interdepartmental network” was established to “discuss various issues related to nanotechnology, and to promote a coordinated federal approach” (Health Canada, 2007, p. 2).² The federal forum is chaired by Industry Canada (2007, p. 2). Currently, Environment Canada and Health Canada propose to regulate nanotechnology under the Canadian Environmental Protection Act (CEPA). These

² Nanomaterials are *not* specifically regulated under Canada’s guidelines for new substances. Several avenues for regulation are being considered through both modification to the CEPA and the New Substances Notification Regulations (NSNR). Existing substances are defined as industrial chemicals and polymers registered on the Domestic Substances List (DSL). While other applications of nanotechnologies, for example in the use of pharmaceuticals, are governed by legislation such as the Food and Drugs Act, such acts do not address “potential environmental and human health impacts from environmental exposure to substances” and as such are targeted by the CEPA 1999. The DSL itself highlights all “known substances” used in Canadian commerce between 1984 and 1986 and those added subsequently to the DSL in conjunction with the adoption of the CEPA 1999. There is considerable concern that nanoscale forms of substances included on the DSL may pose health risks; for example, fine particles of carbon black and Titanium Dioxide have greater toxicological effects than larger particles consisting of the same material (Ferin, Obersorster, Penny, Soderholm, Gelein and Piper, 1990, p. 381-384; Oberdörster, 1996, p. 73-89). Interestingly the Government of Canada uses Titanium Dioxide as an example of a “nanomaterial” currently listed on the DSL which is not considered new “since its nanoscale form does not have unique structures or molecular arrangements, it is not subject to the regulations.” Ferin et al. (1990) and Oberdörster (1996) identify increased toxicity associated with smaller particles of substances such as Titanium Dioxide. When a “new substance” is proposed for industrial use Canadian companies must submit formal notification to Health Canada and Environment Canada following procedures outlined under the NSNR (Government of Canada, 2009). As an interim measure, in 2007, the Government of Canada issued an advisory note on nanotechnologies, cautioning that “the nanoscale form of a substance on the DSL is considered a new substance if it has unique structures or molecular arrangements” (Government of Canada, 2008). Consequently importers, manufactures and additional stakeholders are advised to prepare a New Substances Notification Package before import or manufacture of “nanomaterials” (Government of Canada, 2009). Another proposed framework addresses the regulation of nanomaterials through the Significant New Activity (SNAc) provision of the CEPA 1999. A SNAc Notice is defined as: “[A] notice describing, by inclusion or exclusion, a significant new activity that results or may result in a significantly greater quantity or concentration of the substance in the environment or a significantly different manner or circumstances of exposure to the substance” (Government of Canada, 2008). This form of notice is issued if a “new activity” in relation to the substance under question is believed to contribute to the substance becoming “toxic” as defined by the CEPA 1999.

bodies are currently in the second phase of a two phase project to implement regulation, the first of which began in 2006 (*see* Figure 4).

Figure 4: Proposed Regulatory Frameworks for Nanomaterials under the Canadian Environmental Protection Act, 1999 and the New Substances Notification Regulations



Canada is also currently involved in ISO efforts to establish a consistent definition of nanotechnology. The ISO's Technical Committee 229: Nanotechnologies (TC 229), formed in 2005, consists of three working groups, including Canada's working group on nomenclature and terminology, Japan's working group on characterization and measurement, and the United States' working group on the environment, safety, and health (Government of Canada, 2008). Canada has also partnered with the ISO and the Organization for Economic Co-operation and Development (OECD) to develop 'nanotechnological' research capabilities within a highly internationalized arena (Government of Canada, 2008). Interestingly Canadian provincial and federal bureaucratic language has a tendency to adopt "nanotechnology" as a boundary object, while the ISO uses "nanotechnologies". The federal definition of "nanotechnology" is informed by the ISO definition "nanotechnologies" - - the singularity (re)vision, at least in this case, is as Canadian as maple syrup.

In 2008, TC 229 released a copyrighted Technical Specification (TS) report entitled "ISO/TS 27687 Nanotechnologies – Terminology and definitions for nano-objects – Nanoparticle, nanofibre and nanoplate" (2008). Heavily influenced by industry needs and the necessity to communicate ideas across commercial interests, the document highlights the complexity involved in measuring, defining, and standardizing something like nanotechnology. Embedded in the report is the recognition that particles themselves can be difficult to measure, given that the sample size, method of particle extraction and/or visualization methods used can have a dramatic impact on size estimation. Collectively these factors make it very difficult to compare information on particle measurement across research institutes – a problem for scientists that carries over into the

translation of nanotechnology as a classification into nanotechnology as a standard.

While the ISO/TS 27687 provides a standard definition for nanotechnologies, it is only a temporary one. Protocol at the ISO calls for three years to pass before a TS report can either be officially adopted as an international standard, abandoned or temporary adopted for another three years.

2.3.3 Making Standardization Work Visible – Standards and Power: Visibility as Ethics

- *“all category systems are moral and political entities” (Bowker & Star, 2000, p. 324)*

Although mapping institutional standards can be boring work, standards are not innocent or apolitical. A key consideration is erasure. A cursory look at the Government of Canada’s website reveals little information about the government’s involvement in TC 229 processes. For example, what findings did Canada present to the TC 229 on nomenclature and terminology? What elements were extrapolated for inclusion in the technical committee report? What elements of the findings were abandoned? Countries involved in the ISO also must vote on proposed standards. For a standard to pass two thirds of a committee must vote in favour of it. In the instance of the ISO/TS 27687 report, did Canada, Japan and the United States all vote in support of the standards, if not who didn’t and why? Information governing the history of ISO standards is erased in this sense and complexities of process are reduced to a neat and tidy report -- little information regarding the if, and, why or how is provided. Star and Bowker suggest “rendering voice retrievable” as one way to address the moral and political architecture of classification work, “[b]y keeping the voices of classifiers and their constituents present,

the system can retain maximum political flexibility...by retrievability, we are suggesting that under many circumstances, the “rule by no one” or the “iron cage of bureaucracy” is strengthened by its absence” (2000, p. 325).

This calls into question not only the meanings people assign to scientific projects, but also which stakeholders are left out when the stakes are invoked -- “when classification systems and standards acquire inertia because they are part of invisible infrastructure, the public is de facto excluded from policy participation” (Star & Bowker, 2000, p. 325). Tacit and explicit understandings of appropriate and inappropriate users of standards also speak to power and inequalities. For example, the ISO charges about \$70.00 CN for the definition of nanotechnology. This is cost prohibitive to many. Between rent, books, living expenses and tuition as an undergraduate student I personally would not have been able to purchase the definition without it cutting into my budget for food. Scientific practice is highly stratified along intersecting lines of gender, race, and class (Haraway, 1997) -- nanotechnology and associated standard setting practices are no exception.

2.4 Observation 3: The Singularity (re)vision is Resisted in day-to-day Scientific and Medical Practice Despite Public Representations to the Contrary

2.4.1 Controversy is the Norm, Not the Exception

There is a tidiness to public representations of nanotechnology that does not reflect laboratory practice. Government communiqués and media coverage of nanotechnology seldom address the conflict, ambiguity and stakes involved in definitions of nanotechnology and in the development of standards themselves. If Bruno Latour’s

work has taught us anything it's that this state of controversy is the norm, rather than the exception. In Science in Action (1988), Latour emphasizes that:

When we approach the places where facts and machines are made, we get into the midst of controversies. The closer we are, the more controversial they become. When we go from 'daily life' to scientific activity, from the man on the street to the men in the laboratory, from politics to expert opinion, we do not go from noise to quiet, from passion to reason, from heat to cold. We go from controversies to fiercer controversies (1988, p. 30).

Apart from Latour's use of highly gendered language (Please note Latour women are also bystanders on the street and can be scientists too!) and propensity for dualisms (see Donna Haraway's critiques in this regard – Haraway, 1997) this passage speaks to science in action as necessarily messy and contested – an insight that has informed STS scholarship for over two decades.

2.4.2 Organizational Representations Often Run Contrary to Researcher Perspectives

Early in my research it became apparent that there was a disconnect between official organizational representations of nanotechnology (found on websites in this case) and the perspectives of researchers themselves. For example, a participant at a conference I attended in November of 2007, an industry roundtable on “Nano-Bio Convergence: Nanotechnology in the Life Sciences”, noted that Nanotech BC had to sometimes convince scientists that they were doing nanotechnology. An anonymous scientist who participated in my study also expressed that “I think they [Nanotech BC] are put in an awkward position to have to push something that is unclear as to whether they have to push it or not...local and federal mandates emphasize these kinds of things” (Participant A, interview, January 17th, 2009). The salience of nanotechnology as a

classification cannot be separated from funding agendas, industry pursuits and provincial and federal mandates. As an organization focused on developing “nanotechnology” as a provincial industry sector, of all the organizations in this study, Nanotech BC appeared to be the most heavily invested in the singularity (re)vision. Ebeling comments, “it appears, that in the efforts to define “nanotech” within the context of its commercialization and the way the future financial benefits for investors are described are efforts to make things that are contentious, contingent, uncertain, and ambiguous, certain” (2008, p. 535). This also calls to question how many scientists included in the Nanotech BC/Government of BC survey on provincial nanotechnology researchers (as discussed in Chapter 1) personally identified as nanotechnologists and how many simply agreed to be listed as nanotechnologists with some trepidation or a previous lack of awareness that they were ‘doing’ nanotechnology at all. Ultimately, the stakes involved in the singularity (re)vision are different for different players. Scientists sometimes just play the game to get the research done. Just because nanotechnology is employed as a boundary object does not mean that it is done unselfconsciously or that those who employ it are not critical or reflective of the stakes.

2.4.3 There are Often Slips Between Classifications and Practice

As explored in Chapter 1, particular orientations to scale are adopted in definitions of nanotechnology – this is the case for both Nanotech BC’s definition and the ISO’s temporary standard. I argue that even if particular orientations to scale are adopted in standards and definitions within the context of scientific and medical practice slips will occur – in fact for the wheels of research to run smoothly across and within communities sometimes they must occur. Participant A emphasizes, “if someone wants to call it

nanotechnology they can. It doesn't bother us. We call it a new material. Now we say nanostructures. We make a lot of nanostructures. Nanorods, nanoparticles and yes they are 200 nanometres or less, but if we made one at 250 do we call it a nanostructure? Probably. Just for convenience" (Participant A, interview, January 17th 2008). Another example lay in Chapter 3's discussion of definitions and medical professionals. Medical professionals invested in "nanotechnology" may use altogether different orientations to scale in cancer research, for example (Garnett & Kallinteri, 2006, p. 4). In this instance the perceived preciseness of mathematics and measurement are subsumed by messy necessity.

To reiterate Latour's point about scientific practice – controversy is nothing new. Indeed, where nanotechnology the boundary object meets the body in Chapters 3 and 4 of this thesis, the controversy only grows as the stakes get higher and the players get more diverse. From Canada's participation in the ISO/TS 27687 standards, to the politics of visibility, voice and standardization (Bowker & Star, p. 2000) – the architecture nanotechnology occupies is nuanced and contested.

In the next chapter I document nanotechnology-in-action as it intersects with current biomedical practice in BC. Biotech. business leaders, physicians and scientists characterize a vital nanotechnologically-mediated body renewed with health and subject to improved diagnosis and treatment of disease.

3: NANOTECHNOLOGY AND HEALTH

3.1 Introduction

While there is often a disconnect between scientists' understandings of nanotechnology and formal institutional representations due to economic agendas, in BC today there is an increasing amount of medical research articulated through the nanotechnological. This chapter provides readers with an introduction to the vital nanotechnologically-mediated body. Nanotechnology, from this view, occupies a future of enhanced healthcare, where disease diagnosis is unprecedentedly quick and cost effective and drugs are less toxic to the human body.

3.2 Framing Nanotechnology and Health

3.2.1 Nanomedicine: An Introduction

Many practices articulated through the nanotechnological harbor very real implications in medicine. Scientist Peter Wagner notes that the convergence of chemistry, biology, and microelectronics is particularly promising in this regard (2005, p. 40). Given the intersection of these approaches, several key medical projects emerge, including potential applications in drug delivery (Wagner, 2005, p. 47-49), diagnostics (Bartos, Gotz & Peters, 2004, p. 13), cancer treatment (Norton, 2005, p. 407-425), urological sciences (Shergill, Rao, Arya, Patel & Gill, 2006), organ transplantation (Chang, 2004), bone grafts (Murugan & Ramakrishna, 2005), HIV treatment (Tang, Zhao, Storhoff, Norris, Little & Yarchoan, 2007), the creation of artificial cells (Chang,

2004), cardiovascular medicine (Wickline, Neubauer, Winter, Caruthers & Lanza, 2006) and tissue (Miles & Jarvis, 2001) and nerve regeneration (Soumetz, Giacomini, Pastorino, Phillips, Brown & Ruggiero, 2004, p. 239-240) - to name a few examples. Much of the novelty attributed to nanotechnology in medical literature is located in relationship to the finely tuned targeting of tissues for both imaging and drug delivery, in addition to new platforms for DNA, RNA, and protein analysis. The majority of participants in this study emphasized that applications had yet to reach patients and that work was still being done at the research and development level. Most researchers emphasized that, in BC, patients could look forward to nanotech diagnostics and treatments in approximately 10 years time.

3.2.2 Medical Nanotechnology and the Singularity (Re)vision

When it comes to practices articulated through the nanotechnological, different orientations to scale are often adopted in medical contexts. In the *Journal of Occupational Medicine*, Garnett and Kallinteri emphasize that medical professionals may utilize different scales of measurement for “nanotechnology” than other professionals (2006, p. 307). Elaborating on the work of Garnett and Kallinteri, Stern and McNeil point out that:

Nanoparticles, the building blocks of nanotechnology, have been broadly defined as having at least one dimension at 100 nm or less. For biomedical application, this definition has been expanded to include particles greater than 100 nm, such as liposomes,³ in order to encompass particles sizes that take advantage of anatomical considerations, such as vascular gaps⁴ surrounding tumors (2008, p. 4).

³ Black’s Medical Dictionary emphasizes “these are essentially tiny oil droplets consisting of layers of fatty material” (2006).

⁴ Simply put - gaps in blood vessels surrounding a tumor.

Chapter 2's "singularity (re)vision" is in full force – particles greater and less than 100 nm are both considered nanotechnology. For those scientists and physicians that use nanotechnology as a boundary object, practical research considerations, such as the texture of tumors, influence the boundaries between nanotechnology and other applications.

3.2.3 The “Nano” Prefix

My research on practices articulated through nanotechnology and health took me from the Trev and Joyce Deeley Research Centre (TJDRC) in Victoria, BC, to the many alpaca farms which dot Vancouver Island. Dr. Xiobo Duan, Immunological Researcher and Head of the Antibody Research Unit at TJDRC, goes on to explain:

Dr. Xiobo Duan: Ok, so antibody you know, usually heavy in mammals, it's a big molecule, so it's very big, lots of new applications because this molecule is too big, and I mean, if you treat cancer, or do the imaging in animals or in the humans, because it's too big first, it's difficult to penetrate into the tumor site...too big...then you inject it and in a few hours they will not last long in vivo. So there is a new generation of antibodies, called nanobodies.

Interviewer: Nanobodies?

Dr. Xiobo Duan: But it's not the nanotechnology, but they just use the term nanobody.

Interviewer: I haven't come across that yet, interesting.

Dr. Xiobo Duan: Because they are small, that's naturally in camels you know, you know camel family animal, and then naturally have small antibodies...I know that in the, some of the camel family, like llama, alpacas, all those animals, another group of animals is the shark, they have this kind of antibody so they started using this antibody, exploring the potential to use this antibody to develop drugs. At our lab we also started a little bit of work working with, camels, [I mean] alpacas, because on Vancouver Island they have a lot of alpacas here, but they are huge...antibodies are molecular, nature has given us a big gift, a huge

diversity...you can combine all the particles with whatever nanodevice and use it for many, many different things...(X. Duan, interview, May 8th, 2008).

The smaller size of antibodies in certain shark species and members of the Camelid family has proven useful to researchers working on cancer treatments. Nearly a century ago Paul Ehrlich first conceptualized antibodies as “magic bullets”; since that time, immunological researchers have sought to harness both human and non-human antibodies in the treatment of cancer (Reilly, Sandhu, Alvarez-Diez, Gallinger, Kirsh & Stern, 1995, p. 126) through direct use of antibodies, or in the case of Dr. Duan’s “nanobodies” in the combination of antibodies with other agents or devices. In a study of the use of brine shrimp death as an indicator of plant bioactivity, anthropologist Corinne Hayden emphasizes that drug discovery is “deeply dependent on the enabling presence of other forms of life” (Hayden, 2003, p. 194). These configurations in science also speak to Donna Haraway’s conceptualizations of hybridity (Haraway, 1997); an alpaca “nanobody” is simultaneously animal, research tool, commodity and medicine. Like Haraway’s Onco MouseTM⁵, a tool for cancer research and the world’s first patented life form, the alpaca “nanobody” challenges taxonomic classification and points to the reconfiguration of biology as a field of study. Dr. Xiobo Duan also understands nanobodies as a potent “gift from nature,” allowing immunological researchers to develop cancer treatments in a variety of ways when mixed with human labour.

Although Dr. Xiobo Duan did reference technologies he considered nanotechnology, particularly in regard to lab-on-a-chip assays, he was careful to situate “nanobodies” as “not nanotechnology” (X. Duan, interview, May 8th, 2008). This

⁵ Developed by Harvard and Dupont - the world’s first patented life form and a genetic mouse/human hybrid that reliably produces cancer cells for research.

represents a common slip that occurred throughout my research; interviews often shifted from discussions of medical applications hinged to the nano prefix, but not nanotechnology, to applications considered true nanotechnology.

3.2.4 Organizational Representations Versus Participant Perspectives

As my research progressed I began to realize that researchers often harboured critiques of “nanotechnology” – critiques rendered invisible by formal institutional practice. For example, a press release about the opening of 4D Labs produced by the Provincial BC Ministry of Advanced Education announces “Nanotechnology Research Centre to Open at SFU,” emphasizing that 4D Labs “is also developing partnerships with medical institutes to develop the next generation of medical diagnostics – anything from a blood test to a CAT scan – and new drug therapies” (BC Ministry of Advanced Education, 2005). The 4D Labs website and SFU’s Public Affairs and Media Relations also utilize “nanotechnology” to describe the lab’s activities; however, Participant A emphasized that some of the scientists working in the lab rejected the term and shared the following thoughts with me:

Interviewer: Personally, do you have a definition of nanotechnology? You know, in the lab I’m doing something and this is nanotechnology opposed to something else. Do you think about that at all?

Participant A: We try not to think about it. I’d rather not get into the semantics of it. I mean nanotechnology has a concrete definition. Well it’s technology based on nano, but that can be interpreted in so many different ways. I think it has to have unique properties, but that’s again, really, really small...My opinion is that you don’t have to define something to do good science in the areas, that’s for the granting agencies.

Interviewer: So although you might not care so much about the definitions, certain terms can be useful to flash in terms of funding?

Participant A: O ya, nano is money these days. It's crazy, but I think that we have received money on a project for nanotechnology without using the term nanotechnology once. If you do the science that relies on the nanoscale, great...Nanoscience is one thing; nanotechnology is when you have something at the end of the day that is a technological advancement. So there are very few examples of, technically, nanotechnology, but that's just being argumentative. But nanoscience in general, I mean if you are in it, you are in it. If you are studying something that is nanoscale, does it matter if you are calling it something?...I just don't care. That's why I emphasize that we are a material sciences group, we are a materials facility, we make materials and dealing with materials at a nanoscale, properties at a nanoscale, if somebody wants to call it nanotechnology they can (Participant A, January 17th, 2008).

This represents an apparent disconnect between organizational representations and management understandings of research activities, versus the perspectives of the scientists themselves. Furthermore researchers may not personally identify as doing nanotechnology, but may strategically employ the term as a boundary object in order to secure funding – “nano is money these days.” Participant A is also careful to distinguish “nano”science from nanotechnology – like Dr. Xiobo Duan's “Nanobody,” the “nano” prefix does not necessarily indicate “nanotechnology.”

3.3 Individualized Healthcare and Nanotechnology

3.3.1 Specificity and the Human Body

Scientists, physicians and biotech business leaders commonly envisioned a future of highly individualized healthcare where nanotechnology not only enables unprecedented specificity at the point of treatment, but also in genetic, protein and RNA analyses administered prior to treatment. In this future, nanotechnology not only enables physicians to treat patients, but to treat patients better because medical applications will be suited to each individual's molecular profile.

3.3.2 “Lab-on-a-chip” Technologies

Physicist Harold Craighead identifies lab-on-a-chip technologies as a promising new addition to molecular biology:

Interest in scaled-down analytical processes, combined with advances in microfluidics, is motivating various chip-based methods in which analyses can be carried out more rapidly and at lower cost via small-scale systems than with current laboratory bench-scale methods...a class of research systems is evolving that uses a range of new physical and chemical approaches to biomolecular analysis. The complexity of life processes and the richness of molecular biology provides fertile ground for research with these new lab-on-a-chip approaches (2006, p. 387).

Although lab-on-a-chip technologies are relatively new to BC’s life sciences research community (Roughley, 2008, p. 8-9), the development of quick and cost-effective lab-on-a-chip nanotechnologies – “2 to 3 dollars” – was described by participants as a critical to transforming the future of healthcare. Lab-on-a-chip technologies promise to “change the way the world works” (Fishman, 2002, p. 188) by creating a future where “a physical might take no longer than a minute” (Suplee, 2005, p. 58). Dr. Xiobo Duan emphasized early cancer detection in this regard:

As a patient if you get cancer, if you detect it earlier, if you treat it earlier, the recovery rate is greater, the survival rate is higher, the problem is that we cannot detect it earlier...early detection is education and screening, it’s too expensive to carry out screening, because you use traditional way, you use blood test...in the future nanotechnology or the devices we are trying to work on, you can do it maybe by yourself...it will be a good impact, also, you know the speed of the detection, the patient management, you can treat the early stage ...(X. Duan, interview, May 8th, 2008).

Identified by Dr. Xiobo Duan as more cost effective than “education and screening,” lab-on-a-chip technologies could facilitate the possibility of cheap self-administered cancer tests available, for example, at your local drug store.

Darren Frew, Executive Director of Nanotech BC, also emphasized the revolutionary potential of healthcare administered in this way:

Most of the research these days is really zeroing in on different forms of treatment and one of the things that is a goal, and we used this term this morning in the meeting that I had with people, the whole idea of personalized healthcare, and that doesn't necessarily mean health plans from the government that's suited to fit your health needs. That means that fairly soon the medical community and medical science will be at the stage where the doctors and practitioners will be able to take a look at your individual genomic properties, who you are basically, what makes you tick, and they'll know an awful lot about your genetic and physiological make-up to the degree that when something happens your treatment will be very, very specified and what we will find 15 years from now quite readily...I think Canada will be a healthier place because one of the things that we are looking at is not just trying to be provincially focused, again, if we are looking at something that has fairly wide ranging benefits in terms of people's health, and we want to be able to share that across country...so I think 15 years from now there is going to be some very, very interesting treatments (D. Frew, interview, January 24th, 2008).

Frew's statement that it is our molecular profile that is the essence of who we are -- "who you are basically, what makes you tick" -- speaks to broader social trends mapped by social scientists in recent years -- "a reorganization of the gaze of the life sciences: their institutions, procedures, instruments, spaces of operation, and forms of capitalization" (Rose, 2008, p. 44).

3.3.3 Health, Wellness and "Molecularization"

Nanotechnology is big right now not just because of the alignment of technological capabilities, but because of social trends, investments, values, and particular healthcare paradigms. As a boundary object it unfolds within the context of what de Chadarevian and Kamminga characterize as the increasing "molecularization" (1998) of "life itself" (Rose, 2008). Sociologist Nikolas Rose elaborates:

The “style of thought” of contemporary biomedicine envisages life at the molecular level, as a set of intelligible vital mechanisms among molecular entities that can be identified, isolated, manipulated, mobilized, recombined in new practices of intervention, which are no longer constrained by the apparent normativity of a natural vital order (2008, p. 6).

I argue that this has had a major impact on the growing use of nanotechnology as a classification of practice and as a boundary object. The manipulation of individual molecules - the Natural Resource Council’s “building blocks of nature” - could reconfigure healthcare practices in BC; however, conspicuously absent from much of the discussion of molecules and health is the social, historical and political context in which biotechnologies unfold.

For example, while BC’s provincial slogan is “The Best Place on Earth” (Province of BC, 2009), BC has the highest rates of child poverty in Canada (First Call, 2008), and the Health Officers Council of BC has drawn salient links between poverty and health, recommending the improvement of “daily living conditions” and the “inequitable distribution of power, money and resources” in the province (HOC BC, 2008, p. 77). Health outcomes and access to treatment are also highly racialized in the province. FitzGerald, Wang, and Elwood emphasize, linked in part to “socioeconomic” determinants, “the prevalence of tuberculosis infection is much higher in aboriginal communities than among Canadian-born nonaboriginal people” (FitzGerald et al., 2000, p. 35). Medical applications articulated through the nanotechnological may transform the experience of a physical in BC or allow access to protein, RNA and DNA tests at local drug stores, but “the glamour and the razzmatazz” of high tech solutions can also serve to obscure more ‘mundane’ issues like the salient connections between poverty and health (Franklin, 2008, p. 5).

3.3.4 Drug Delivery and Nanotechnology

Dr. Chris Nguan, Surgical Director of the Renal Transplant Program at Vancouver General Hospital in Robotic Surgery and Urological Sciences, describes the finely tuned delivery of pharmaceutical agents as “the holy grail” of nanotechnologically enabled healthcare (C. Nguan, interview, April 11th, 2008). Some commentators argue that by 2003 there were already thirty nanotechnological drug delivery products on the market (Arnell, 2003, p. 25-26). Researchers also emphasize that the trend towards molecularization points to the growing likelihood “that the pharmaceutical industry will transition from a paradigm of drug discovery by screening compounds to the purposeful engineering of targeted molecules” (LaVan & Langer, 2001, p. 79-83). Rose notes that, “in the pharmaceutical industry and therapeutic research more generally, it is at the molecular level that therapeutic agents are selected, manipulated, trialled, and developed” (2008, p. 13).

While researchers in BC are exploring a variety of applications for nanotech drug delivery, participants again and again emphasized the promise of targeted drug delivery for cancer treatments. Participants from both communities of practice invested in medical R&D and industry explicitly emphasized the role of the BC Cancer Research Agency in this regard, including the agency’s high international standing -- “[t]he Province has world-leading efforts and companies in cancer research and genomics supported by Genome BC and the BC Cancer Research Agency” (Marziali & Associates, p. 2006, p. 3). A recent report by Marziali and Associates (2006) on “bionanotechnology”—another, although one could argue less successful, boundary object employed within local contexts – identifies the tendency of local pharmaceutical

corporations to collaborate with large American counterparts in clinical trial development. Without access to substantial “financing rounds” it is “difficult for companies to pursue clinical trials” in the province (Marziali & Associates, 2006, p. 40).

In terms of the development of cancer treatments, Darren Frew discussed new possibilities for chemotherapy:

So the cure is almost as bad as the disease [chemotherapy]...it certainly takes a toll on you and now these folks [BC Cancer Research Agency and pharmaceutical companies] have been looking at isolating the medicine and getting it right to the tumor site with a variety of cancers...medicines will be more tailored to our individual bodies and there will be much, much less left over toxicity because the medicines will be going where they are supposed to be going (D. Frew, interview, January 24th, 2008).

The devastating impact of chemotherapy on the body could be reduced with enhanced tissue targeting techniques. Within provincial contexts, researchers are also working extensively with gold to cure and diagnose cancer.

3.4 Gold Nanoparticles and Medicine

3.4.1 Introducing the Gold Nanoparticle

One of the critical differences in medicines articulated through the nanotechnological, compared to standard treatments, is the idea of simultaneous imaging and treatment. Regardless of community of practice, nearly all provincial interest groups invested in medial nanotechnological research and development emphasized the use of gold nanoparticles in this regard. Participant B, self-identified as the “business side of science,” and referred from Genome BC, expressed that, “I don’t think there is a contemporary researcher who isn’t using a gold nanoparticle for something” (Participant B, interview, February 1st, 2008).

Gold nanoparticles have been adapted for a variety of uses; for example, in the construction of diagnostic microarrays (Thaxton & Mirkin, 2004, p. 288-307). The use of gold nanoparticles as indicators, rather than fluorophore, provides electrical as well as visual methods of detection; furthermore, the triangulation of DNA, RNA and protein analysis facilitates analysis of immunological responses to pathogens, disease presence and genetic variation (NanoSphere, 2006).

Traditional “DNA assays,” “gene-chips” or “micro-arrays” (Thaxton & Mirkin, 2004, p. 293) take advantage of the binding properties of oligonucleotides, or chains of nucleotides (sugars with base-pairs of adenine, guanine, thymine, and cytosine) that constitute DNA (Johnson, 2000, p. 60-61). These assays generally draw from photolithography, a somewhat complex optical process utilized to transfer patterns onto a substrate (Micron, 2005). By transferring selected oligonucleotides which are tagged with photon producing (and thus fluorescent) fluorophore onto a slide, then exposing the slide to a sample of DNA, researchers are able to detect complementary oligonucleotide sequences which form chemical bonds to the slide matrix (Thaxton & Mirkin, 2004, p. 293). In short, if a DNA sample “sticks” to the patterns configured on the slide it means that the DNA properties being scanned for are present. “Gold nanospheres” or “nanoparticles” were found to surpass the use of fluorophore as a molecular marker offering researchers increased sensitivity (Taton, Mirkin & Letsinger, 2000, p. 1757-1760) and the possibility of both optical and electrical expressions of detection (Thaxton & Mirkin, 2004, p. 291-292). Busque, Roozrokh and Sarwal point to the possibility of utilizing such diagnostic technologies for organ transplantation in the provision of

immunosuppressive therapies tailored to a patient's specific genetic profile (2005, p. 432-438).

3.4.2 Cooking Cancer and Imaging Tumors

Innovations in cancer diagnosis and treatment have also been promising, in both the therapeutic targeting of cancer cells and in the characterization of cells while in the body (Norton, 2005, p. 407-424). Throughout this study, the BC Cancer Research Agency was cited as the critical organization working with gold nanoparticles. Immunological researcher Dr. Xiobo Duan emphasizes that, "they have like different nanoparticles that show different colors, I saw that and I thought it was really attractive. So you can use this to label the antibody in imaging potentially...they can pick out those particles in vivo, just by labelling them...they can like kill cancer just by heating it up" ... (X. Duan, interview, May 8th, 2008). Dr. Xiobo Duan also expresses that he first heard about nanotechnology from chemists working with gold nanoparticles; "what attracted my attention first was the gold nanoparticles" (X. Duan, interview, May 8th, 2008).

One of the many ways to work with gold nanoparticles is to take a silica particle (glass) and coat it with varying thicknesses of gold. Adjusting the thickness of the gold on the outer shell prompts different responses to light and thus different colors in imaging. The gold nanoparticle is then coated in antibodies and clings to the tumor site, at which point heating may be provided by a light powerful enough to penetrate the epidermis. As the gold nanoparticles heat up, they also "cook" the cancer. Research is still taking place in this regard, but the applications in cancer treatment are promising. Zhang et al. also emphasize that "many biomaterials, such as DNA, viruses, and sugars, have been used as biological templates to grow nanostructures of noble metals" (2006, p.

1134). Such structures can be utilized for everything from electrical wiring to cancer research.

3.5 The Adoption Gap: “From Bench Top to Bedside”

3.5.1 Medicinal Nanobots: Not Quite Human

The idea of mainstreaming nanotechnology as clinical practice often bumps up against the *realities* of clinical application. In this sense the hype, buzz and promise of nanotechnology, emphasized in grant applications, in the media and by institutions, can come crashing down once it enters day-to-day life outside of the lab. Dr. Chris Nguan, and the two anonymous participants referred from 4D Labs and Genome BC, emphasized the likelihood of a pronounced “adoption gap” in terms of the use of nanotechnologies in clinical settings (C. Nguan, interview, April 11th, 2008). Drawing from his experience conducting “Canada’s first robot assisted living donor kidney surgery” with the Da Vinci Robot at Vancouver General Hospital (Vancouver Coastal Health, 2007, p. 1), Dr. Chris Nguan goes on to explain that:

You’ve got to realize that people who do any sort of clinical work will never be the first in line because they are so cautious about it, especially in a completely new field like nanotechnology where it’s not an evolution of something, it’s a completely new thing, in which case the penetration would be markedly slower....I think it’s just like robotics, people were scared for a little while, AHHH I don’t want, you know, robot hands, I want my surgeon to have hands, human hands and the bottom line is the machine’s action refine the human components. I don’t know if that’s the case for nano, I don’t know if they are completely autonomous in any way, but it’s just getting over that mindset, the public perception and that only happens if you have proof of concept (C. Nguan, interview, April 11th, 2008).

Evident in Dr. Nguan’s narrative is an understanding of nanotechnology as completely distinct from previous technological innovations; “it’s not an evolution of

something, it's completely new.” He also expresses uncertainty as to the capacity of “nanobots” to operate the same way as the Da Vinci Robot in computed corrections to human hands. Furthermore, nanobots, like the Da Vinci Robot, are suspect because they are not human -- the adoption gap is perceived as a distinct consequence of negative public perception.

Although researchers emphasize that nanobots have yet to be developed, science fiction publications and the work of futurist Eric Drexler (1986) have influenced the perception of nanobots. For example, in a report prepared for the United States National Science Foundation (NSF), Smalley emphasizes: “The principal fear is that it may be possible to create a new life form, a self-replicating nanoscale robot, a “nanobot”. . . . These nanobots are both enabling fantasy and dark nightmare in the popularized conception of nanotechnology. . . .” (Smalley, 2000, p. 116). In a 2004 publication, Drexler emphasized that the fear of nanobots in the US has impacted the flow of funding for nanotechnological research – with the government directing resources away from suspect research paradigms (Drexler, 2004).

3.5.2 Quality of Life Versus Clinical Application

Informant A stressed the disconnect that can occur between medical research in the lab and the realities of clinical application:

I had a mortifying conversation with one of the hospitals here and it was probably one of the most culturally challenging conversations...we have some technology and I was going in naive and I was even naiver, there are layers and layers of this, and we had a technology that we thought was now great for drug delivery and we went in there, this is a new potential drug delivery system and you know, it uses different types of light and we went down to the skin centre and pitched it as a, you know, it's activated by ambient light, if you have a tumor on your skin...you use this on your

skin in a salve and it just slowly releases so that every time you step out in the sun, so you don't have to go and get treatment. They explained the cultural situation. They put a reality check on it. You're a patient. You come in and you have a big gnarly tumor on your skin. You've got two choices. They can put salves on it [or] they can irradiate it, ours I think is better, but they can irradiate it with light and they can kill the tumor and you can watch this big gnarly tumor thing kinda get grown over and leave scars or they can cut it out and give you a scar. Which would you choose?

Interviewer: I'm going to go for the scar in a day.

In this response it becomes clear that innovations in the lab do not always fare well in practice. The acceptance or refusal of treatment may be linked not to the outcome, but to the treatment process itself and the treatment's impact on quality of life, comfort, and in the case of "gnarly tumors," even the aesthetic impact of a slowly languishing tumor.

3.5.3 Structural Issues in the Healthcare System

Participant B emphasizes an already existent lag in the adoption of medical technologies developed 15 years ago, let alone nanotechnology. Also central is the idea of clinician trust of new technologies. Participant B goes on to explain:

There is what I always call an adoption gap. This adoption lags and sometimes it's very serious because there are technologies that were developed 15 years ago and they are just getting into the medical system and it has a lot to do with how clinicians are, I suppose, open to using them. So it has a lot to do with how quickly they can trust these diagnostics and how often they pay or reimburse the payment of it. I think it is going to be a long time, and long meaning 10 years, before we start commonly using this as if we were to use anything today - anything that's accepted today, and that's unfortunate because the technology is probably sooner than that and we could probably accelerate it if we wanted as well (Participant B, interview, February 1st, 2008).

Participant B also emphasizes structural issues and the "fragility" of nanotechnology:

Health systems also don't have the bandwidth either from a training or infrastructure standpoint or indeed, more importantly, from a financial standpoint, to start replicating those tests in a parallel sense, right? They

just want to use something that is as cheap as possible, the best from a false negative or false positive standpoint and that's what they have in the system right now and they are imperfect, they could be a lot better but the investment probably isn't worth it at this point because you know really this technology is still quite fragile (Participant B, interview, February 1st, 2008).

If Participant B's opinion about the costs of nanotechnologies as a barrier to clinical adoption are true, then cost-effective lab-on-a-chip technologies may be the first applications articulated through the nanotechnological in BC to adopted for clinical use.

3.6 Medical Nanotechnology, Transdisciplinary Alliances and “Good Science”

3.6.1 Good Science is Transdisciplinary

Collaborative medical research networks abound in British Columbia. Some of the networks are obvious (immunologists and physicians), some of them less so (geologists and urologists). Medical researchers repeatedly emphasized a personal need to be open to unlikely collaborations and transdisciplinary perspectives. This came as no surprise given that nanotechnology is commonly characterized in medical and scientific literature as unprecedentedly transdisciplinary. These understandings were echoed throughout the interviews, with the exception of Participant A, who commented: “I don't see nanotechnology as being as unique in that approach or that aspect of it, there are a lot of aspects in genomics that require everything from computer engineers to the biologists” (Participant A, January 17th, 2008). Participant A also explicitly qualified “good science” as “transdisciplinary” in nature.

3.6.2 Reverse Engineering Kidney Stones and Nucleation Crystal Growth

At the time of my interviews, 4DLabs was actively seeking movement from a “conversational” collaboration with UBC’s Robotic Surgery Centre to a full “research” collaboration. The connection? Kidney stones. When I contacted the VCHARI for a suggestion regarding participants to interview, the associate director directed me to Dr. Larry Goldenberg, who in turn recommended Dr. Chris Nguan. Dr. Nguan discussed transdisciplinary research alliances, including the link between geology and urological surgery:

I read widely and I explore widely with my colleges and I go to seminars in fields that don’t seem related to medicine, like geology for instance or mathematics and that’s kind of what you need to do in order to cross pollinate your brain, because who would have thought that geologic fragmentation principles as well as acoustics would be involved in one of the ways that we deal with one of the most important urological problems like kidney stones, and who would have thought we need to know about fracture lines and all that stuff (C. Nguan, interview, April 11th, 2008).

4D Labs researchers have met directly with urological surgeons to discuss potential approaches to kidney stones. Synthetic chemists at 4D Labs can “reverse engineer” a kidney stone or map “nucleation crystal growth” to gain a better understanding of how kidney stones are formed. Throughout my interview Participant A described a close working relationship with local hospitals and a desire to collaborate and assist surgeons “elbow deep in patients” (Participant A, January 17th, 2008). Participant A emphasized that after an initial consultation with surgeons, for example, research at 4D Labs tended to adopt the following trajectory:

We have to identify, ok, we are going to need biochemists, and molecular biologists, we’re going to need to get our new materials integrated so that the cells don’t just reject them, for example, and then biochemists, when they show success, the next step is to have kinesologists, tissue modeling

people, animal modeling people, who have program models to see if they work in the nanomodel and you can go onto the next stage of the patient model. In imaging you have to have radiologists, you have to have all the different engineers on board. So we, before we even figure out what is the role of each one in it's specific science, is what are the different team members that are needed, hypothetically, for the project and then we find the team members and with the help of the team members we hone down the idea so it's actually now a project to take on.

Computer programs that provide models for working with live tissue can be central to transdisciplinary problem solving within medical contexts. In this sense, virtual reality is enrolled in medical research, and at the far end of the spectrum in clinical application itself. The Israeli start-up company Optimata, in collaboration with Nottingham City Hospital and Cancer Research UK, recently developed a "Virtual Cancer Patient Engine" (VCP) (Blackburn, 2006). A clinical trial of the computer program "enabled doctors to correctly predict how individual breast cancer patients will respond to chemotherapy treatment" (Blackburn, 2006). With an accuracy rate of 70%, the VCP allowed a 40% increase in "predictability" with a small sample of 33 patients. While such innovations speak to promising new developments in cancer treatments, there are also concerns. Haraway notes the propensity for model fetishization in technoscience, cautioning that models strip away social, historical and political, context mistaking "the map and its reified entities for the bumptious, nonliteral world" (1997, p. 135). The use of complex computer technologies also calls attention the vast networks of resources, tools and relationships that stand behind a boundary object like nanotechnology.

In the next chapter I document nanotechnology-in-action as it intersects with communities of practice invested in toxicology and regulation in BC. Policy analysts, activists, and those critical of the food industry characterize a threatened

nanotechnologically-mediated body subject to the toxic impact of nanoparticles. The intersection of communities of practice invested in nanotechnology and the body is also explored through the case study of the Canadian Cancer Society.

4: NANOTECHNOLOGY AND HARM

- Interviewer: I have a stack of medical studies pointing to some of the toxicity concerns on my desk and the other pile speaks to the medical applications that people are working on, a very interesting issue.

- Participant C, Environmental Policy Analyst: It's not without benefits, absolutely, but to ensure that the benefits do not come with their own set of costs is, in the end, advantageous from all perspectives.

4.1 Introduction

Chapter 3 introduced the vital nanotechnologically-mediated body -- the hope for better treatments and diagnoses of disease. This hope was located in the specificity of nanotechnological applications – the finely tuned targeting of cells and treatments geared to individual molecular profiles. But this same specificity also alarms regulators, environmental activists and consumer groups. It is the tininess of nanoparticles, their ability to collect in human tissue in a manner quite different from larger particles, that characterizes the nanotechnologically-mediated body as threatened. Chapter 4 addresses communities of practice primarily invested in toxicology and regulation – locations where nanotechnology is understood to pose a danger to the human health. Finally, intersections of communities of practice are explored; for example, the Canadian Cancer Society's involvement both in the articulation of research through the nanotechnological and in efforts to regulate nanotechnology itself.

4.2 1. From Nanotechnology to Nanoparticles: Nanotoxicology in the 21st Century

4.2.1 Nanoparticles and Harm

“Nanotoxicology⁶” was proposed as a new subcategory of toxicology in 2004 by Donaldson, Stone, Tran, Kreyling and Borm in the *Journal of Occupational and Environmental Medicine* (2004, p. 728). The proposal came in the wake of increasing concerns regarding the toxicity of ‘nanoparticles’ (NPs) and the growing use of engineered NPs in food additives, diagnostics, medical research and industrial products. Like other authors (Faux, Tran, Miller, Jones, Monteiller & Donaldson, 2003), Donaldson et al. characterize NPs as qualitatively different from their larger counterparts. They point out, “[i]t is self evident that the smaller particles are, the more surface area they have per unit mass; therefore any intrinsic toxicity of the particle surface will be emphasized” (2004, p. 727).

Specific ‘nano’ particles can themselves be rallied as boundary objects within diverse communities of practice. Carbon molecule C⁶⁰, the Bucky Ball or Fullerene, named after architect Buckminster Fuller for his geodesic dome designs, is often used as a symbol of nanotechnology across communities of practice. For example, Nanotech BC incorporates a Bucky Ball into its logo. In the field of “nanotoxicology” the

⁶ Nanotoxicology, from the Greek “Nano” + “Toxicos” + “logos.” In “Murdered Words: Some Recent Linguistic History” John Healy emphasizes: “In classical Greek, *toxicos* meant ‘relating to the bow or archery.’ It was a practice of Scythian archers to smear a mixture of dung, snake venom and human blood on the tips of their arrows, and the poison so used was referred to by the Greeks as *toxikon pharmakon*, ‘the archery drug.’ By the time the adjective *toxicos* entered the Latin language (as *toxicus*), the meaning of the noun *pharmakon* --- drug or poison --- had attached itself to the adjective *toxicos*, which thus came to mean not ‘of the bow’ but ‘poisonous’ (2003, p. 1).” *Nano* refers to “dwarf” (Fogelberg & Glimell, 2003, p. 10) and *logos* is derived from the verb “legō,” meaning to “count,” “say,” or “speak” (Liddell & Scott, 1996).

characterization of nanoparticles takes on additional meaning as researchers, regulators, environmental activists and consumer groups attempt to assess threats to human health.

Nanotoxicological studies have a tendency to break down NPs into ‘natural’ NPs, or existing nanoparticles, ‘unintentional’ NPs, such as those produced as a consequence of car pollution, and ‘intentional’ NPs, or those specifically engineered by humans. As later sections of this chapter emphasize, natural and unintentional NPs are often rallied in arguments against ‘restrictive’ regulations, but they are also sometimes rallied in arguments for stricter regulation. In the literature, intentional NPs tend to be situated as in need of further study or a cause for considerable concern in regards to toxicity.

In 2004 the United Kingdom’s Royal Society and Royal Academy of Engineering released “Nanoscience and Nanotechnology: Opportunities and Uncertainties,” a report assessing nanotechnology as an emergent field (Royal Society & Royal Academy of Engineering, 2004). Drawing from past studies of pharmaceuticals,⁷ air pollution,⁸ quartz,⁹ and asbestos,¹⁰ the RSRAE situate the key determinants of NP toxicity in relation to: 1) the combined surface area presented to organs; 2) the actual dimensions of the NPs, which facilitate penetration into organs or cells or block NP removal; 3) potentially, the solubility of the NPs, i.e. their ability to disperse before the onset of a toxic reaction; and 4) the “chemical reactivity of the surface (including any surface components such as

⁷ *see* Borm & Kreyling 2004; Illum et al. 1987

⁸ *see* Dennekamp, Mehenni, Cherrie and Seaton, 2002; Brook et al., 2004; Peters et al., 2000; Peters et al., 1999

⁹ *see* Seaton et al., 1995; Vallyathan 1994

¹⁰ *see* Mossman, Bignon, Corn, Seaton, Gee, 1990; Wagner et al., 1982

transition metals and coatings), and particularly its ability to take part in reactions and release free radicals”¹¹ (Royal Society & Royal Academy of Engineering, 2004, p. 41).

Researchers have highlighted key pathways for human exposure to NPs, including skin contact, ingestion, inhalation and exposure through infusion or injection (Stern & McNeil, 2008, p. 5). Chan-Remillard and Kapustka emphasize that potential for exposure can occur throughout the lifecycle of a NP, including during the research and development phase, manufacturing, commercial use and following disposal (2008). While the majority of studies of NP toxicology in vivo¹² focus on the impact of NPs on the mammalian respiratory system (Oberdörster, Oberdörster & Oberdörster, 2005, p. 829), collectively studies point to the negative impacts of certain NPs on not only the lungs, but also the skin, particularly damaged, dry or creased skin (Oberdörster et al., 2005, p. 834), blood (Kreyling, Semmler & Moller, 2004), the heart (Donaldson et al., 2004, p. 728), the liver (Oberdörster et al., 2005, p. 837), gut (Hussain, Jaitley & Florence, 2001), brain (Kreuter, Shamenkov, Petrov, Ränge, Cychutek & Koch-Brandt, 2002; Orberdorster, 2004), nervous system (Donaldson et al., 2004, p. 728), bone marrow (Oberdörster et al., 2005, p. 823), spleen (Oberdörster et al., 2005, p. 823), kidneys (Oberdörster et al., 2005, p. 837), lymph nodes (Oberdörster et al., 2005, p. 823) and mitochondria (DeLorenzo, 1970; Foley, Crowley, Smaih, Bonfils, Erlanger & Seta, 2002). NPs may also bind to proteins with unexpected consequences, including possible functional changes in proteins (Donaldson et al., 2004, p. 727).

¹¹ Materials with high chemical reactivity are of concern to toxicologists. “Free radicals” are molecules which contain an odd number of electrons and have a half, or open, bond and are, therefore, very reactive and have the potential to cause harm to the human body (Taber's Cyclopedic Medical Dictionary, 2009).

¹² Simply put – in a living organism.

One of the most broadly cited studies of NPs and toxicology describes the oxidative stress¹³ of uncoated fullerenes (C⁶⁰)¹⁴ on the brains of juvenile largemouth bass and indicates both depletion of glutathione¹⁵ levels and oxidative damage (Overdörster, 2004, p. 1058). In a recent Canadian study, 14¹⁶ NPs were tested in marine water, freshwater, and terrestrial environments, including: Sheepshead Minnow and bacteria in marine water; Fathead Minnow, Algae, and Daphnia¹⁷ in freshwater; and Nematode¹⁸ and Alfalfa in a terrestrial environment (Chan-Remillard & Kapustka, 2008). Toxicity was found to occur in each “ecological compartment”¹⁹ and all “trophic levels,²⁰” raising considerable concern (Chan-Remillard & Kapustka., 2008). However, the study also found toxicity to be dependent on the types of particles under study, the manner in which the particles aggregated and the particular organisms utilized for testing. Political Scientist, Sylvia Tesh (1996), has highlighted scientific disputes regarding the use of animals as models for humans in toxicity studies. Tesh emphasizes the difficulties in translating results across species. For example, in studies of carcinogens, rats are often used as test subjects; however, rats commonly receive much more concentrated doses

¹³ “Oxidative stress” refers to the damage to cells caused by the formation of “oxygen-derived” free radicals in the body (Taber’s Cyclopedic Medical Dictionary, 2009).

¹⁴ A particular type of engineered carbon molecule often used as a ‘flag’ or ‘symbol’ for nanotechnology more generally.

¹⁵ Glutathione levels are important for many reasons, including the “[protection of] red blood cells from oxidative damage” described in the footnote above (Youngson, 2005).

¹⁶ Among the 14 NPs studied were diamond, cerium oxide, multiwalled nanotubes, titanium oxide, hydroxyapatite, aluminum oxide, silver, silver copper, silicon dioxide, barium strontium titanium oxide, carbon, copper, graphite and C⁶⁰.

¹⁷ More commonly - water flea.

¹⁸ More commonly – round worm.

¹⁹ The concept of ecological “compartments” can be used in ecological risk assessments to delineate species “that have similar routes of exposure due to their common trophic habits” (Suter, Sample, Jones, Ashwood & Loar, 1995: 3-1). Suter et al. point out that “trophic groups are not necessarily similar in their sensitivity to contaminant exposures because they may include species from different taxonomic classes” (1995: 3-1).

²⁰ Trophic levels can be understood as the position each species is seen to occupy on the food chain – what a species likes to eat and what likes to eat it (Lévêque 2003: 134).

“than humans would be expected to receive” given that “enormously large numbers of rats would be necessary to detect a toxin administered at doses corresponding to human exposure” (Tesh, 1996, p. 53). Like other toxicological studies, the bodies of animals are pervasively enrolled in debates regarding the safety of nanotechnology and the impact of NPs on the human body.

4.2.2 The Controversial Quantum Dot

Quantum Dots (QDs) are “fragments of semiconductor consisting of hundreds to many thousands of atoms-with the bulk bonding geometry and with surface states eliminated by enclosure in a material that has a larger band gap” (Alivisatos, 1996, p. 993). QDs also “exhibit strongly size-dependent optical and electrical properties” (1996, p. 993). Due to these unique properties, including their small size and “long-term fluorescence stability,” Quantum Dot (QD) NPs are widely used as biomarkers (Clancy, 2007, p. 2). Researchers can choose from an assortment of colours, ranging from “Hops Yellow” to “Lake Placid Blue” (4enr.com, 2007). In visualizations of cells, for example, colours may be mixed and matched to produce not only an image of an individual cell – but parts and “functions” of the cell itself. Because QDs are engineered particles, researchers can “easily modify the surfaces of such particles for specificity to certain tissues or molecules” (Marziali & Associates, 2006, p. 11).

Participants in this study emphasize that Quantum Dots are used extensively by researchers in British Columbia. It is the unique optical properties of materials as they approach the size of the wavelength of light itself that facilitates the fluorescent capabilities of QDs (Marziali & Associates, 2006, p. 11).

In a study conducted at the University of Alberta, the uptake of QDs in chicken embryos were found to “collect significantly within blood vessel tissue of the CAM [chorioallantoic membrane]²¹ of the embryo,” pointing to the toxic impact of NPs on embryos more generally (Clancy, 2007, p. 97). The researcher concludes that the pervasive use of QDs as biomarkers “despite insufficient knowledge of their physical interactions with biological tissues” may be ill advised (2007, p.2). Participant B echoes this view: “using quantum dots or some sort of nano-particle to carry a fluorescent imaging particle, and that’s starting to happen, I think there’s still a toxicity question around that” (Participant B, interview, February 1st, 2008).

4.2.3 Occupational Safety

Given NP exposure concerns, the Canadian Safety Council (CSC) has actively highlighted “nanotechnology” as an emerging worker safety risk (CSC, 2006). The United States National Institute for Occupational Safety and Health has issued the following statement:

The unique physical and chemical properties of nanomaterials, the increasing growth of nanotechnology in the workplace, and information suggesting that engineered nanoscale materials may pose a health and safety hazard to workers all underscore the need for medical and hazard surveillance for nanotechnology. Every workplace dealing with nanoparticles, engineered materials, or other aspects of nanotechnology should consider the need for an occupational health surveillance program (Department of Health and Human Services, Centre for Disease Control and Prevention and the National Institute for Safety and Health, 2007, p. 138).

While specific definitions of nanotechnology diverge, very real health concerns are articulated through the nanotechnological and NPs more generally. In this case,

²¹ The CAM can be understood as a key membrane within a rich network of blood vessels, arteries and veins linked to embryonic circulation (Dye, 2002).

stabilization of terminology may be linked to the ability to regulate and protect workers and consumers from harm. Commenting on Canada's involvement with the International Organization for Standardization's efforts to standardize nanotechnologies, Journalist Rob McMahon states: "Alan Guest [former Executive Director of Nanotech BC] talks about how there is an international body that is trying to come up with a standardized definition of what nanotechnology is, so once you have those kinds of definitions in place you have more regulation" (R. McMahon, interview, April 10th, 2008). Still, critics remain, citing the fact that much research remains to be done and that the focus should be on "material-specific," rather than "size-dependent," analysis (Stern & McNeil, 2008, p. 4-5). Whatever the arguments may be, certain particles, governed in previously unrealized ways, demonstrate the potential for both help and harm to human health.

4.3 2. Rallying Incidental Nanoparticles

4.3.1 The Case of Air Pollution

"Natural" and "incidental" nanoparticles are often cited in arguments for the relative safety of nanotechnology and, in Canadian contexts, the effectiveness of current Canadian health regulations to govern "nanoscale" particles. Incidental nanoparticles, as a consequence of pollution, are particularly emphasized. During the course of my interview Participant B compared nanotechnology directly to air pollution:

Is nanotechnology potentially dangerous? Yes, but anything is. We've been breathing stuff out of smoke stacks for a hundred years, is that dangerous? Potentially, yes. So it's all about giving people information, the big problem is this preconceived notion around what these enabling technologies, what these very high tech things are (Participant B, interview, February 1st, 2008).

In juxtaposition, the United Kingdom's Royal Society and Royal Academy of Engineering's report on nanotechnology uses previous studies examining air pollution and health to underscore distinct concerns associated with nanotechnology. In this sense "incidental" nanoparticles can be rallied to highlight either difference from, or continuity with, other materials in terms of potential threats to human health.

4.4 3. "We already eat 1, 000, 000, 000, 000 Nanoparticles Per Day": Nanotechnology and the Food Industry

4.4.1 Nanotechnology in Your Food

In efforts to counter "negative perceptions" of nanotechnology, Stern & McNeil indicate that tiny particles are already part of a "normal" diet -- "it is estimated that the average person consumes 1012 submicron-sized particles per day in a normal diet as a result of food additives consisting primarily of titanium dioxide (TiO₂) and aluminosilicates" (Lomer cited in Stern & McNeil, 2008, p. 5). Titanium dioxide, the chemical invoked as part of the "average" diet, is commonly explored in nanotoxicology. While larger particles of titanium dioxide have proven relatively harmless, research indicates that smaller particles of substances such as titanium dioxide can cause an assortment of health concerns, including damaged tissue and pulmonary inflammation (Oberdörster, Ferin, Finkelstein, Wade & Corson, 1990; Oberdörster, Ferin, Gelein, Soderholm & Finkelstein, 1992; Oberdörster 1996). Participant C, a environmental policy analyst from the David Suzuki Foundation, emphasizes this tension in relationship to Canada's National Pollutant Release Inventory (NPRI): "[there exists] the possibility that some industrial facilities in Canada [will] move away from larger volume chemicals

that are captured by the NPRI and [will] switch to lower volume, but potentially more toxic products” (Participant C, interview, April 24th, 2008).

4.4.2 Nanotechnology Versus the Organic Movement

With experience as a “beat reporter” for Canada’s Baking Industry, journalist Rob McMahon has explored the use of “nanotechnology” for nutritional and flavour enhancement, preservation and anti-microbial properties. Within markets in British Columbia there is growing emphasis on food sustainability and local organic foods. Rob emphasized the tension between this trend in BC and the use of practices articulated through the nanotechnological in food production:

...based on interviews with the food industry [about nanotechnology], I mean some people say there is going to be a massive impact on the industry, billions of dollars funnelling into products, but then other people, including one of the people I interviewed, say that it kind of goes against the general trend in food, we’re kind of moving towards more organic food and just sort of more naturally sourced things (R. McMahon, interview, April 10th, 2008).

Author and activist, Stacy Malkin also emphasized the movement toward organic products, including the ways advertisers utilize the organic label for marketing. Central to Malkin’s discussion is the use of carcinogen 1, 4 - Dioxane in shampoos and beauty products:

There aren’t any regulations that help consumers tell the difference between truly natural products and those marketing themselves as natural...you’ll find that Herbal Essences [shampoo] is actually masquerading as a natural product...they use to have that marketing campaign, the organic experience, with the sexual scene, you know it was the orgasmic experience was the undertone...but it’s really the petro-chemical experience and it was the product that was found to have the highest levels of 1,4 - Dioxane according to product tests done last January (S. Malkin, interview, February 28th, 2009).

These issues not only tie into the strategic use of “nature” in advertising, but current debates regarding Genetically Modified Organisms and perceptions of nanotechnology.

4.4.3 Comparisons to Genetically Modified Organisms

Nanotechnology is often compared to GMOs and GMOs have framed much of the debates regarding nanotechnology and health. Rob McMahon emphasizes:

...in the current nanotechnology environment there is that tension and that GMO background I guess...one of the articles, one of the sources, I should say [that Rob interviewed], that was somebody from the consumer group, I believe, they talk about that actually, like the connection. The potential it might have for their marketing department in terms of the GMO connection, there are certainly companies that don't use it (R. McMahon, interview, April 10th, 2008).

At the Nanotech BC sponsored Cascadia Nanotech Symposium several presenters placed emphasis on the need to “control” public perception, albeit with the argument from the conference's only participating social scientist, Maryse de la Giroday, that you cannot control public perception (de la Giroday, 2008). In the United Kingdom, the pronounced enrolment of social scientists in ethical, legal and social think tanks addressing nanotechnology and health has been fostered in large part by negative reactions to GMOs in the country (Doubleday, 2006). Participant B describes negative responses to GMOs:

I can't think of an area [nanotechnology] that's been more assaulted by previous cartoons and previous science fiction...I'll tell you there are a lot of people who think genomics is scary and it's because it's this genetic modification thing, it's the Frankenfood, who came up with that moniker I don't know but media certainly rode it, you know, I'm not pinning it on media by any means, they do the best they can do, but frankly there is always some paranoia, in some ways some excitement and some hope. Depends on what your stance is, but there is paranoia now (Participant B, interview, February 1st, 2008).

As Darren Frew outlined different province's investments in nanotechnological research he discussed nanotechnology and agricultural research in Saskatchewan:

Generally speaking if you really want to understand your community, understand how you are industrially. It just happens that we have a lot of industries here in British Columbia that can benefit from nanoscale technology. If you are simply in agriculture, you know Saskatchewan... probably one of the most developed plant biotech clusters in the world; however, there is not a lot of use for nanotechnology [there] outside of agriculture (D. Frew, interview, January 24th, 2008).

The concept of nanotechnologically enhanced agriculture is particularly prevalent in the United States. For example, at the 2006 Annual Society for Social Studies of Science Meeting in Vancouver, BC, I found posters and flyers for a conference on "Agro-Nanotechnology" at Michigan State University. On the flyers was a (re)vision of the iconic painting "American Gothic" by Grant Wood (1930). A couple made out of what appear to be tiny molecules stand in a future reconfigured, pitchfork floating between them. Armless, they stand beneath a giant question mark, over which the words "Agrofood Nanotechnology? Applications, Participation and Convergence" are superimposed. I did not come across as much emphasis on "agro-nanotechnology" in Canadian literature, with the exception of a heavy critique from the environmental organization the ETC. Group lead by Pat Mooney in Ottawa, Ontario (ETC Group, 2009). However, the (re)vision of "American Gothic" may speak to future invocations of "Agro-Nanotechnology" in Canadian contexts.

4.5 Advertising and the Nanotech Moniker

4.5.1 To use or not to use the Nanotech moniker?

Central to my conversations with Rob McMahon was the tension regarding whether or not companies should choose to use the nanotech moniker for marketing. While the nano prefix has been utilized for everything from Apple's "iPod Nano" music player, to Kleinmann's "Magic Nano" bathroom cleaner, and the Eagnas "Nano Tennis String" there are reports that some companies have gone so far as to label their products "nano-free" (Hartman Group cited in McMahon, 2007). Rob emphasizes, "you know personally, I want to have the choice to ingest those kinds of things" (R. McMahon, interview, 2008, April 10th, 2008). Participant B also comments, "there is actually a lot of people who use nanotechnology who absolutely refuse to call themselves nanotechnology, because that is their, whoever they are selling to, or relating to, will get the wrong idea about what they do" (Participant B, interview, February 1st, 2008).

One of the most widely reported incidents of toxicity associated with nanotechnology is the case of the German bathroom cleaner "Magic Nano" (Wolinsky, 2006). Magic Nano was found to cause respiratory problems. The harmful effects of the product were publicized by groups arguing for stricter regulation of nanotechnology; however, Wolinsky emphasizes that respiratory ailments associated with its use were likely the consequence of ethanol-water spray (2006). Whether 'eaten' or 'breathed', NPs are rallied for a variety of arguments regarding nanotechnology and human health.

4.6 Corporate Pink Ribbons, Medical Waste and Cosmetics: Topographies of Nanotechnology and Trust

4.6.1 Trust

You know my grandmother had breast cancer; I had a breast cancer scare. I think all of us know [someone] and if it hasn't happened to us then someone close to us. Breast cancer is touching all of our lives...we hear a lot about hoping for the cure and this sort of passive waiting for the pharmaceutical companies to figure it out and help us save the day, all of which is important, but it's equally important to look at, ok, how can we prevent this disease and how can we reduce carcinogens in the environment. So it's disturbing to see these beauty companies using the pink ribbon as a marketing sales tactic and yet not willing to come to the table and discuss their use of carcinogens. – Stacy Malkin

Central to Malkin's understanding of nanotechnology and health is her work with the international coalition "Healthcare Without Harm" and the national coalition "Campaign for Safe Cosmetics." Malkin situates these projects with a sense of irony noting "hospitals [hospital incinerators] are pumping out one of the worst carcinogens" and that "companies using the pink ribbon as a marketing tactic" are "not willing to come to the table to discuss their use of carcinogens" (S. Malkin, interview, February 28th, 2008). Social scientists have commented on the "context-stripping effect" of biomedical discourse and practice (Mishler, 1978, p. 1-18). For example, Tesh emphasizes that:

These medical issues would not engage us, nor would they elicit such passion from scientists, were it not for the political issues underlying them. The environmental hypothesis, as I have described it, points to industrial production as the cause of disease and forces its proponents to the conclusion that to have a healthy population we must make changes in the economy. In other words, it wears its politics on its sleeve, in marked contrast to the germ theory and the lifestyle theory, which although as "political" as the environmental theory, appear to be neutral because they do not challenge the status quo" (1996, p. 55).

In this sense pharmaceutical research into cancer treatment often overshadows government regulations and the wide availability of carcinogenic products. This context framed Malkin's discussion of nanotechnology and health. In an excerpt from her book, reproduced in the BC magazine "Common Ground," Malkin emphasizes that:

As if there weren't enough concerns about the toxicity of cosmetic chemicals, manufacturers are rushing to incorporate nanotechnology that uses particles 80,000 times smaller than the width of a human hair. Nanotechnology has been touted as the next revolution in cosmetics and packaging. However nanoparticles, being so tiny, have the potential to penetrate unusually deeply into the skin and organs, causing exotic physical effects....Animal studies show that some nanoparticles can penetrate cells and tissues, move through the body and brain and cause biochemical damage. As one example, carbon fullerenes – also called buckyballs, and currently being used in some moisturizers – can cause brain damage in fish, and even low levels of exposure can be toxic to human liver cells. The health impacts of nanomaterials in cosmetics and sunscreens remain largely unknown, pending completion of long-range studies that have only recently begun. But that's not stopping the cosmetics industry from leading the charge to incorporate the inadequately tested technology into products we put on our faces and in our hair (Malkin, 2007, p. 52-53).

Malkin firmly places nanotechnology in a domain of little trust. Furthermore, in discussions of nanotechnology and health, Malkin does not differentiate between the environment and humans: "the environment is our bodies, it's about our health" (S. Malkin, interview, February 28th, 2008). Ultimately nanotechnology occupies a highly contentious domain of both trust and little trust in corporate conduct.

4.6.2 Biomonitoring

Stacy Malkin and Participant C, Environmental Policy Analyst for the David Suzuki Foundation, emphasize the use of human "biomonitoring" in their efforts to reform health regulations. Rooted in ecology, biomonitoring can be understood as the measurement of chemical substances in the body. In humans "measurements are usually

taken in blood and urine” and sometimes “hair, saliva or breast milk” (Government of Canada, 2008). One of the critical recommendations in the Suzuki Foundation’s “Prescription for a Healthy Canada Report” is consistent biomonitoring to assess the impact of chemicals on Canadians. Participant C notes that:

One of the recommendations in there has to do with consistent and regular biomonitoring, just to find out, to have a better sense of what chemicals, what products are in bodies of Canadians... that includes some of the nanotechnology products and byproducts and will help us to better understand exposure levels, and then obviously again increasingly the resources for environmental health research so that there is more information available about what the consequences might be of those exposures (Participant C, interview, April 24th, 2008).

Malkin situates the birth of babies “pre-polluted:”

When you start to see and think about the science of bio-monitoring, that chemicals are in all our bodies and in all our breast milk, getting into babies before they are even born, that to me is at the point which we really have to say, how can we do things differently than we’ve been doing them (S. Malkin, interview, February 28th, 2008).

Within Canadian contexts landscapes of pollution are also highly stratified. For example, rural aboriginal communities have long borne the brunt of mercury pollution in the country as a consequence of industrial activity (Wheatley & Paradis, 1995).

Throughout my study, participants B and C both emphasized the need for Environment Canada to invest more spending in environmental research, including nanotechnological “risk assessment.” Contractor, Participant B remarks that “I don’t think the money is available. It’s not anywhere right now. The toxicology stuff is funded through our granting agencies and things like that but there aren’t any nanotech programs” (Participant B, interview, February 1st, 2008).

4.6.3 An Environmentally Friendly Nanotechnology

At the Cascadia Nanotech Symposium (2008), many of the presenters also emphasized an environmentally friendly nanotechnology, in the use of nanotechnological applications to clean up pollution. This is in line with recent media reports which indicate applications in everything from water purification: “cleaning up contaminated water is big business which explains all the companies coming up with tiny solutions” (Haiken, 2007); to oil spills: “Nano-technology 'paper' absorbs oil, cleans up pollution” (Vancouver Sun, 2008); and radioactive waste: “Nanoporous Sands Could Help Clean Up Radioactive Pollution” (Nanotechnology, 2004).

4.7 “Absence of Evidence is not Evidence of Safety”

4.7.1 “They’ve Got it Backwards”

Although Participant C, Environmental Policy Analyst from the David Suzuki Foundation, and Stacy Malkin are based in Canada and the United States respectively, both emphasized what they saw as a similar error in chemical governance; specifically, the tendency to allow the use of chemicals until proven harmful, versus extensive testing before market entry. In this view nanotechnology, like other chemicals, undergoes inadequate testing before entering consumer products and our bodies. Participant C explains:

We don’t know enough about how or where or in what quantities these chemicals are entering the environment and so when you don’t know that then it’s very hard to make good policy... The thing I want to highlight about the recommendations around stronger laws and regulations have to do with the idea, sort of a catch phrase, I guess, in international chemical management best practice would be ‘no data, no market.’ So that industries wishing to make use of new products and new chemicals need to demonstrate that they don’t pose unacceptable or environmental risk...we kind of got it backwards when we are in a position globally

where thousands of tons of nanotechnology products are being produced worldwide and yet now, after the fact, there is research that is starting to emerge about some pretty concerning health consequences. I mean, really, it should go the other way around, that some of those studies are done to assure us of a responsible safety margin before new products and technologies are going to be distributed... the development of nanotechnology should not proceed independent of a robust assessment of its environmental and health impacts... there is some research going on sort of on the side but the product to market is moving on a different path and that's just not responsible and not sustainable (Participant C, interview, April 24th, 2008).

Malkin also points out:

There is a lot that we don't know about chemicals that are in products and that's a challenge that we run into over and over again just with all of this work on environmental health there's a huge amount of stuff that we don't know. An absence of evidence is not evidence of safety, is what we say. And also the frustrating thing that we run into is the perception that, well, it's not even a perception, it's the way that the law works in the US, that you have to be able to prove harm before we can take action...you know what we know so far is that a lot of beauty products do, at least a couple of hundred have been identified that claim to use nano - a lot more might use it but aren't saying. And you know it's just another example of beauty industry claiming safety when they don't have any evidence of safety, sort of let's just put this stuff in products and worry about the problem later...I think that's where it really makes sense to employ the precautionary principle where you see that there are evidence of problems so let's hold off on putting it on our faces until we investigate it a little bit more...(S. Malkin, interview, February 28th, 2008).

Malkin further provides a comparison of chemical governance in Canada, Europe and the United States:

There is a hot list of chemicals in Canada that aren't exactly banned but chemicals that the government is warning industry away from. Europe of course has the list of 11,000 chemicals that have been banned from personal care products – then there is a list of CMR carcinogens, meaning the reproductive toxins – they call it the CMR list. In the US we have no lists, well there is a list of, like, 11 things you can't use as products, like asbestos and vinyl chloride (S. Malkin, interview, February 28th, 2008).

The David Suzuki Foundation's "Prescription for a Healthy Canada" also critiques Canada's "hot list" of chemicals, the Pollutant Release Inventory. Boyd notes that the list is rendered ineffectual by several factors, including corporate self-reporting, no independent audit of reporting and the inclusion of only about 300 of the "thousands" of chemicals in use in Canada (2007, p. 39). The list also does not cover consumer products; "pollution from mobile sources such as cars and trucks;" pollution from gas stations, dry cleaners, smaller manufacturing facilities, agriculture; and urban runoff (Boyd, 2007, p. 39). Another point of focus in interviews with Malkin and Participant C was the cumulative impact of chemical use on the human body – a little hair gel with endocrine disrupters here, some carcinogens in make-up there, a dose of chemicals from vinyl shower curtains every morning - in short, the gradual build up of chemicals in the body every day. Malkin discusses the difficulty at times in drawing a direct line of "cause and effect" in scientific testing, when exposures reflect a gradual culmination of chemical use over the years and over a span of products. Human biomonitoring, in this regard, is a powerful tool for the Suzuki Foundation, Healthcare Without Harm and Campaign for Safe Cosmetics.

4.8 Nanotechnology and Multiple Articulations: The Canadian Cancer Society

4.8.1 The Canadian Cancer Society

The BC Cancer Research Centre and the Canadian Cancer Society at times work together in the development of cancer treatments, including the Canadian Cancer Society's financial sponsorship of the BC Cancer Research Centre's research facilities and affiliated projects. At a point in this study, groups invested in cancer research and

nanotechnology collided two-fold: first, in research pertaining to cancer treatment; second, in support of the Suzuki Foundation's proposal for a national health strategy, "Prescription for a Healthy Canada" (Boyd, 2007). Participant C notes that,

The conclusion of this report lays out a proposed framework for a national environmental health strategy in Canada that would be a way of prioritizing work in this area. Rationally establishing priorities and consistently addressing threats to environmental health so the report, I guess, is both a kind of illustration of the problem and in a way the solution and through the response that it received. We have been really happy to work with some of the leading public health authorities in Canada on the report, it was actually launched in conjunction of the annual meeting of the Public Health Association ... the proposal for a national environmental strategy has received the support of the Canadian Medical Association as well as the Canadian Cancer Society (Participant C, interview, April 24th, 2008).

"Nanotechnology" is central to the report's recommendations and appears predominately in two sections. In Table 1.1, "Twelve Breakthrough Studies in Environmental Health," sandwiched between "5. Living near major roads affects children's lung development" and "7. Prenatal exposure to toxic chemicals can cause cancer in adults," nanotechnology appears as number 6; "Nanotechnology can have a wide range of toxic effects" (Boyd, 2007, p. 6-7). Another section of the report addressing "nanotechnology" emphasizes the inadequacy of Canada's National Pollutant Release Inventory, noting the NPRI does not require reporting on "new products generated by nanotechnology and biotechnology" (Boyd, 2007, p. 39). In this sense, the Canadian Cancer Society's support of "Prescription for a Healthy Canada" represents multiple articulations of nanotechnology – nanotechnology and health, in the support of the development of medical applications, and nanotechnology and harm, in the emphasis on nanotoxicology, risk and regulation.

The nanotechnologically-mediated body and nanotoxicology remain highly politicized issues. Many of the moral and political questions that follow are in fact rooted in existing technological practice, corporate conduct and economic paradigms haunted by an aversion to context. Canada's involvement with ISO efforts to standardize nanotechnologies may lead to enhanced regulatory paradigms – the protection of consumers and workers from something elusive yet salient – the boundary object nanotechnology.

5: CONCLUSION

5.1 Anthropological Contributions to Bioethics

With its emphasis on participant observation, day-to-day life, and phenomenological explorations of scientific practice, anthropology incorporates powerful critiques of bioethical paradigms. Medical anthropologist Rayna Rapp notes that, “the basic corpus of bioethical work currently exhibits a magisterial definition of American “society” as a unified field and a presumption that the impact of advances in medicine and its technologies might be universally assessed” (2000, p. 44). Participant B, self identified as the “business side of science” and referred from Genome BC, emphasizes that: “I think what we need to do is spend generously on the various social and environmental issues around nanotechnology, spend vigorously so that we can get it out of the way” (Participant B, interview, February 1st, 2008).

For anthropologists, ‘environmental’ and ‘social’ issues are never set aside. Context shapes the very idea of science and the very way science manifests in practice - always. This includes, humans and nonhumans, histories, politics, technologies, representations of life and the interventions into life that emerge from such projects. Anthropologists have also interrogated technological determinism and notions of unilinear social evolution for nearly a century (Boas, 1912, 1928), assertions often invoked in bioethics debates.

Ethnography’s emphasis on context rich investigation and insistence upon multivocality produces rigorous paradigms for examining the moral and political

questions that arise from biotechnological interventions. As much as anything else nanotechnology has origins. To tell this story, indeed the multiple stories, accounting for nanotechnology's birth in British Columbian medical contexts requires a commitment to multiple perspectives. My research calls for new ways to think about nanotechnology and the body, including the political and regulatory issues that arise. While ethnography has been used extensively in the United States and Europe to explore nanotechnology as practice, little research has been conducted in Canada in this regard. It is my hope that policy makers will take context seriously when formulating regulatory paradigms for nanotechnology in Canada and that healthcare practices articulated through the nanotechnological won't drop the link between health and less glamorous struggles for survival which mark the lives of so many in our province today (First Call BC, 2008; Health Officers Council of BC, 2008).

5.2 Observations: Nanotechnology and the Body Revisited

Drawing from ethnographic observations, an analysis of websites as information artefacts and qualitative interviews, I examined the following three questions:

- How can nanotechnology “inhabit multiple contexts at once and have both local and shared meaning?”
- How can people who live in one community “draw their meanings from people and objects situated there” and “communicate with those inhabiting another?”
- “What moral and political consequences attend” each of these questions” (Bowker & Star, 2000, p. 293)?

These three questions flowed from an initial question: What communities of practice in BC articulate their work in relationship to nanotechnology and the body and how do

people negotiate something as complex, ill defined and difficult to standardize in practice as nanotechnology? The answers to these questions took me from ISO decisions in Geneva to the many alpaca farms which dot Vancouver Island, to cancer treatments utilizing gold and “babies born pre-polluted.”

As a location of diverse embodied perception and powerful social semiosis, the body is elusive. Medical anthropologist Margaret Lock emphasizes that: “[d]espite increasing pressures we should, I believe, resist all pressures from the Other to produce tidy answers and “Just So” stories, remain eclectic in our approach, and be content with a body that refuses to hold still” (Lock, 1993, p. 148). In my own research, the nanotechnologically-mediated body occupied multiple contexts at once, accruing both local and shared meaning as my research progressed.

As examined in Chapter 2 of this thesis, three key observations follow from this investigation into the body and nanotechnology in BC. First, nanotechnology can be understood as a boundary object. Intermingled communities of practice in BC invested in the body utilized “nanotechnology” to bridge divergent worlds of practice and to negotiate agendas, hopes, fears and confusions affixed to the molecular.

Second, I found nanotechnology as a boundary object and classification of practices to be in the midst of transition to a standard. Increasingly there have been efforts to standardize nanotechnology, or nanotechnologies (depending on the boundary object chosen), at both the national and international level. In conjunction with the ISO the Government of Canada has played a central role in this push to standardize.

Third, actors collapsed nanotechnologies (a multiplicity) into nanotechnology (a singularity), a feat I call the singularity (re)vision, in order to meet the demands, promises

and potential of the market place. To reiterate -- much like the idea of wave function collapse in quantum mechanics, where wave function (a multiplicity) collapses into a single state upon introduction to the external world, nanotechnologies are reduced to a singularity where they meet the needs, agendas, ideas, histories and contingencies of market places, scientists, regulators and publics. The singularity (re)vision simultaneously collapses a multiplicity into a singularity, a boundary object and a classification. Furthermore, it is resisted in day-to-day scientific and medical practice despite public representations to the contrary.

5.3 Interview Themes: The Vital Nanotechnologically-mediated Body

Several key themes were gleaned from interviews with scientists, physicians, business leaders, and individuals invested in toxicology and regulation. In terms of the vital nanotechnologically-mediated body:

- In medical research, day-to-day issues in the laboratory, such as the texture of tumors, may impact the definition of “nanotechnology” and its use as a boundary object.
- For scientists and physicians the “nano” prefix does not necessarily signal “nanotechnology.”
- Medical research articulated through the nanotechnological is conducted within a value of highly individualized care and, as Rose (2008) points out, within the context of the increasing molecularization of life itself, including a “reorganization of the gaze of the life sciences: their institutions, procedures, instruments, spaces of operation, and forms of capitalization” (Rose, 2008, p. 44).
- Participants situate BC’s greatest contribution to nanotechnology in cancer research, particularly work by the BC Cancer Research Agency.

- Researchers perceive an adoption gap when it comes to practices articulated through the nanotechnological reaching patients, including: public and physician distrust of “nanotechnology,” inadequate healthcare infrastructure to support clinical nanotech applications, and quality of life issues that arise when innovations in the laboratory are put into practice.
- Researchers predict that medical applications articulated through the nanotechnological will reach patients in about 10 years time.
- Given participant responses, it is quite likely cheap “lab-on-a-chip” technologies will be the first medical applications articulated through the nanotechnological to reach patients in BC.
- Nanotech medical research is highly transdisciplinary, marked by unlikely collaborations, for example, between seismic scientists and urologists.

5.4 Interview Themes: The Threatened Nanotechnologically-mediated Body

In juxtaposition, interviews characterizing the threatened nanotechnologically medicated body spoke to the following themes:

- Ironically quantum dots, used extensively for medical research in BC, may in fact be toxic.
- The “nanoparticle” is a symbolically, socially and politically loaded concept and garners additional meaning within the context of debates regarding nanotechnology, health and regulation. Incidental, natural and engineered nanoparticles are rallied in arguments both for and against stricter regulation of nanotechnology in Canada
- Nanotechnology is often compared to Genetically Modified Organisms.
- The idea of nanotechnology in food runs counter to a current trend toward local organic foodstuff. Furthermore, “organic” or “nano,” “nano-free” may be employed by marketers strategically to secure consumers dollars.
- Context matters – current regulatory policies and corporate practice seldom take environmental models of health into consideration. For example, hospital

incinerators produce carcinogens and the cumulative effect of toxins in day-to-day consumer products is poorly recognized. This may in part be due to the fact that environmental models of health threaten the “status quo,” while highly individualized understandings of health locate illness in context-stripped biological processes or understandings of individualized, ‘risky’ behaviours (Tesh, 1995, p. 55). In this regard, biomonitoring was highlighted as a particularly effective tool for environmental organizations given the difficulty in accounting for the gradual accumulation of toxins in the human body.

- Nanotechnology occupies a tense zone of trust and little trust in corporate conduct.
- Policy researchers point out that the “absence of evidence is not evidence of safety,” expressing that in Canada and the United States the safety of products is not properly assessed given a lack of adequate testing prior to market entry.
- Communities of practice may harbour considerable nuance in their relationship to nanotechnology and the body. The Canadian Cancer Society, for example, occupies spaces engaged with both the vital AND the threatened nanotechnologically-mediated body.

5.5 Continuities and Departures

Medical anthropologist Courtney Mykytyn explores how predictions regarding nanotechnology’s future are linked to scientists’ moral “duty to predict” (Mykytyn, 2006, p. 23). Predictions, Mykytyn argues, “are a particularly ripe part of the ethnographic record as they tell us as much about our future and present as they do our past” (2006, p. 3). In my own research, predictions were so prevalent that definitions themselves often contained references to the future. For example, Health Canada emphasizes:

Nanotechnology is described as the application of nanoscience to develop new materials and products, and involves the manipulation of matter at the nanometer scale. It is a rapidly growing area **that could touch upon every aspect of modern life** (Health Canada, 2007, p. 1).

Nanotechnology represents both continuities with and departures from past scientific projects. There are also parallels to how previous technologies have been imagined. For example, a 1961 article by Radio Corporation of America staff writer Don Parker expounds upon the future of magnetic tape: “in the next ten years a thin ribbon of plastic, coated with minute flecks of iron oxide, will probably cause many changes in the life of the average person” (Parker, 1961, p. 119). Parker goes on to predict:

- “An electric hand movie camera that uses tape instead of film;”
- “Tape-directed robot housekeepers;”
- “A satellite postal system;”
- “Individual medical histories that will be recorded on tape, beginning with the first heartbeat;”
- “Miniature recording devices that will tape telephone messages;”
- “An attachment for home television sets that will tape-record television shows;”
- A reading device that could “not only be able to read a book electronically but also be able to translate it into several languages at lighting speed – say about five minutes” (p. 119).

There is also a multidisciplinary element akin to nanotechnology in Parker’s discussions. He emphasizes that “entertainment, industry, education, commerce, medicine and technological research” will be radically transformed by “the promises of magnetic tape” (p. 119). Cyrus Mody’s discussions of angstronics, scanning probe microscopy and nanotechnology, explored earlier in this thesis, also demonstrates how history is ever present in ideas about the future.

5.6 Nanomarkets

Nanotechnology's potential is also limited by and creatively articulated through the perils and promises of the market place. Furthermore, efforts to secure Ebeling's "nanomarkets" clearly shape the way nanotechnology is conceptualized and distributed. When applications articulated through the nanotechnological merge with understandings of progress and perfectibility – including understandings of material (economic), social and even biological evolution – economic investment in nanotechnology is naturalized. There is, therefore, a powerful connection between the framing of nanotechnology as the next Industrial Revolution and efforts by government and industry to secure nanomarkets as a viable economic endeavour.

5.7 Getting to the Bottom of Things

As an undergraduate student, the potency of "nanotechnology" as a topic of study first struck me because of the way nature as a concept is rallied in discussions of nanotech – the mastery implied in playing with the "building blocks" of life.

In 1935 scholar and physician Ludwick Fleck characterized the co-constructed aspects of scientific practice and "thought collectives" more generally. Fleck emphasized that "the explanation given to any relation can survive and develop within a given society only if this explanation is stylized in conformity with the prevailing thought style" (1979, p. 2). Concepts, facts, systems of reasoning, subjects and objects are all configured and affirmed (or rejected) in relation to the norms and values of a dominant "thought collective" (1979, p. 38-51). Drawing from the work of Fleck, Nikolas Rose points to emergent shifts in understandings of the body:

The brain, for the contemporary sciences of the brain, is not what it was in the 1950s; the cell, in cellular biology, is not what it was in the 1960s; “the gene” – if it still makes sense to call it that – is not what it was before genomes were sequenced, and so on. The new style of thought that has taken shape in the life sciences has so modified each of its objects that they appear in a new way, with new properties, and new relations and distinctions with other objects (2007, p. 12).

The molecular, as a particular a style of reasoning, emerges in direct relation to a world rich in politics, history and social norms. In 1916 the molecule was conceived of as a series of interlocking cubic atoms (Lewis, 1916, p. 767); in the 17th century it was visualized as consisting of barbed and hooked units (Waller, 2004, p. 53). From free floating ‘átomos’ brought together by chance collisions (Levere, 2001, p. 15) to highly controlled and regulated ‘building blocks,’ the molecular has gone through a series of configurations cross-regionally and historically.

In one of the first social studies of nanotechnologies informed by ethnographic methods (conducted between 1997-2001), Swedish researchers Hans Fogelberg and Hans Glimell unpack the building block metaphor:

We have to become masters of matter at its most fundamental level, i.e. where it first materializes and organizes itself into a myriad of constellations: the molecular level. There, on the bottom line of present knowledge, awaits nothing less than another spectacular conquest for the troops of technoscience. Back to basics in fact means going back to nature, in a great attempt to “pull out” the solutions to our (self made) problems from its tiniest little realms (2002, p. 6).

The building block metaphor carries with it not only the molecular, but nature in its tiniest and, therefore, most essential form. As a concept nature also carries with it a potent history. Haraway emphasizes:

[I]n the fabled country called the West,²² nature, no matter how protean and contradictory its manifestations, has been the key operator in foundational, grounding discourses for a very long time. The foil for culture, nature is the zone of constraints, of the given, and of matter as resource; nature is the necessary raw material for human action, the field for the imposition of choice, and the corollary of mind. Nature has also served as the model for human action; nature has been a potent ground for moral discourse. To be unnatural, or act unnaturally, has not been considered healthy, moral, legal, or, in general, a good idea (1997, p. 102).

Recurrently in narratives of nanotechnologies nature is understood as passé: “nano-structures will take the place of some of the biologically derived tools we now use, such as antibodies...they are still biological entities, and as such, limited in what they can do” (Suplee, 2005); as leverage when mixed with human labour: “we argue that DNA can not be used as a passive mechanical or memory nanosubstrate, but also as an active mechanical, electrical, photonic and information-flow network” (Barbu, Morf & Barbu, 2005, p. 144); and as ultimately conflated with the artificial: “as nanoscience progresses, and as researchers gradually learn to mimic – if not control – the elegant and efficient ways in which biological systems create order from disorder, the familiar distinction between the “natural” and the “artificial” will grow increasingly tenuous” (Suplee, 2005). Like GMOS and other biotechnologies, nanotechnologies disrupt socially salient distinctions drawn between the ‘natural’ and ‘cultural,’ and open up new maps, albeit from old plans, for both moralizing discourses and economic endeavours. As science, society and medicine are concurrently restructured along molecular lines there emerges a growing belief that “research into the infinitesimal will yield all missing relations of cause and effect” (Grossinger, 2000, p. 242).

²² Here Haraway is challenging the concept of the West as discrete and unified.

5.8 Conclusion

The nanotechnologically-mediated body in BC is subject to the toxic impact of nanoparticles in food and skin care products. Yet this same body may experience reduced drug toxicity in emerging medical treatments given the finely tuned targeting of tissues. As Chapters 3 and 4 of this thesis demonstrate, it is understood to be simultaneously damaged and renewed with vitality and health. The nanotechnologically-mediated body manifests within a market context where carcinogenic products are widely available and where new treatments articulated through the molecular are being explored to cure cancer. Nanotechnology is understood as the next Industrial Revolution, yet, as Chapter 1 points out, is as old as ancient Egypt. Nanotechnology is also moving towards standardization, yet Chapter 2's singularity revision is resisted in scientific practice. These are nuances captured best with Haraway's "ethnographic attitude" (1997, p. 199). This thesis calls for an attunement to power -- the power of silences implicated in fact making and the power of multiple perspectives.²³

²³ Sections of this thesis have been presented at various conferences under the maiden name "Karen-Marie Woods."

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