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Nanotechnology and Neoliberalism

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Nanotechnology has been heavily hyped through the turn of the millennium. The term refers to the technologies necessary to visualise, design and build at nano scales (10^{-9} or a billionth of a metre)[1] and to scientific pursuits that examine quantum behaviours of particles and materials on this scale. Like “macro” or “micro”, “nano” is a scale of becoming with its own properties. It is qualitatively different, with a complex relationship to other scales of any given physical element; it is not just quantitatively smaller. Nano-scaled entities are not visible but sensed haptically, through tactile technologies such as scanning-tunnelling electron microscopy. They are not tangible but exist on the atomic scale as part mass, part energy and thus are virtualities to be objectified through lab technologies and practices.[2] Nanotechnology promises to yield massive economic benefits as well as to serve as a pervasive, powerful platform for reconceiving the creation of products and solutions, both large and small. The latter include diagnostic products (such as a genetics and “lab on a chip” devices to simple colour-change indicators of health status – from pregnancy to tuberculosis) and solutions for climate change and the bioremediation of wastes. Both a child of, and a vehicle for, neoliberal forms of research organisation, nanotechnology is itself a laboratory for reorganizing the production of knowledge.

This chapter investigates the relationship between innovation in emerging technologies and neoliberalism as it is implemented in the case of the National Institute for Nanotechnology (NINT) on the campus of the University of Alberta in Edmonton, Canada.[3] Neoliberalism in this context

is defined as a series of critiques of bureaucracies' abilities to understand and regulate the economy and a valorization of the ability of communities to self-govern (Hayek, 1945). In this chapter, neoliberal refers to the theories of von Hayek, on one hand, and is presented as used by the diverse participants in an community-based, ethnographic research project. I reflect on the case of the NINT using ethnographic and geographical approaches, using narrative to capture the complexity of a local place. This goes beyond local socioeconomic conditions in order to map the microphysics of co-evolving cultural repertoires and community institutions within which neoliberal science policy and programs are deployed. Drawing on and critiquing Mitchell Dean's four axes of governance, governmentality is used as a rubric under which to examine the interaction between neoliberal forms of capitalism and research in emergent sciences as recounted in the narratives of participants in our ethnographic study.[4] There were a total of 104 participants who represented the public locally, experts and various policy and industry actors (see below). Finally, I hypothesize that nanotechnology may initiate a shift from a biopolitical to "nanopolitical" governmentality that requires a fundamental recasting of what we understand as the governmental rationalities of neo-liberalism and its objects.

Nanotechnology emerged from a disparate set of micro-electronics, atomic and quantum applications as a new, synthetic field based on access to the new, shared facilities, labs and tools such as scanning-tunnelling electron microscopes. Unlike the Cold War stress on engineering and the physical sciences, nanotechnology included biosciences in the United States' National Nanotechnology Strategy (NNI), a competitive response to global leads by Japan and Germany in synthesizing carbon nanotubes (see Crawford, 1991; JTEC, 1994).

Nanotech also has been seen as echoing neoliberal notions of autonomy and self-organisation: "In much the same way that [Hayek's] neoliberal theory regards markets as self-regulating mechanisms that instantiate a higher degree of rationality than any individual would be capable of" (Gelfert, 2012: 160). It links the market as a spontaneous order with an ideal of autonomous voluntary communities (Hayek, 1976:151). "In the discourse on nanotechnology, 'self-organisation' (with or without self-

replication) functions as the analogue to ‘spontaneous order’” (Gelfert, 2012: 160-1) as nanobots evolve adaptively and autonomously supporting small “self-sufficient communities”, “without bureaucracies or large factories” (Drexler, 1990: 235). The association of nanotechnology and neoliberalism is a coincidence, but their parallels can be more critically examined in the context of changing institutions and nanoscience projects that search for commercialisable knowledge.

Nanotech in a Northern Climate

Edmonton and the Alberta Capital Region (2014 CMA pop. ~1.3 million) is located in the Prairies at the centre of the Province of Alberta making it the most northerly, large Canadian city. As such, it is currently a hub for the northwest with an oil and gas services economy. However, Edmonton was an Aboriginal meeting place at a river-crossing and a Hudson's Bay Company trading outpost from the late 1700s. Furs were Edmonton's earliest commodity. At first they were shipped down the river that winds its way toward Hudson's Bay; later Edmonton was the northern terminus of late 19th century railroads and capital of a new province from 1905. The place has long been seized by colonial and global empires and participates in contemporary military adventures globally. As such it is one of those bell-weathers of economic change at both the local and global scale.

It has remained unexpectedly prosperous through recent economic and oil-price downturns with a less well known university-based research environment, military base and a history of starting-up mass-market retail chains and early role-playing videogames. Edmonton is known for hockey teams, inventing the mega-mall in the early 1980s (Hopkins, 1991), and for pioneering municipal recycling and waste diversion. Carol Greenhouse argues that neoliberalism encourages these mass forms of mechanical solidarity over and against the interdependent organic solidarity of more specialised twentieth century metropolitan economies, changing relationships and raising ethnographic questions concerning communities (Greenhouse, 2011:3; Comaroff and Comaroff, 2001).

In 2002, the Provincial and Federal governments funded the creation of a US$200 million National Institute for Nanotechnology (NINT) with hopes that it would foster a more diversified economy in Alberta (AITF, 2007).

The residents of Edmonton (from 2004-2014 one of the top four local economies in North America by regional GDP) found themselves a would-be engine of a new source of wealth in a globalised economy, perhaps “branding” the city-region as the seat of nanotech products "when the oil runs out". However, more familiar with mass-market sports, consumption and production forms, our respondents doubted that NINTs elite efforts were synchronised with local needs (see quotations below).

NINT has proven successful in the academic world but the other ‘spin-off’ benefits like jobs and urban renewal have been slower to emerge and are less easy to assess. How can the dream of nanotechnology innovation be translated into the reality of enhanced regional development and direct benefits for the local community? How does one make innovation driven by economic goals locally relevant to the needs and desires of citizens? Research on commercialisation (Beaudry and Schiffauerova, 2011) and academic publications (Hu et al., 2012) identify Edmonton as having a medium-sized concentration of nanotechnology companies within Canada, albeit less integrated into the global market compared to Ottawa, Toronto, or Montreal.

The establishment of NINT has been part of an ambition to create a regional industrial concentration of nanotech firms. These “industrial clusters” are a spatial construct that approaches a reflexive sense of “economic place” in that an agglomeration of activity in or supporting a given sector is understood to exist (Porter, 2000; Wolfe and Gertler, 2004) even though no clear or stable boundary can be drawn. Nor do clusters have a minimum density or size. These are spatial expressions of concentrations of capital and talent sufficient to determine the direction of global markets and become centres of decision-making as well as production and thus sites of economic power. They refer to how economic activity is cast in a spatial form or to “social spatialisation”.

The space or site in which science occurs matters. The city-region is seen by many as lacking charm: an "ugly" place planned around the car, despite the initial quality of its prairie environment. It is a region where high-tech industry doesn’t quite belong (Gow and Sandy, 2007). It is important not to under-estimate the impact on both residents and investors of media representations of place and of rising or falling global economics and

military coalitions. This adds to, or negates, a sense of sustainability into the future, especially given ambivalent place-images (Shields, 1991) and Edmonton's negative place-myth of a sprawling blue-collar winter city. Despite its distance from other centres, both the global oil prices and global politics, including the invasions of Afghanistan and Iraq/Syria, impacted the city-region viscerally during the five years of our investigations.

Such spatialisations cast these places as summits within a wider topology of “places-for-this and places-for-that.” Ferguson and Gupta’s (2002) work on neoliberal governmentality argues that the spatial metaphors through which the state has been imagined are being challenged. This has included changes to the “vertical” understanding of how localities are “encompassed” by and “within” nation-states amidst cross-cutting transnational, national and regional scales of organization, governance and authority. Analysis of places and clusters is often further complicated by the place becoming a metaphor for the activities it hosts (Shields, 1991 Ch. 1). The rhetoric of clusters thus tends to attract and concentrate capital and talent as a type of self-fulfilling prophecy. However, one of the chicken-and-egg problems of the literature on clusters is a lack of critique of the extent to which it has relied on an unexamined spatialisation that over-estimates the power of the abstractions and theoretical representations of places produced by urban and regional planning and economic management professionals to frame our imagination of what places can be (i.e. as places or “spaces of representation") against actual, everyday practices (Shields, 1991).

Ethnographic Approach to Governmentality

Governmentality is the set of techniques and tools by which activities are governed, where conduct is shaped by a cultural system of values and knowledge (see Pyykkonen, 2007). It is expressed in social spatialisations that serve as proxies for the governance of affect (Davidson, et al., 2011:113), catering to and legitimating seriousness in centres of production and decision-making, and levity and play in liminal zones and ludic margins (Shields, 1991). As a simplified example, consider Edmonton as a site of production and long double-shift work-hours is connected by many

direct air flights to its spatial alter-egos, Las Vegas and Palm Springs: sites of relaxation, play, consumption, sun and warmth (Davidson et al., 2011: 113). Governance also changes in time insofar as it is structured as a historical configuration of knowledges of government, governing technologies and conceptions of the subject (Foucault, 2008). At any given time, each of these modes of governmentality seems completely commonsensical when taken on its own terms. Neoliberal political rationalities reconfigure the relationship between the state and citizens to govern individuals indirectly as customers who are responsible for their own choices and well-being rather than having an expectation of guarantees of their quality of life underwritten by the state as under the liberal welfare state of the 20th century (Foucault, 2008; Joseph, 2012; Rose and Miller, 1992).

The discussion of governmentality will be organised using Dean's description that argues governmentalities are actualised on four axes that operate in analyses of discourse and practices (2009: 33ff):

> -its objects of governance, both actual and possible, such as risk: What do we seek to act upon?
>
> -technologies, means and systems of governing including rationalisations, and informational technologies which reveal or make knowable processes, such as the statistical surveying of populations: How do we govern this substance (cf. Dean 1996)?
>
> -the roles, responsibilities, rights and duties within institutions that are internalised by actors: Who are we when we are governed in such a manner?
>
> -the ideals or principles which serve as ethical objectives and social goals: Why do we govern or why are we governed?

To these, we will see that a fifth, *affective* dimension must be added to the analysis of governmentality. Lacking this, such models do not capture sentiment, the swings of individual outlook and collective mood, which are important motivational aspects of everyday life that are poorly institutionalised and often only figure in social analyses as suppressed elements of individual psychology such as models of professionalism at work and civility in public life.

It is also important to note that the discourses that are often the focus of studies of governmentality derive their significance by being mutually correlated rather than through absolute denotation. Within these studies the self-evident character of rationalities of governing have to be subjected to an immanent critique to show the artificial quality and conditions of possibility of any mode of governmentality. Our research addresses criticisms that the linkage between the structuralist analysis that underpins studies of governmentality and empirical cases is weak (Marrtila, 2013). How does governmentality, as a sustained configuration of heterogeneous but consistently effective statements, practices and institutional norms, relate to the selection of cases and their analysis? The dynamics of nanotech innovation in the Edmonton region were examined using a qualitative case study approach (Mason, 2002) and grounded in a "public research" model (see Patchett and Shields, 2012) that drew its research questions from community workshops that mobilised public curiosity.

Are studies of “governmentality” captive to second-order observation issues (Fuchs, 2001) or to a *post hoc ergo procter hoc* bias (by which the analysis reveals just what theory highlights by fitting empirical data into categories established in advance)? To respond to such critiques of bias, Bourdieu and Wacquant (1992) propose a self-reflexive approach for social research generally. This recognizes that social reality is mediated by the discourses of respondents and other sources. In our research, we are therefore cognisant that we are dealing with respondents’ stories about the world, not the world per se, and divergences, omissions, what is stressed and what is not talked about are of interest. From 2010 to 2015 in partnership with Kevin Jones and Nils Petersen, we conducted focus groups followed by a weekend “Citizen Summit” (Shields et al., 2013; Irwin, 1995) on nanotechnology, participatory presentations to the public and tours of key innovation sites locally (Jones et al., 2015; Davies et al., 2013) from which we gathered feedback in the form of audio transcripts, participatory photography and reflections during events hosted by Edmonton's Telus World of Science museum.

All of these complementary forms and methods extend the opportunities for capturing different perspectives and meaning-making about the complex of policies, opportunities and local needs by those directly

involved over time. In addition, we observe participants responding to social science expertise and theory – not in an anecdotal tone but with a sense of evaluation of local-global conditions. Global neoliberal discourses appear as only one element to be weighed.

The problem of communication has become a major day-to-day limit on collaboration and coordination:

> But having been [at NINT] for a while, talking to people, one of the big issues that not a lot gets out I think is based on intellectual property issues. The government's goal, or as far as I can tell NRC's goal, is that tangible products come out of the research at NINT. They want industry to invest, and so I was involved last week in working on a project that was going to look at knowledge mobilisation from one of the research groups at NINT. And he's partnered with industry and the CEO of that company which is privately held. He was so worried about, he didn't actually want us to have access to any of the information because he said "people can infer, you may not even be intending, you can talk about general stuff but if you're in the industry then you can infer x y and z. And the next thing I know my intellectual property is gone." So we can't really engage in this project because your tangible product might be compromised in some way (Focus group participant 2011).

Over and above Dean's objects, roles and ideals of governance (above), the *affect* of anxiety and fear in the above quotation from a respondent is an essential but overlooked aspect of neoliberal marketisation. A rollercoaster of emotions that cycle between heights of empowerment and ambition followed by melancholic dives into disempowerment and frustration accompanies the rational acquisition and processing of information. This is true even in rational technical research and cautious investment practice. Perhaps the most important contrast between what our respondents report and theories of neoliberal governmentality is this role of affect and other intangible virtualities including trust and identity (see quotations below; see Shields, 2003). Lived neoliberalisms are heady ecologies of affect, rashness and confusion.

Neoliberalism, Knowledge and Research

Lack of understanding of action, sentiment and choices is at the heart of the neoliberal critique of welfare economies. As neoliberal rationalities have become dominant, state research and development, a legacy of the military investment in science and technology during the Second World War and the Cold War, has been selectively privatised and de-funded. On the one hand this has been understood as a reduction of state technological capability in support of regulation and forensic testing of products and processes. On the other hand, it has constituted a withdrawal of the public from most exploratory science or technological projects. Neoliberal rationalities have advocated the creation of markets in all systems, even the environment and climate (Oels, 2005). Although the parameters of these rationalities may be difficult to define, they tend to lead to the same outcome: the reduction or elimination of funding, and the closure of agencies or the restriction of their activities. Examples of this include both funding reductions for academic research and the reduction of national research agencies such as NASA or the National Research Council of Canada.

What remains as a focus of public funding is the formation of scientific expertise in support of the high tech sector, and increasingly in the 2000s, in sectors that support military and security technologies. In turn, these sectors draw on frontiers of science that are not commercial endeavours but accrue prestige for the state and underpin international participation in international collaborations that could be understood as a form of scientific diplomacy. This has favoured nanotechnology and other highbrow sciences at the frontiers of technical capacity and theoretical insight (e.g. particle physics and theoretical cosmology) or scientific missions that legitimize and actualize contested claims of sovereignty such as in the Arctic (e.g. CHARS, Cambridge Bay, Nunavut).

While there does not exist one consistent global neoliberal logic, the variations of the theory are similar insofar as they are distinct from a simple laissez-faire market capitalism (Foucault, 2008). Despite critiques of business influence, values and management techniques in academia since the time of Thorsten Veblen (the important early modern social

analyst of the governance of education and training (1918)), Canadian federal science policies have been used to encourage private investment in science and partnerships between universities and industry, in part by eliminating government regulatory labs and decreasing public funding for academic research (on the neoliberalisation of Canadian academia see Buchbinder and Newson,1990; Brownlee, 2014; Lave et al., 2010: 661-2). The explicit goal of Canadian science and technology policy is to increase commercialisation and to direct research toward international collaborations in areas of strategic importance to the Canadian economy (Industry Canada, 2014). However, an important brake on shifting to the stereotype of the neoliberal, business-minded and corporately-tied university in Canada is that educational institutions are not vested nationally but regionally within the jurisdiction of each provincial government (Schuetze and Bruneau, 2004)

As neoliberal rationalities have taken hold, information and knowledge are increasingly treated as commercial goods (Drake, 2011). This shift links academics and universities as knowledge-producers and knowledge institutions to commercial interests (Brown, 2000) with intellectual property (IP) as the central "object" produced and monetised in the form of patents and royalties managed via Material Transfer Agreements (MTA). Patenting has in turn become as important to science careers and evaluation as publications and citation rates, leading to a rise in "vanity patents" on the one hand and a focus on searching for patentable knowledge, rather than, for example, laws of nature (Lave et al., 2010).

This is, however, hardly a one-way street. These changes have been implemented in the context of inherited political and economic rationalities and configurations and local socioeconomic conditions (see Dorow, Howard, Li, and Mitchell and Lizotte, this volume). For example, struggles between regional elites or by neoliberal political ideologists against the fiscal autonomy of scientific and medical elites that depend on State financing (in the case of all nationally-funded medical systems) inflect implementation. Struggles to brand policies with the identities of the political party in power or to favour particular economic lobbies or industries transform neoliberalism into a kaleidoscope of actual policies and political rationalities.

Nanotechnology, Neo-liberalism and Place

A significant problem that has emerged from the federal government's approach to nanotechnology and other emergent sciences is that top-down models of innovation investments fail to recognize that development is difficult to direct (Varlander 2007; Lorentzen, 2008; Bair 2008).[5] They ignore what Elias referred to as the "figuration" in place with its local and institutionalised divisions between cliques, insiders and outsiders (Elias and Scotson, 1994). Such approaches as Elias and Scotsons' can further extend governmentality from general theory to the specific embodiments, routines and "figurations" of neoliberalism. It is difficult even for insiders to cognitively map the local network which also has important "players" who may be international partners elsewhere or coalitions of clusters that constitute a transnational scale of organisation folded into the local insider enclave of the would-be nanotech "cluster". Yet the local site is significant: in the case of nanotechnology, exceptional facilities with "clean rooms" and even a silent seismic and radio-frequency environment, mean that the buildings for the scanning-tunnelling microscopes cannot be situated just anywhere and require extensive technical staff to maintain this exacting environment. Lacking a broader view, respondents often focus on the objects of governance:

> I've worked with a consultant who previously worked for [company] … And he honestly didn't know about all of the facilities, nanotechnology facilities and supporting infrastructure. So I was shocked because he didn't know, he was shocked because he didn't know, and he's in the industry (Focus group participant, 2011).[6]

Until almost a decade after NINT opened, there was little investment in policy infrastructure to promote commercialisation beyond NINT, leaving this to private investors and a university-municipality partnership in a commercialisation incubator, TEC Edmonton. This problem of the connecting tissue from innovation to products in use globally was often raised in focus groups, tours of innovation sites and at the Citizen Summit (Shields et al., 2013):

> Okay. So that piece is – there's a lot of nano-medical companies and they need to get in, and we can't even sell it here. They have to go always somewhere else. So that's what you can help with (Focus

> group participant, 2013).
>
> Ninety-percent of our products that we make are sent outside of Canada, for someone else. We have a company that's asking us to make this sensor to find oil underground. It's great but it goes to Saudi Arabia, it goes to Mexico. We have the largest oil deposit in the world a couple of hours north. We do nothing in that space and we don't have customers that want us to do anything in that space just yet. That's part of it, is that they don't even know that we exist (Focus group participant, 2011).

The spatial complexity is significant. The discussions around nanotechnology and the exploration of the weave of companies, training programs, incubators, NINT, governments and global corporate interests shifted to a focus on innovation and the institutional isolation of some of the key players locally (Sluggett et al., 2015). Elsewhere we argue that research fora such as the Citizen Summit allowed "difficult" discussions on local futures to take place (Shields et al., 2013).

> P1: ...Are there tensions then between not just the science, but between the university and the overall city, in terms of where [nanotechnology] fits and what that relationship is?
> P2: I think there is just no relationship.
> P3: There is no relationship.
> P2: There's not tension, it's just non-existent (Focus group participants, 2011).

There never has been, for example, a strong identification between nanotechnology and the city-region: no "nano-Edmonton", "nano-north", especially in comparison to the much hyped image of the hydrocarbon resource economy which experienced both boom (2004-2008) and bust (2008-11), partial recovery (2011-14) and another slump (2014-15) in oil prices driven not by economic supply but by international economic warfare and competition as US shale-oil flooded the market followed by Saudi exports.

In group discussions, participants struggled with the location and spatialisation of Edmonton, and the power of stereotypes to undermine innovation. They raised, again and again, questions of community, civic and place identity and how they relate to each other in a complex trialectic.

> PI: Thinking about our unique context of how far north we are and how popular we are compared to other towns or cities this far north and like that's almost like a human-centred design approach for innovation is like thinking about your context and then going forward with new ideas based on that too.
> F: So our north-ness is an advantage in innovating in some things, is that right?
> P1: Yeah, or like creating solutions or ideas that are really based around that human context too for our city.
> P2: It sort of forces us to adopt that mind-frame of innovation because we don't have a choice.
> F: That's interesting because in our earlier research a lot of people said we can't really be an innovative city because we're far too much of a winter city, we can't attract people, people don't want to live here, too far away from markets.
> P3: And I think those are, we use those challenges – it's about if that's the local context you need to design or innovative or like plan to that context and I think that's what can be overcome. You can overcome it and plan through it and recognize it as opposed to adopting what someone would do in say Florida because clearly we're not Florida (Focus group participants, 2013).

Place therefore blurs with and challenges us to rethink Dean's second axis of "means" as a suite of capabilities and affordances that contribute to an ecology that is both concrete (objects) and virtual (a set of elements including place-myths and identities, an atmosphere or milieu). They also allude to challenges or "tests" which validate these capabilities (cf. Boltanski and Thevenot, 2006). It is important to note the way that ambition as an affect is tied to place through boosterism (see next quote). As an example of the neoliberal governance of affect through spatialisation, citations of place accompany calls for the investment of affect in a collective project.

The question of scale is central to not only nanotechnology but to neoliberalism because of its incubation and promulgation in international institutions such as the International Monetary Fund, and the explicit pairing of global markets with local productivity, identifying national

economic and import policies in between as the barrier to harnessing the two extremes together (Larner, 2001; Ferguson and Gupta, 2002; Greenhouse, 2011).

However, the shift to discuss innovation was also a moment at which the nanoscale and the challenges of new materials and objects were re-inserted into a comfortable dominant discourse of private entrepreneurial innovation. At the level of detail that was being discussed, a different participatory research process, such as responding to different future scenarios, would have been necessary to imagine and explore alternative figurations and spatialisations of innovation. Such alternatives are nonetheless clearly evident in the implications of nanotechnology that include not only neoliberal narratives of knowledge, innovation and market success but also disruptive innovation that completely recasts these linkages.

Essential to neoliberal rationalities is the biopolitical production of "responsibilised" forms of individuation and subjectivity (Foucault, 2007, 2008; Collier, 2009: 81; Rose, 1999) that direct attention to individual reflexivity, choice and risk-taking (Jones and Irwin, 2012). Respondents often repeated the formula of individual responsibility and industry. This is not merely a matter of internalizing responsibilisation but integrating this with the collective interactions, routines and projects of the city-region as both an aspiration and present context (see also Degen, 2003). Nanotechnology spills over into neighbourhood revitalisation as part of an enabling rhetoric of the affective "grandeur" of place and community:

> I see Edmonton in a new light; my perspective of the city has shifted from grim unease to that of cautious optimism for our future – provided we can work together to foster the kind of environment that promotes innovation and the creativity necessary for large-scale change, social evolution and advancement to occur. Participating in these kinds of activities is what will drive our collective goals to fruition, and, after experiencing this phenomenally eye-opening tour, I would encourage Edmontonians to engage in constructive, forward thinking conversation with one another about the nature of our neighbourhoods, the progression of our local projects and developments, where our decisions today will lead us in the long-term, and whether that vision of the future promotes us as an

> adaptable and sustainably focused hub of innovation (Focus group participant, 2013).

Analysts have argued that the entrepreneur as a figure embodies these changes and appears frequently in popular and media discourses as a sort of hero figure or ideal (see Miller and Rose, 1990; Bührmann 2006)) – an idea that appears in the popularity of the epithet "social entrepreneur", the notion of the "academic entrepreneur" and is reflected in the changing bases of evaluation of success in academia. This was also reflected in our participants' comments, which identify the ideal entrepreneur as alienated from institutions such as incubators and commercialisation programs (a situation that is perhaps changing over time with the revision of this ideal notion of the rugged individualistic entrepreneur):

> P1: So I think that part of this collaboration is just to get the companies together. I mean it's great that they're bumping up in these facilities, but many companies I know won't go near those kind of facilities, they won't go near TEC Edmonton.
> P2: Absolutely, yeah.
> P1: They think very differently, and it has to be entrepreneur-to-entrepreneur because that's the only kind of people they trust. And I'm sorry, I know you guys are – I'm saying it to your face – but they will only trust entrepreneurs who are like them. And it's almost like they're part of a knighthood [laughs] and you have to be one, you can't fake it, and that's sort of how they think. So we need more opportunities for collaboration, you're absolutely right, but part of who they are is it has to be entrepreneur-to-entrepreneur (Focus group participants, 2013).

These comments – with trust at their centre – suggest that the institutional form of nanoscience and technology expresses a convergence not only around shared tools but shared projects and ideals that link, for example, computer visualisation (of nano-scale phenomena) to physics, applied chemistry and materials science (such as new lightweight structures and materials), with medicine and bio-engineering to create profitable products such as prostheses and medical devices. The institutional isolation noted earlier is evoked as a need for "more opportunities for collaboration" but with an important caveat of who is admitted. An affective belonging, not just place-based, propinquitous community is required, challenging the

neoliberal citations of place. What is significant is this struggle over the power of the local as binding people, public and private actors around projects such as a nano-cluster.

Even if supported by medical insurance or state health care, these products are intended for global markets that have been opened up under neoliberal trade agreements. There is no simple hegemony of private interests or of global corporations, but both the purpose and the bindings of scientific research activities have changed in response to demands such as those of the Canadian Business Council on National Issues and the Corporate Higher Education Forum (BCNI, 1993), giving rise to debate and contestation around identities, powers and agendas to include training and private funding in research. Science is produced for particular clients and market interests while impacts and issues born by others may be left as undisclosed or unresearched "white areas" on the "map" of science.

As more technologies implicate bodies, cultural identities, and the environment, and circulate around the world under neoliberal trade arrangements, science has become implicated in a wide array of social movements of the right and left, from large professionalised national networks to small under-resourced community groups (Moore et al., 2011: 528). This has both benefitted and harmed those who deal with the products and wastes of nanotechnologies (Pellow, 2007), thereby altering the relationship of scientists to trust and authority and has brought others into the governance of science and technology, a process referred to as "epistemic modernisation" (Moore, 2008; Moore et al., 2011). Corresponding to the global standardisation of markets, the locus and arenas of governance have moved to the international scale and technical experts. Rather than being values-based regulation has become a norm which has limited the scope for government regulations (e.g. The International Standards Organisation and other coordinating bodies; see also Gibbons et al., 1994; Della Porta and Tarrow 2005).

Nanotechnology and Neoliberal Research

In von Humboldt's organizing vision of the modern multi-subject university divided between the arts and sciences, research and teaching went hand-in-hand with a pedagogy for creating critical citizens. In the

establishment of NINT, advanced research was removed from the "learning spaces" of the university to a secured State institution which barred the idly curious and admitted only select members of research teams. This separation had a negative impact on the Institute's image locally but reflects the priority given to commercialisable research for global markets over teaching in the neoliberal university (Lambert et al., 2007; Larner and Le Heron, 2002).

> There is an intimate connection between the neoliberal recasting of the market as an information processor, and the growth of the conviction that knowledge should be commodified. This connection seems all the stronger when one considers that, as several recent studies have pointed out, for the vast majority of universities patenting has been a losing financial proposition (Lave et al., 2010: 666).

With the withdrawal of public funding and limits on the ability of universities in many jurisdictions to charge the actual cost of tuition, this creates a tension between the need to meet the market imperative of increasing commercial sponsorship while allowing research to remain value free and part of an open public sphere of science. The result is the proliferation of contradictions. What is accepted as good research becomes contested and adjudicated not only through peer review and other traditional mechanisms of science but by market and quantifiable practical implementation.

> The character of science is changing as privatised management shifts the sources and quantities of funding, organisation of research and teaching, and the intellectual and commercial status of knowledge claims (Lave et al., 2010: 669).

To this changing institutional context, nanotechnology research adds a further twist. It encourages the convergence of disciplines around shared tools and facilities that would otherwise be out of reach of most universities and commercial establishments. Given this expense, nano-characterisation and research labs have been justified as *workshops* producing not only discoveries but prototypes and new hybrid instruments and tools for the benefit of multiple disciplines. It is not unusual to find an

osteopath co-funding and sharing a lab with a civil engineer interested in the properties of wood because both use the same scanning equipment.

Nanopower and Nano-politics

The objective of Foucault's “bio-power” was to show how the biological details of humans became the object of political strategy, that is, a form of governmentality. Similarly, I could suggest “*nano-power”* in which the quantum possibilities of all existence become a mode of governmentality of all matter, things and subjects: *nano-politics*. This becomes both an ideal and practice which reconfigures the arrangement of disciplines, institutions, industrial sectors and Enlightenment divisions such as between the body and its environment, subject and object, static solid and dynamic fluids, matter and energy. Although this may seem far-fetched, nano-scale processes and objects are already present in everyday life (e.g. CD and DVD recording processes and air fresheners, respectively) and have realigned disciplines and university-industry relationships as argued above.

Drawing on our participatory research, respondents – mostly highly educated -- identified these shifts without reference to governmentality, neoliberal economics or ideologies. However, familiar tropes such as globalisation, risk, entrepreneurialism and new forms of property appeared often. Participants were ambivalent about familiar neoliberal objects of concern: the role of the state, the autonomy of science and academic institutions from the local economy, and incomplete transitions to the knowledge economy.

How does the local figuration (Elias and Scotson, 1994) around nanotechnology coincide or depart from the axes of governmentality suggested above? All four of Dean's axes shift. In particular, the objects of governance require a more nuanced ontology beyond the division of “actual and possible” (an unexamined material-ideal dualism at the core of most theories of governmentality to date). Nano-power offers an atomic view of the world from processes below the threshold of everyday life that unify the biological and physical, bodies and objects, static things and quantum process. It is the ultimate "naturalisation" of being and the order of the world while at the same time including probabilistic and virtual

objects as well as material and abstract entities. The required technologies of governance subsume biotechnologies. The qualities of nano-objects depart from those of the same element at the scale of everyday objects, meaning that its properties can be manipulated (for example, by changing the energy level of ions colours change, allowing coloured indicators to be used in technologies such as a home pregnancy test). Because of the huge surface area of such fine versus gross everyday particles, they are exceptionally soluble and reactive at room temperature transforming metallurgy and synthetic operations. At the same time, new forms of risk and opportunity arise such as unanticipated applications and interactions and challenges around containment and contamination.

A significant shift in the understanding of “manufacture” and “creation” accompanies nanotechnology. Rather than “grinding-down”, nanotechnology “builds-up” from elementary particles and energy states. A simple example is found in the shift from photocopy toner created by grinding carbon, to synthesised, multicoloured toner with consistent, much finer, particles that have allowed personal laser printers to achieve high resolutions. A similar idea is found in the conception of 3D printing.

Nanotechnology eludes contemporary political forms that have evolved to represent and govern tangible entities. Only when anthropomorphised as “nano-robots” -- in other words as new actors or personae in Dean's third axis -- did our respondents interact with the risk and wider social implications of nanotechnology. This is reflected in a relative lack of affective engagement that we discuss elsewhere (Ghimn and Shields, 2015): while respondents quickly supported the boosterism around NINT and place, they were neither articular nor did they seem sure how they *felt* about nano-objects and nanotechnology. A general silence of the humanities on the ideals and ethical objectives of nanotechnology, a lack of counter-movements and failure of critical thinkers, ensures the development and success of nanopower but this quietude has slowed the understanding and take-up of nanotechnology because of lack of awareness, perhaps only postponing other difficult conversations.

Reprise

Nanotechnology is presented as pervasive, persistent, and powerful. It permeates and displaces more complex totalities such as mind, environment and climate, proffering "can-do" technical solutions to mega-problems such as depression and anxiety, pollution and climate change. Nanotechnologies require a more nuanced understanding of the real as not only actual (concrete, present) but virtual (ideal-real), where "things" have multiple states (or energy levels) and are co-presences of potentialities and latent states. Nano-objects are neither controlled directly as actual things and actions, nor abstractly through representations, but instead they are managed probabilistically, as actual statistical possibilities (on these categories, see Shields, 2003). Our respondents reported their development of standards and ethical practices as a bottom-up development of laboratory techniques not as an ethical project.

Our ethnographic study shows that neoliberalism is being implemented in the geographic context of Edmonton, Alberta and Canada as a place governed according to overlapping or nested jurisdictions: federal science and technology policy, joint federal and provincial funding of NINT, and the city in partnership with the academic institution to promote commercialisation in the form of technology start-ups. These administrations have developed distinct governmentalities historically with their own social and cultural strengths, capacities and configurations. Our respondents agonised over the gaps in policy and outcomes that resulted from lack of coordination or conflicts between institutions at these different scales:

> I really wasn't tuned into nanotechnology until a couple of years ago. It was something that was germane to electronics, but it wasn't something that was all that germane to the forest sector. So I don't remember all of the hype and the expectations that were being touted. I would suggest to you that there probably isn't enough said about NINT, the university, and nanotechnology and business spinoff. I don't think the community is all that aware that it even exists. There's probably more awareness amongst some of the international community than right here in Edmonton… The average citizen of

> Edmonton probably doesn't realize that NINT exists at the university (Focus group participant 2011).

Our participants were candid about the struggles between academics, the organisation of universities around Fordist mass-education of the welfare state and neoliberal demands for elite socialisation of leaders plus technical vocational training. These led also to conflicting roles and a tension between the global corporate orientation of NINT and the community's demands for transparency and orientation to local benefits (although they stopped short of demanding a role in governance). They were also willing to reconfigure their city to enhance corporate collaboration at other scales and to erode the separation that marks the University, with its campus and NINT on one side of the river, from downtown, on the other side. This remains an evolving situation, only a decade into an important socioeconomic experiment. Our research turned to affect and place as missing registers in the analysis of governmentality, notably the spatialisation of place as a mode of governing affect, in Edmonton's case the project to create a nano-cluster. In relation to Dean's four axes of governance, our respondents suggest:

> –the significance of a new scale and range of material and virtual objects of governance.
>
> – new means, technologies and systematic approaches in knowledge and economic activity in which the haptic and other sensing technologies are linked to the visible through computer-aided visualisation. The prominence of affects such as trust, a sense of community and place as logics of social assembly and mediators of interaction.
>
> – Neoliberal roles such as the entrepreneur, the researcher, the nano-robot and the citizen but a less explicit understanding of the deconstruction of bodies into basic biochemical processes by nanotechnology.
>
> – Challenges in ethical judgement and an absence of debate — risk is to be managed technically but the goals and ideal ends of nanotechnology are not considered.

Nano-politics takes seriously the claims that a pervasive, persistent and powerful new basis for technology and industry has been introduced

through visualizing, controlling and designing at the nano-scale that includes both the organic and inorganic. This process introduces new objects of governmentality while synchronizing with and deepening neoliberal and bio-political modes. It is both produced within a neoliberal logic that applies science as innovation, while creating new entities and actualising new capabilities in the ordinary physical elements. In so doing, it changes how we understand the real and the possible, fundamentally altering the biopolitical and governmental rationalities of neoliberalism.

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