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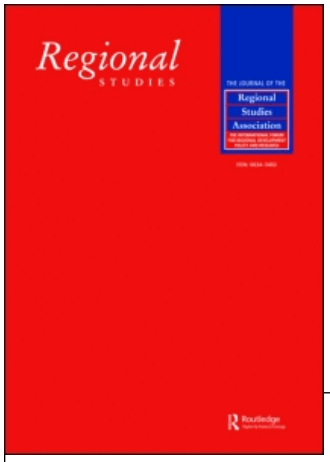

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Building on Diversity: Institutional Foundations of Hybrid Strategies in Toronto's Life Sciences Complex

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Building on Diversity: Institutional Foundations of Hybrid Strategies in Toronto's Life Sciences Complex

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LOWE N. J. and GERTLER M. S. Building on diversity: institutional foundations of hybrid strategies in Toronto's life sciences complex, *Regional Studies*. Geographical studies of innovation typically examine the impact of regional institutions on new product and process development. This study considers the influence of these institutional systems on business strategy and firm-level responses to competitive challenges. The paper examines case of Toronto's life science complex and the growing prevalence of a business strategy of hybridization. Toronto's hybrid firms combine core strengths in biotechnology and biomedical technologies with service activities like contract research and manufacturing, blood bank and data management, and device repair and distribution. This strategy is often viewed as a response to lengthy product development cycles, impatient financiers, and the pressure to identify secondary sources of revenue. However, this explanation overlooks an equally compelling rationale stemming from the larger institutional context that shapes and constrains their strategic choices.

Biomedical industry Innovation systems Institutions Economic development

LOWE N. J. et GERTLER M. S. Développer la notion de diversité: les fondements institutionnels des stratégies hybrides du Centre des sciences de la vie à Toronto, *Regional Studies*. Comme d'habitude, les études géographiques sur l'innovation examinent l'impact des instances régionales sur le développement des nouveaux produits et des nouveaux procédés. La présente étude considère l'influence de ces systèmes institutionnels sur la stratégie commerciale et les réponses aux défis compétitifs sur le plan des entreprises. On considère comme étude de cas le centre des sciences de la vie à Toronto et la fréquence croissante d'une stratégie commerciale de d'hybridation. Les entreprises situées à Toronto combinent les principales forces de la biotechnologie et des technologies biomédicales avec des services, tels la recherche ou la production industrielle contractuelles, la gestion des banques du sang et des données, et la réparation et la distribution des dispositifs. Souvent une telle stratégie est considérée une réponse aux cycles de développement longs des produits, aux financiers impatients, et à la nécessité d'identifier des sources de revenu secondaires. Cependant, cette explication ne considère pas une raison d'être tout aussi convaincante qui provient du contexte institutionnel plus large qui détermine et contraint les choix stratégiques.

Industrie biomédicale Systèmes d'innovation Institutions Développement économique

LOWE N. J. und GERTLER M. S. Aufbau auf Vielfalt: Institutionelle Grundlagen für hybride Strategien im Life-Science-Komplex von Toronto, *Regional Studies*. In den geografischen Studien über Innovation wird in der Regel die Auswirkung regionaler Institutionen auf die Entwicklung von neuen Produkten und Verfahren untersucht. In dieser Studie untersuchen wir, wie diese institutionellen Systeme die Geschäftsstrategie und die Reaktionen von Firmen auf Herausforderungen der Konkurrenz beeinflussen. Untersucht werden der Fall des Life-Science-Komplexes in Toronto und die wachsende Prävalenz einer Geschäftsstrategie der Hybridisierung. Die hybriden Firmen in Toronto kombinieren zentrale Stärken in den Bereichen der Biotechnologie und der biomedizinischen Technologien mit Dienstleistungen wie Auftragsforschung und -produktion, Blutbank- und Datenverwaltung sowie mit der Reparatur und dem Vertrieb von Geräten. Diese Strategie wird oft als Antwort auf langwierige Produktentwicklungszyklen, ungeduldige Geldgeber und den Druck zur Erschließung zusätzlicher Einkommensquellen betrachtet. In dieser Erklärung wird jedoch ein ebenso überzeugender Grund übersehen, der sich aus dem größeren institutionellen Kontext ableitet, welcher die strategischen Entscheidungen dieser Firmen prägt und begrenzt.

Biomedizinische Industrie Innovationssysteme Institutionen Wirtschaftsentwicklung

LOWE N. J. y GERTLER M. S. Construir la diversidad: bases institucionales de estrategias híbridas en un complejo de las ciencias de la vida en Toronto, *Regional Studies*. En los estudios geográficos sobre información se suelen examinar los efectos de las instituciones

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regionales en el desarrollo de nuevos productos y procesos. En este estudio analizamos la influencia de estos sistemas institucionales en la estrategia comercial y las respuestas de las empresas a los retos de la competencia. Examinamos el caso del complejo de las ciencias de la vida en Toronto y el creciente predominio de una estrategia comercial de hibridación. Las empresas híbridas en Toronto combinan las ventajas centrales en biotecnología y las tecnologías biomédicas con las actividades de servicios tales como la investigación y manufacturación contratadas, gestión de bancos de sangre y de datos, y la reparación y distribución de dispositivos. Esta estrategia muchas veces se considera una respuesta a la lentitud en los ciclos de desarrollos de productos, la impaciencia de inversores y la presión por identificar fuentes secundarias de ingresos. Sin embargo, esta explicación ignora una lógica igualmente convincente que procede del contexto institucional más amplio que conforma y limita sus opciones estratégicas.

Industria biomédica Sistemas de innovación Instituciones Desarrollo económico

JEL classifications: O, R

INTRODUCTION

Efforts to replicate the successes of leading biomedical clusters in North America – including Boston in Massachusetts, and San Francisco and San Diego in California – often begin with a checklist of 'success factors' and prerequisites. This reflects a widespread belief that dynamic biomedical clusters share a common set of factors, including well-funded research universities, effective commercialization systems, abundant venture financing, active industrial associations, 'star scientist' recruitment programmes, and a wealth of experienced managers and entrepreneurs. Yet, in their efforts to compile lists of cluster-shaping factors, policy-makers in aspiring biomedical regions often overlook important differences in local, regional, and national institutional configurations and their impact on firm-level practices in the very lead 'clusters' they seek to emulate. While superficial comparisons of successful North American biomedical centres highlight the importance of similar local conditions, closer inspection reveals specific institutional dynamics that work to influence the paths to innovation followed by resident firms. To quote Owen-Smith and Powell (2004) (also Feldman, 2001):

> studies that link entrepreneurship ... to regional characteristics and capabilities open the possibility that very similar outcomes may emerge from widely disparate processes.
>
> (p. 2)

The recent literature on the evolution of biotechnology clusters reflects a growing awareness of the role that background institutions – at different spatial scales – play in shaping their development path. For example, Owen-Smith and Powell (2004) demonstrate how differences in prevailing intellectual property regimes shape the distinctive evolution of individual biotechnology regions. Similarly, Casper and Whitley (2004) show how the framework of national and regional institutions supporting life sciences in Germany has strongly shaped the nature of the biotechnology industry that has emerged there recently. These institutional forces have largely frustrated the aspirations of the German government, through its BioRegio programme, to replicate the successes of Boston, San Francisco, or Cambridge in the UK. Together, these studies highlight the extent to which the collection of institutions shaping science policy, intellectual property rights, labour market mobility, ease of new firm entry, and public investment in research and infrastructure can influence the evolutionary trajectory of local and regional industrial clusters. In this sense, these analyses are consistent with more general arguments about the impact of rule-shaping institutions on economic behaviour (Christopherson, 2002; Gertler, 2004; Thelen, 2004).

The present study contributes to this growing body of work by considering the influence of multilevel institutional systems on business strategy and specifically firm-level responses to competitive challenges. The empirical focus is Toronto's life science complex and the growing use of a distinctive business strategy – which is called here 'hybridization' – prevalent amongst a significant number of firms in the region, including some of the most prominent ones. Hybridization is defined as the combination of two or more distinct technology fields *or* technology service areas – in other words, a business strategy that combines technology inputs *or* outputs. While a narrow definition might only consider the technology origins of firms, the definition is more encompassing and includes 'multi-product firms' that target multiple technology users and service domains.

Interestingly, this tendency towards hybridization appears to fly in the face of the conventional model characteristic of other biotechnology clusters, which favours specialization in the form of 'dedicated' or 'core' biotechnology firms (Niosi and Bas, 2003). In contrast to this purist model, Toronto's hybrid firms *combine* core strengths in biotechnology and biomedical technologies *with* service activities such as contract research and manufacturing, blood bank and data management, and device repair and distribution. As such, hybrid firms are moving away from standard (and perceived 'best') business practice that emphasizes specialization and a focus on a firm's core competency. Instead, hybrid operations embrace

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additional activities outside of their traditional areas of expertise in *de novo* drug-discovery and new product development.

One could easily interpret the use of this strategy as a rational response to lengthy product development cycles, impatient financiers, and the pressure to identify secondary sources of revenue. It is argued instead that the adoption of these hybrid strategies is facilitated by a set of institutional forces originating at the local, regional and national levels.

After a brief discussion of the prevalence of the hybrid strategy, Toronto's larger institutional context and its role in shaping firm-level and 'cluster'-level practices is examined. It is argued that the dominance of the hybrid strategy among biomedical firms in Toronto is better understood as an outgrowth of the region's unique industrial structure and institutional environment. Included here are the city's large concentration of teaching hospitals and research centres, its diverse range of industry players (including traditional and generic pharmaceutical firms, as well as a large number of producers of biomedical technologies and devices), the global reach of local investors, the influence of older, established hybrid firms on industry newcomers, and efforts by specialized industry associations to lobby for hybrid-friendly regulatory reforms. The paper concludes by drawing on the central findings to suggest an alternative policy path for strengthening regional life science innovation systems – one that embraces, rather than undermines, hybrid-shaping institutions and industry support networks.

DIVERSITY VERSUS SPECIALIZATION

Economic diversity has long been valued as a source of regional strength. Studies of urbanization economies have carefully documented the regional benefits associated with close proximity of a diverse range of final goods producers, suppliers and service providers (HALL, 1999; GLAESER *et al.*, 1992; GLASMEIER, 2000). Firms in this environment are able to adapt to new opportunities by developing strategic sourcing arrangements with local input suppliers and specialist service providers. In recent years, diversification of another type has been recognized for its contribution to firm resilience, especially given an ever changing global economy. In contrast to urbanization economies that emphasize coordination across *highly specialized* firms, this new approach to diversification entails a deliberate *broadening* of in-house or within-firm skills. In this case, production-oriented firms expand the range of activities performed within their respective establishments. This can include the adoption of new, convergent technologies, as well as the development of revenue-generating client services, like contract research, data management and consulting support.

Initial studies of intra-firm activity-mixing focused on the alternative growth paths available to firms adopting diversified business strategies. AMSDEN and TAKESHI (1994), for example, have shown that diversified business strategies have provided firms in Asia with a broad range of experiences on which to draw when honing their 'organizational management' and 'project execution' skills. These skills are particularly important to start-up firms as they move to deepen their investments in and commitment to more profitable activities and services.

In recent years, research has also looked outside the firm to examine the networking opportunities that arise from intra-firm diversification. SABEL (2001) has argued that activity mixing within a firm actually creates the conditions for more effective, broad-reaching industry partnerships. In contrast to cases where firms specialize or focus on one part of the value chain, intra-firm diversification results in overlapping regional skill sets. This enables groups of diversified firms to work together to codify areas of shared knowledge and specify a common language that captures and documents shared goals, experiences and constraints. This act of codifying seemingly tacit knowledge enables firms to engage in collective problem-solving and, in the process, quickly adapt to unforeseen local and global challenges. Similar arguments about the relationship between a firm's internal capabilities and resources, and its ability to absorb new knowledge and capabilities from external sources, have been put forward by COHEN and LEVINTHAL (1990), who approach diversity in terms of the range of occupationally defined capabilities residing within the firm. A related point has been made by MALMBERG and MASKELL (2002), who note the potentially limiting effects on learning dynamics in clusters when excessive 'cognitive distance' exists between local firms. While some cognitive distance between firms is desirable, too much cognitive distance can mean that firms are unable to learn from one another because of insufficient degrees of overlap in knowledge bases and capabilities. One way to ensure sufficient overlap is through the accumulation of a more diverse range of capabilities in-house.

By emphasizing opportunities for up-skilling, capacity building and alliance formation, these studies move beyond transaction cost analyses, which simply view intra-firm diversification as a strategy for controlling against opportunism on the part of specialized suppliers and service providers (WILLIAMSON, 1985). As such, they provide a richer explanation about why firms might choose to diversify in response to economic volatility. Where they are less helpful, however, is in providing a meaningful explanation for why firms come to embrace activity-mixing as the preferred and logical response to globally experienced economic pressures and challenges. Specialization strategies, after all, continue to be adopted by contemporary firms in high-risk industries. The range of strategies adopted

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in equally challenging economic environments suggests that intra-firm diversification is better understood as a parallel, rather than necessarily superior path of development. This, in turn, raises important questions about firm characteristics and more generally about the dynamic interplay between regional environment and firm-level practice. The paper turns next to Toronto's biomedical industry in order to explore this dynamic.

TORONTO'S HYBRIDS

Toronto is home to a diverse set of biomedical firms and supporting institutions, leading some scholars to categorize the region as a life science 'megacentre' (COOKE, 2004; NIOSI and BAS, 2003). While a complete review is beyond the scope of this paper (LOWE and GERTLER, 2005), it is important to highlight a few defining features of the city-region's biomedical cluster. In addition to hosting 23 generic and brand name pharmaceutical firms, the Greater Toronto Area (GTA) is home to approximately 285 medical and assistive technology and device (MAT) manufacturers. The region also hosts a growing number of biotechnology firms. In 2001, Statistics Canada identified 55 dedicated biotechnology firms in the GTA – a close second to Montreal, Canada's largest biotechnology 'cluster'.

The present research has identified two variants of hybrid strategies amongst Toronto's biomedical firms. The first type, which is called here *technology extension*, refers to firms that combine new product development with the provision of specialized support services (Table 1). In the case of *medical and assistive technology and device (MAT)* manufacturers, for example, technology-extending hybrids not only manufacture their own proprietary technologies, but also often service, repair and/or distribute foreign-made products in the local market. In *biotechnology*, mid- and late-stage hybrid firms combine *de novo* research and development – or what is commonly referred to as drug-discovery work – with customer-oriented services such as contract manufacturing and contract research, including, in some cases, the management of clinical trials in the GTA. Among the *pharma* subgroup, hybrid firms combine later-stage drug development with innovations in healthcare management, including disease management centres designed to help patients and practitioners enhance the effectiveness of drug therapies.

A second, emerging category of hybrids refers to firms that pursue *technology convergence* strategies by working at the interface of two or more distinct technology areas (Table 2). This category includes firms that combine novel science in molecular biology and biotechnology with complementary capabilities in material sciences or information technology. Also included are firms that manufacture drug-delivery devices or systems that are used in conjunction with internally developed drug therapies. For simplicity, firms in this latter group are referred as MAT–biotechnology or information technology (IT)–biotechnology hybrid operations.

These strategies – along with their institutional roots – were identified through a combination of qualitative research methods. The findings are based primarily on structured interviews conducted in 2003 and 2004. In total, over 100 managers of biomedical firms including dedicated biotechnology companies, MAT producers, prescription drug-makers and contract research firms were interviewed. Over a dozen interviews were also completed with other local actors, including policy-makers, financial investors, university researchers, technology transfer specialists, hospital procurement managers, and industry association representatives. A close review of primary and secondary materials from other sources provided additional support for the interview findings, as did on-site observations at key industry

Table 1. *Pathways of hybridization. Type I: technology extension*

Firm type	Hybrid strategy		Examples
MAT	Repair, distribution	→ Product improvement, development, innovation	RadioCare, First Step, endoscope case
	Product development	→ Contract manufacturing	MDS, Medionics
Core biotechnology	Drug discovery	→ Contract research and manufacturing, storage	Cangene, Biovail, NoAb, Hemosol, Insception, MDS
	Drug recycling	→ Developments in drug delivery	Biovail, Orbus Pharma Inc.
Pharmaceutical	Drug development	→ Healthcare management innovations	Merck, GSK
	Generic drug manufacturing	→ Drug discovery	Apotex
	Contract generic drug manufacturing	→ Developments in drug delivery	Orbus Pharma Inc.

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Table 2. Pathways of hybridization. Type II: Technology convergence

Firm type	Hybrid strategy		Examples
MAT–biotechnology interface	Material science	→ Drug therapy	Interface, Rimon
	Material science	→ Diagnostic device	Toxin Alert, Safe Guard Biosystems Inc.
	Drug therapy	→ Medical device	MDS, Pheromone Science, VisualSonics, Delex
MAT–information technology interface	Diagnostic device	→ Data storage	TM Biosciences, Safe Guard Biosystems Inc.

Note: MAT, medical and assistive technology and device.

events and government-sponsored networking sessions in the biomedical sector.

Medical and assistive technologies and devices (MAT)[1]

How prevalent are hybrid strategies in the GTA? The medical and assistive technologies and devices (MAT) industry is the most hybridized subsector of the region's life science industry. Close to half of the MAT firms interviewed for this study started out as dedicated distributors or specialty service and repair shops. Eventually, these firms integrated backwards into product manufacturing, often exploiting their working knowledge of an existing product flaw or shifting customer demand. The following examples illustrate this strategy.

Radiocare Ltd[2] began as an importer of European and US-made radiology equipment. Eventually the firm branched out into other areas of medical technology, importing cardiology and pain management equipment from Europe and selling it to hospitals in Montreal and the GTA. Face-to-face interaction with hospital practitioners and technicians – the front-line users of imported technology – helped the firm see an opportunity to improve upon an existing cardiology machine. In the late 1990s, the firm entered into a formal research agreement with medical researchers from the GTA to develop and test a new device to be used in paediatric surgery. This localized relationship in turn opened new opportunities for research collaboration with GTA-based healthcare providers in the area of pain management. Today, the firm sells its own proprietary technologies to national and global markets and continues to import and distribute complementary product lines in cardiology, radiology and pain management.

Another example involves a GTA-based firm that started out as an endoscope service-and-repair shop for local area hospitals in the early 1990s. Through their repair work and daily interaction with lower-level hospital administrators and front-line practitioners, the firm's managers saw an opportunity to become involved in manufacturing and, in the process, created a more durable line of products. While the firm focused initially on the GTA market, it has recently entered into an agreement with a global endoscope manufacturer to acquire the global firm's GTA branch facilities. This, in turn, has allowed the firm to extend its market reach outside the region, as well as address local skill shortages in endoscopic repair. As with the other cases, the firm continues to use a mixed strategy of imported product distribution and internal product development.

The extensive use of hybrid strategies among MAT manufacturers is confirmed by recent data gathered by GTA-based Health Technology Exchange (HTX).[3] In compiling its database of Ontario MAT firms, HTX sought to document the full range of activities performed at the firm level. According to this database, 131 (or 70%) of the GTA's 187 Canadian-owned MAT manufacturing firms performed at least *one* of the following three additional types of activities: distribution of other companies' products; product repair and maintenance; or fee-based consulting or logistics services. Hybrid strategies that combine manufacturing of proprietary devices and technologies with distribution of other company products are most common. Close to 25% of the region's 131 MAT hybrids perform *two or more* of these additional activities. This figure does not capture within-activity hybrid strategies, such as the case of Markham-based dialysis machine-maker Medionics, which combines different *types* of manufacturing activities: contract manufacturing services and production of its own line of proprietary devices. This omission suggests that the true rate of hybridization within the region's MAT industry is likely higher than indicated by the HTX database.

'BIG PHARMA' AND BIOTECHNOLOGY HYBRIDS

While hybrid strategies seem to be especially prevalent amongst MAT firms, the research has uncovered many hybrid firms in pharmaceuticals and biotechnology. As documented in the following section, there is also evidence of increased *institutional* support to GTA-based biotech/pharma firms employing hybrid growth strategies. This suggests the possibility for widening strategy diffusion in years to come.

In the pharma and biotechnology categories, one of the most prominent examples is MDS Inc., a publicly traded life science conglomerate with annual revenues

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of over US$1.5 billion in 2003 (a net income of US$48 million), headquartered in the GTA.[4] MDS Inc. is the quintessential hybrid firm, testing out and combining its diverse skills in laboratory and investor services, medical technologies, scientific devices and proteomics research. Since its creation in 1969 by former IBM employees, the firm has adopted a strategy of acquiring local and non-local firms, assembling a full set of life science and medical health-related activities. In 1970, MDS Inc. acquired Toronto Medical Labs, allowing it to move into laboratory diagnostics and testing – a core activity and major revenue generator for the firm even today. In 1981, the firm acquired SCIentific EXport, a manufacturer of mass spectrometers. The creation of this division proved to be a strategic move of considerable significance, as mass spectrometers have become one of the key types of capital good used in the analysis of protein structures for the purposes of drug discovery (as described below). In 1995, the firm also acquired PanLabs International, a US-based contract research firm that was renamed MDS Pharmaceutical Services in 1996. The firm's clinical trial facilities, headquartered in Montreal, also perform clinical research in the GTA region.

Protana Inc. is MDS's latest creation. Protana's mission is to build on earlier work performed by the firm's core biotechnology division, MDS Proteomics (established in 1999). Protana Inc. absorbed MDS Proteomics in 2004 after the latter failed to launch a successful initial public offering (KIRBY, 2004). MDS Inc. and MDS Capital (the firm's in-house venture capital division) supported this restructuring in order to generate additional company revenue by providing analytical services in protein identification and characterization for drug-discovery firms in the Toronto region and elsewhere.[5] To perform this work, Protana also draws on MDS Sciex's existing expertise in mass spectrometry. Interestingly, MDS Inc. has adopted the language of hybridization as indicated in a published statement that describes this technology partnership and activity-mixing as:

> a '*hybrid*' approach (that) will jump start the process of lead discovery and optimization by greatly reducing the number of components that need to be physically screened and synthesized.[6]

Biovail Corp. is another local leader in the hybridization process. In addition to developing proprietary technologies, Biovail offers contract research services to local and non-local biopharma operations. The firm originally targeted GTA-based generic drug manufacturers – companies that initially lacked the internal resources and know-how to manage highly regulated equivalency-testing programmes. Biovail Contract Research is currently based in Scarborough (in the north-eastern quadrant of the GTA) and employs over 200 clinical trial experts and related support staff. Since its founding, the company has completed more than 2500 clinical trials involving some 25 000 healthy volunteers from the GTA region.

Biovail is also pursuing a hybrid strategy in the area of drug discovery in so far as it combines research and development-intensive product development work with incremental or marginal improvements to *existing* drug therapies. The firm finds novel ways to extract new value from other firms' intellectual property by taking existing prescription drugs with expiring patents and remanufacturing them with the company's proprietary, slow-release technology. In doing so, Biovail has avoided much of the high start-up cost associated with *de novo* drug-discovery and development work.

Cangene, one of the larger, mature biotechnology firms in the GTA, provides both contract research and contract manufacturing services. While its contract manufacturing operations are based in Manitoba, they are organized from the firm's Mississauga facilities. NoAb Biodiscoveries, a mid-stage firm, is yet another example of GTA-based biotechnology operations that provide contract research services while simultaneously working to develop novel drug therapies of their own. Finally, Insception Biosciences, a stem cell research start-up firm, provides specialized client services through its cord blood bank, an existing operation known as the Toronto Cord Blood Programme that it acquired from GTA-based Mt. Sinai Hospital.[7]

In addition to these technology-extension hybrid strategies, convergence-based hybrid strategies are central to the evolution of other GTA-based biotechnology start-ups, including Delex Therapeutics, Rimon Therapeutics, TM Bioscience, VisualSonics, Interface Biologics and Pheromone Science. In each of these cases, firms are working at the interface of biotechnology and medical and assistive technologies. In the case of TM Bioscience, for example, the firm combines technologies to develop new DNA testing techniques and complementary testing devices for identifying genetic mutations related to thrombosis, cystic fibrosis, drug metabolism and common hereditary diseases. A second example, Interface Biologics, is working with:

> polymers to yield materials with increased biostability, improved biocompatibility, improved membrane selectivity, and reduced protein fouling.[8]

The polymer technology is applied to medical devices that are inserted into the human body during surgery.

The widening use of diversified business strategies by biotechnology firms in the GTA has been captured by Statistics Canada's Biotechnology Use and Development Survey (RAOUB *et al.*, 2005). One important measure of intra-firm diversity reported by this survey is the proportion of total research and development expenditures allocated to pure biotechnology activities by recognized biotechnology establishments. While

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this information is only reported at the provincial level, some important generalizations about municipal-level growth trends, due to the concentration of biotechnology establishments in large urban areas, can still be made.

Data from the latest reported Use and Development survey conducted in 2003 indicate that only 57% of total research and development expenditures went to pure biotechnology activities by Ontario-based biotechnology establishments, leaving 43% for other areas of research and development. These figures are especially telling when they are compared with those reported by firms in other lead biomedical provinces in Canada. In 2003, Quebec-based firms reported spending 74% of their research and development funds on 'core' biotechnology activities. In the case of British Columbia, this number jumps as high as 92%, leading analysts from Statistics Canada to describe this province's biotechnology industry as one of the country's 'most specialized' (RAOUB *et al.*, 2005, p. 22). Historical data also indicate an historic preference for specialization by biotechnology firms in Quebec, British Columbia and Alberta.[9] In 1998, 79% of Quebec's[10] research and development expenditures went to pure biotechnology activities. In British Columbia and Alberta, these figures were 85% and 74%, respectively. In contrast, only 54% of research and development expenditures made by Ontario-based biotechnology firms were destined to pure biotechnology activities in 1998, indicating a distinct regional preference for diversified or hybrid business strategies.

HYBRIDIZATION: INDIVIDUAL INITIATIVE OR INSTITUTIONALIZED PRACTICE?

On one level, hybrid responses such as the ones described above reflect individual initiative on the part of firms, stemming from a variety of motivations. In the case of MAT manufacturing, for example, GTA firms admit to using local sales of imported goods to stabilize their revenue streams and, in the process, develop proprietary technologies despite limited sources of external financing.[11] Similarly, by continuing to offer distribution and repair services, smaller firms find they are in a better position to secure contracts from local area hospitals for their internally developed products despite procurement systems that favour products manufactured by multinational device and equipment makers. In pharma, GTA-based operations are also combining traditional drug development activities with new client services as a way to buffer themselves against intensified market competition at the local and global level. Along these lines, pharma firms have created disease management centres to replicate clinical trial conditions and, in turn, provide a more structured environment for patient therapy. Their role is to facilitate greater communication between patients and practitioners, as well as to bring together teams of specialists to develop customized treatment regimens. In the process, these outreach centres are expected to provide locally based pharma operations with an additional means of learning about new uses and applications of existing and combined therapies, at the same time that they enable firms to promote brand and product loyalty in the region. Finally, in core biotechnology, GTA-based firms admit to using hybrid strategies as a way to deal with the chronic financial uncertainty that is endemic to the industry. Hybrid strategies involving contract research services have been employed by GTA biotechnology firms in order to generate additional, supplementary revenue to finance more risky drug-discovery work. These efforts have been especially critical in recent years as investors – both in Canada and the USA – take a more conservative stance towards biotechnology financing (THE ECONOMIST, 2004; POLLACK, 2004; TRAORÉ, 2003). In addition to generating income for drug-discovery activities, hybrid strategies help improve the financial standing of GTA firms by illustrating to the investment community their willingness and ability to manage and support revenue-generating activities. As the following quote by a GTA biotechnology entrepreneur illustrates, hybrid strategies enable biotechnology firms to establish formal linkages to the pharma community by offering these firms specialized contract services:

> We are offering services to generate revenue. We're not a pure research-based biotech company ... and we are not a pure CRO. Actually it's a hybrid. What we want to do is establish a revenue stream to fund or to at least help out in the money burning venture like biotech research. (2003)

As these examples illustrate, firms in the GTA are cognisant of the benefits of combining distinct activities. Still, to leave the analysis here – that is, as a story of individual and firm-level agency in the face of greater economic and technological uncertainty – misses an important part of the story. One could argue that it is helpful to step back from the company office (or, in some cases, laboratory) and reflect on the institutional foundations and legacies that structure and give rise to this adaptive local response. Why are GTA firms prone to adopt hybrid growth strategies, especially at a time when firms in other Canadian biomedical clusters are pursuing greater intra-firm specialization? What explains the widespread use of hybrid strategies across multiple categories of GTA-based life science firms? What local and non-local structures and actors provide support to and/or reinforce intra-firm hybridization within the region? Stated another way, what impact does the regional innovation system have on the adoption and diffusion of hybrid pathways in the GTA life science industry?

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These questions are examined in the next section. It is argued that widespread use of hybridization among GTA-based life science firms is not simply an outgrowth of individual initiative or a reflection of optimal choice in the face of emerging economic and technological constraints – as SABEL (2001) and AMSDEN and TAKESHI (1994) would have one initially believe. Rather, this response is a reflection of a rich, evolving regional institutional environment that is quite distinct.

STRUCTURAL AND ACTIVE INSTITUTIONAL SHAPING OF LIFE SCIENCE INNOVATION

At first glance, the GTA's existing institutional architecture resembles that found in other life science-rich regions in North America. On closer inspection, however, a number of distinct features and qualities are found that, in turn, explain the widespread adoption of hybrid growth strategies by GTA-based life science firms. It is argued that it is the presence and collective reinforcement of the region's distinctive institutions that ultimately explains why life science firms in the GTA have embraced hybridization (rather than specialization) as a logical and preferred local response.

Institutional supports for hybridization fall into two categories. Traditionally, existing institutions in the region have acted as *structural*, rather than active, supports. They are slowly changing features of the local political–economic landscape and their visible presence, while clearly creating conditions conducive to hybridization, has not wholly determined this as a dominant firm response. In many cases, the entrepreneur is aware of these structural supports and acts to exploit them in pursuit of a stated economic goal. In other words, the firm owner or entrepreneur is the central, strategic actor here, determining if and when to internalize and drawing on these structural supports to combine or mix distinct activity types. Still, these supports shape the decision-making process in ways not fully recognized by firms themselves, often by reinforcing taken-for-granted norms and practices.

The second group – which are referred to here as *coordinating or enabling actors* – includes a new generation of venture capitalists, economic development practitioners, and industry mentors familiar with 'knowledge economy' management and specializing in supporting life science entrepreneurship. Enabling actors have, over the course of their life science careers, had a close association with established hybrid firms in the region. In the process they have not only developed an acute awareness of the benefits of this organizational form, but also, more importantly, have shifted their 'worldview' to conform with and reflect that of other, established life science actors. These actors promote hybrid strategies to industry newcomers through their ongoing participation in regional financial markets and industry associations. They also coordinate efforts that deepen the relationship between existing institutional supports.

So what are these institutional supports and how do they set the GTA apart from other life science-rich regions? Three categories of institutional supports have been identified: policy, financial, and networking supports. Each category includes examples of both *structural supports* and *enabling actors*, with the latter acting to bolster or deepen the former.

HEALTHCARE

As Canada's most populous province,[12] Ontario is a key player and national trend setter in public healthcare policy and management. The province's increasing healthcare demands not only justify continued support for improved medical technologies, but also explain simultaneous efforts to reduce the financial burden of provincially supported healthcare services and medical insurance. Reflecting these 'competing goals', a province is found that not only receives the largest share of medical research funds in Canada, but also leads the nation in policy reforms aimed at lowering prescription drug costs through government-monitored drug-pricing programmes.

Shifting scales to the GTA – Canada's most populated metropolitan area – three components of the region's system come into play in the analysis: the procurement systems of local-area hospitals and healthcare clinics; early demand for contract research support by GTA-based generic drug makers; and finally, the diversity of life science research that encourages experimentation across traditional disciplinary boundaries.

Among MAT firms, the region's diverse hospital base has created opportunities for firm owners to engage in and combine distribution, repair and manufacturing activities. The GTA is home to a large number of publicly funded teaching hospitals, including the University of Toronto's twenty affiliated teaching hospitals (LOWE and GERTLER, 2005; DE REUS, 2004). There are also numerous public and private community clinics and regional healthcare centres.[13] In addition to helping improve the quality of life for GTA residents, the region's healthcare institutions play an important role in the local economy by purchasing medical equipment (P. Goodhand, personal communication, 7 January 2005).

Policy analysts from the region tend to be critical of hospital procurement systems, claiming that the centralized nature of product purchasing by local-area hospitals limits sourcing opportunities for indigenous MAT firms (for example, MARTIN, 2003). While the research does reveal the dominance of foreign-made technologies, it also shows that procurement systems in the region remain *porous* enough to encourage considerable local product penetration. Expensive, bulky machinery

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such as magnetic resonance imaging (MRI) scanners, and non-specialized or standardized goods – such as syringes, tongue depressors, and basic surgical instruments – tend to be purchased through centralized procurement offices and inter-hospital buying networks or regional 'clubs'. As such, contracts for these products tend to be captured by high-volume, multinational producers and distributors (e.g., GE, Baxter, Johnson & Johnson, Medtronics). However, the interviews confirm that specialty and customized products are purchased on request of front-line practitioners and division administrators. Even in the case of the University Health Network – considered the most centralized purchasing system in use in the GTA – 50% of all products are purchased on request by front-line practitioners.

This bifurcated system has not gone unnoticed by locally owned specialty-goods producers and distributors. Rather, owners of small, indigenous operations take advantage of decentralized procurement channels to identify and respond to local demand for specialty goods and customized equipment. At the same time, they benefit from the large numbers of hospitals and healthcare clinics in the region, which – despite recent attempts to coordinate better local purchasing through inter-hospital logistics management and online ordering systems (KING, 2004) – provide continuing opportunities for local sourcing.

The large concentration of healthcare personnel in the GTA is another contributing factor to the hybridization process and one that reflects the density of healthcare facilities in the GTA. While this characteristic is hardly unique to the GTA, it does help to reinforce hybrid strategies by enabling firms to tap diverse healthcare supports. As one medical device executive from the GTA expressed it in 2003:

> it's really a medical research pot here . . . which is valuable . . . because we have a lot of relationships with clinicians, surgeons, with universities and so on.

Ultimately, the region's diverse healthcare strengths enable firms to combine specializations, as demonstrated by this 2003 statement from an executive of a GTA division of a multinational pharmaceutical firm:

> Typically, disease management projects . . . require clinician leaders who can . . . identify gaps in care between the trial and the treatment. and to do that kind of rigorous analysis and intervention, you need people who are very interested in [*both*] research and also clinical practice.
>
> (emphasis added)

According to one estimate, the GTA is now home to over 8200 physicians and 54 000 health professionals.[14] A significant number of the firms included in the study were established by locally based and trained healthcare professionals or emergency service workers. This subset of life science entrepreneurs admit to using their existing professional connections and medical knowledge to embed themselves further within the GTA hospital and healthcare network, both as product distributors/repairers and eventually as innovators.

Related to this, owners of GTA-based MAT establishments often build on earlier educational links to local area universities and technical colleges, including the University of Toronto, McMaster University, and Seneca and Sheridan colleges. In some cases, MAT entrepreneurs have turned to their college and university mentors for assistance in product development. Some have taken steps to formalize these relationships by securing grants to support collaborative research and clinical testing. The interviews suggest that these relationships have been especially helpful to firms attempting to make the transition from product repair and distribution to product improvement and innovation.

In *core biotechnology*, density of another kind comes into play – specifically, the high concentration of brand name and generic pharmaceutical firms. According to Rx&D, an industry association that represents brand name pharmaceutical firms in Canada, Ontario is now home to thirty brand name firms, most based in the GTA.[15] Second in the nation is Quebec with twenty-five firms. The region is also considered the centre of generic drug development in Canada, hosting seven of the nation's twelve generic prescription drug makers.[16] This itself reflects federal and provincial policies dating back to the 1960s – namely federal legislation that required brand name prescription drug-makers to license their products to Canadian generic drug-makers, combined with Ontario's drug formulary that favoured the purchase of generic drugs through the reimbursement programmes it developed in the early 1970s (GORECKI, 1993; JENISH, 2003).

As mentioned above, the large presence of generic drug-makers in the GTA created a strong local demand for contract research services in the 1970s. In recent years, brand name pharmaceutical firms in the region have followed suit, outsourcing research, clinical trial management and manufacturing tasks. This has helped to fuel additional demand for contract research and manufacturing service providers. It is not surprising, then, that the GTA now hosts a large number of contract research operations, including indigenous firms such as Patheon Inc. and Biovail Contract Research. The growing demand for these services has opened new possibilities for core biotechnology firms.

At the same time, core research strengths in the GTA have helped support hybrid strategies, including technology crossovers involving biology and material sciences. From 1996 to 2000, the province ranked first in the nation for biotechnology-related publications, generating 41% of the nation's 6827 scientific articles (HOLBROOK and CLAYMAN, 2003).[17] In addition to this, the GTA is home to a large number of renowned academic research centres. Core strengths in multiple fields, as well as national and provincial

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support for interdisciplinary research, has further encouraged activity or discipline mixing across life science and physical science fields. As will be shown in the next section, seed-fund managers and technology transfer agents are actively working to extend this interdisciplinary tradition.

The previously mentioned examples could be categorized as structural policy supports. The regional concentration of hospitals, healthcare centres, research institutions, brand name and generic pharmaceutical firms, while not consciously developed for the purpose of creating life science hybrids, clearly supports this localized response. As such, local policy interventions to develop and sustain an affordable and high-quality healthcare system contribute to the regional innovation system by creating additional inputs and demand for hybrid goods, as well as foundational supports for knowledge development and deepening. In recent years, regional policy actors from Ontario's Ministry of Economic Development and Trade (MEDT) and Ministry of Research and Innovation (MRI) have, together with their federal (Industry Canada) and local (City of Toronto) counterparts, taken steps to formalize local policy supports for hybridization. As such, they are categorized as *enabling actors*. Two interconnected initiatives are the visible result of their work: Toronto's Medical and Related Sciences (MaRS) Discovery District and Ontario's Biotechnology Cluster Innovation Program.

The MaRS Discovery District is a life science convergence centre located in downtown Toronto. Phase one of the project was completed in May 2005 and hosts a range of life science establishments in its 700 000 square-foot facility.[18] Financing for the project comes from the federal, provincial and municipal government agencies. Early MaRS tenants include a number of key institutional players in the region such as the Canadian Medical Discoveries Fund (a labour-sponsored investment fund supplying venture capital to life science firms), the Innovations Foundation (the University of Toronto's largest technology transfer office), the University Health Network (a network of University of Toronto-affiliated teaching hospitals), and the Royal Bank of Canada's technology venture division. MaRS aims to support technology convergence – a specific type of hybridization discussed above – by facilitating interdisciplinary research-and-forging linkages between life science firms and other firms specializing in information technology, nanotechnology and related fields (MaRS News, 2003a, b). The Center has also leased research and office space to existing biomedical hybrids, including MDS Sciex and Interface Biologics, a MAT–biotechnology hybrid discussed above.[19]

Finally, MEDT's Biotechnology Cluster Innovation Program (BCIP) – created in 2003, and subsequently moved to MRI when the latter ministry was formed in 2005 – has helped to increase awareness of hybridization through its support for research on distinct regional approaches to life science industry development in Ontario. BCIP-funded research has revealed hybridization as a dominant strategy among GTA-based biomedical technology and device firms and an emerging strategy within the region's core biotechnology and pharma group (Hickling Arthurs Low, 2004). The results of this research are being used to encourage Ontario regions to identify, build on and share information about successful growth strategies. In the process, existing supports for hybridization – including those affecting decisions about hospital procurement, research outsourcing, technology convergence and intellectual property recycling – are expected to receive additional policy attention.

FINANCIAL SUPPORTS

Venture capitalists have long shaped the growth strategy of the region's biotechnology industry through their investment decisions. In recent years, their influence on the hybridization process has intensified, especially in *core biotechnology*. In the late 1990s, punitive steps – often involving the withdrawal or withholding of funds from high-risk ventures – sent a strong message to the region's core biotechnology community and, in the process, encouraged local firms to experiment with and internalize revenue-generating activities, including contract research, contract manufacturing and specialized storage services. It should be noted here that the GTA life science industry has traditionally received a higher share of its venture capital from private sector sources, compared with neighbouring life science centres such as Montreal, where venture financing from public and quasi-public sources predominates (Lowe and Gertler, 2005; Niosi and Bas, 2003). As mentioned above, private investors now take a more conservative stance towards biotechnology funding and, for the past three years, have virtually eliminated financing for intermediate or mid-stage firms. This obviously has had an effect on the GTA's life science industry, as it has created an additional risk of financial shortfall for maturing biotechnology firms. Mid-stage firms are adopting hybrid strategies in an effort to mitigate this challenge.

A small number of newly formed boutique venture capital operations in the GTA – those specialized in seed financing for early-stage firms – now provide additional support for hybridization, shifting from a reactive to an enabling role. In most cases, this support reflects a local awareness of the financial challenges that await start-up firms as they make the transition from early drug-discovery work to the proof-of-principle phase. Seed fund managers are now actively encouraging start-up entrepreneurs in the region to plan ahead and, in the process, help them test and develop revenue-generating activities.

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Interestingly, growing support for hybridization by one local seed fund also reflects their earlier affiliation with MDS Capital. In this case, the majority of the firm's financial and business advisors had worked previously at MDS Capital and, as a result, have had direct exposure to the daily workings of the region's lead hybrid operation, MDS Inc. This seed fund recently helped one of its start-up clients (Insception Biosciences, discussed above) to negotiate a deal with a local hospital to acquire an existing blood storage bank. Profits from storage fees will be used to smooth out financing for the firm's core drug-discovery work. The same seed fund is also helping a start-up firm to negotiate an alliance with an existing medical device manufacturer. Through this relationship, the client firm is in a better position to broaden its focus from drug discovery to product innovation, in this case creating a novel drug-delivery mechanism that has the potential to be licensed out to both core biotechnology and traditional pharmaceutical operations in the region. This last example reflects the growing interest by GTA-based venture capitalists in drug and device convergence. To quote a statement made by one GTA investment fund in 2003:

> The convergence of the drug and device world is expected to create tremendous revenue growth over the next three to five years. . . . This round of (convergence) investments by the Fund represents an excellent cross-section of companies well positioned for success in these areas, including developing drug eluting devices, tissue and bone regeneration technology and specialized tools for early cancer detection.[20]

Financial advisors and fund managers are providing additional support for hybrid strategies through their efforts to bolster previously under-utilized structural supports. In one example, a GTA-based life science venture capital firm has helped to elevate the status of a university technology transfer office within the local life science community. They are doing so by working with technology transfer officers to organize formal, monthly networking events to help university scientists interested in identifying commercial uses of applied research. This is important as technology transfer offices in the GTA have long been regarded as weak institutions, especially in the area of biotechnology and life sciences (for more details, see LOWE and GERTLER, 2005). By co-hosting formal events, university officials have been able to highlight recent improvements to their technology transfer system, as well as feature successful life science firms that have benefited from their support. Through these events, technology transfer agents are also learning more about the portfolio of the venture capital firm and in the process have been able to interact and dialogue with technology extension and technology convergence hybrids from the GTA. This is helping to inspire additional rounds of hybrid promotion within the university setting.

NETWORKING, MATCH-MAKING AND MENTORING

The final category involves related forms of inter-firm networking. Here are included formal interactions that are facilitated through association and other group memberships. Also included are informal mentoring relationships and, specifically, the ongoing role played by lead hybrids – namely MDS Inc. and Biovail – in sensitizing local entrepreneurs to the benefits of and local institutions available to support alternative growth strategies. As already mentioned, investment decisions by some locally based seed fund managers reflect earlier employment links to one of the region's largest hybrid operations: MDS Inc. Start-up entrepreneurs and managers from the region have similar employment histories, acquiring earlier industry and research experience at MDS Inc. and other lead hybrids, such as Biovail. In some cases, individuals have also acquired earlier work experience at large pharmaceutical firms and late-stage biotechnology firms in the region, including Allelix, Cangene and Glycodesign. Through these experiences they have learned to value revenue-generating activities and, as a result, have turned to hybridization as a way to generate cash flow for their smaller life science firms and start-up operations.

Local awareness of hybridization is further reinforced through industry events, association meetings, and local media coverage of key firms and industry trends. MDS Inc., for example, actively publicizes its support for hybrid operations, including its on-going experiment with activity mixing (note again the newly formed MDS Protana, whose central mission is to bridge the work of MDS Proteomics and MDS Sciex). Through their participation in local associations and industry support groups, executives from all divisions of MDS Inc. help to bring additional attention to the firm's continued commitment to hybridization. Biovail too has helped to shape and reinforce local growth strategies. Despite their organizational similarity with brand name pharmaceutical firms in the GTA, they remain an active member of BIOTECanada, a nationwide association of core biotechnology firms and start-ups, not Rx&D, the region's brand name pharmaceutical association. Similarly, Biovail Contract Research is an active member of the GTA-based Canadian Generic Manufacturers Association, again reinforcing the firm's link to local/national, rather than multinational interests. Biovail's formal affiliations are important for several reasons. First, they help to reinforce Biovail as a home-grown success even as it moves to globalize its interests and investments further. Second, they help to legitimize growth strategies that seek to extend the commercial life of existing drug therapies through innovations in drug-delivery systems and devices and through new combinations with other drug therapies. And third, they provide an internationally recognized

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model of lower-risk, sustained growth, which local biotechnology firms use when pitching their own hybrid strategies to more cautious potential investors and collaborators, both locally and non-locally.

Early- and mid-stage biotechnology hybrids are also starting to use industry associations and informal networks to push forward regulatory reforms that encourage greater activity mixing. In one case, a half-dozen local hybrid operations have formed a small group to monitor changing regulations in the USA aimed at eliminating duplications in the product approval process. Traditionally, hybrid operations that combine biological and device technologies have had to file two separate applications in the USA, one seeking approval for the drug therapy, the other for the medical device or delivery system. The group – with links to a science seminar series at the University of Toronto – is actively taking steps to encourage regulators in Canada to adopt similar reforms.

Finally, associations also play an enabling role in strategy formation in other segments of the life science industry. In *medical and assistive technologies*, the former director of Health Technology Exchange (HTX) – a 'civic entrepreneur' with earlier connections to a biomedical technology and device association – has played a lead role as sector coordinator and, as a result, provided direct support to the hybridization process. Based out of Markham's Innovation Synergy Centre in the Northern GTA, HTX – a non-profit, member-based organization – was established to provide match-making services to MAT firms throughout the province. It does so by coordinating formal and informal exchanges between medical device firms, specialty distributors and industry suppliers.

HTX's support for the MAT industry, while still in the early stages, is having a positive impact on firm growth in the region. At the same time, their work has helped hybrid operations deepen their commitment to product manufacturing. It was thanks to an HTX-facilitated exchange that the earlier mentioned endoscope repair firm acquired a GTA-based endoscope production facility from a large, multinational medical device firm. This exchange, in turn, enabled the locally owned endoscope firm to increase its share of the North America market. In other cases, hybrid operations have turned to HTX to identify and connect with local area consultants, product designers, and engineers that offer assistance with product improvement and development. HTX-facilitated exchanges with specialty distributors and divisions of multinational distribution firms have also helped hybrid MAT operations negotiate long-term, stable contracts with local area hospitals and clinics.

CONCLUSION

Industry analysts from outside the Greater Toronto region have expressed concern about the sustainability of Toronto's hybrid strategy. Two interrelated arguments have been put forward for why firms should specialize in, rather than diversity away from, their core area of expertise. First, hybrid strategies are said to dilute and stretch already limited managerial and business resources, particularly in cases where firms attempt to combine research and service activities, rather than merge technologies and disciplinary fields. Related to this, arguments have been heard about the potential risks of having innovative firms become overly revenue driven and dependent. The concern here is that biomedical firms, and especially early-stage dedicated biotechnology firms, will undervalue the importance of and need for on-going research and development and, in turn, will undermine the firm's (and region's) innovative capacity.

There is some validity to these claims which the present research, to some extent, helps to support. It can be argued, for example, that MDS Inc. prematurely closed and transferred the assets of its biotechnology division (MDS Proteomics) to its protein analysis operation, MDS Protana – a decision which indicated a favouring of revenue-generating services over more innovative drug-discovery work. The financial success of MDS's other divisions – including its laboratory service and spectrometry operations – is partly to blame here as company executives and shareholders have grown accustomed to a steady stream of quarterly earnings and returns. As a result, MDS Proteomics lacked the 'patient capital' needed to finance initially costly *de novo* discovery work and wait out the ten years or so it typically takes for a biotechnology firm to commercialize a new product or process successfully – MDS Proteomics was only five years old at the time of its 2004 closure. The present study also suggests that a handful of smaller hybrids – in both medical devices and dedicated biotechnology – do face considerable managerial and entrepreneurial challenges which are often exacerbated by early decisions to multi-task.

Yet, to conclude this paper with arguments for why GTA firms should avoid, rather than embrace, hybrid strategies ignores two additional elements of the anti-hybrid argument. First, scepticism of this strategy tends to come from individuals and analysts located outside the GTA and, for that matter, Ontario. In fact, the most vocal critics are residents of two other major life science centres: Montreal and Vancouver. These regions have not only very different institutional environments from that of the GTA, but also unique institutional support systems that are more closely aligned with firms adopting specialized, rather than hybrid, growth strategies. In these regions, industry role models tend to be highly specialized biotechnology firms, including QLT in Vancouver and BioChem Pharma in Montreal, not hybrid operations like MDS Inc., Biovail, or even Allelix, which started out as an agricultural–human health hybrid by using canola seed sales to finance breakthrough medical discoveries

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in the 1980s. Similarly, national and international financial markets favour and reward specialization strategies, as do university research supports and technology transfer offices (for more details on Montreal's life science institutions, see LOWE and GERTLER, 2005).

This brings the paper to the authors' second point: in contrast to Toronto, institutional actors in these regions not only are less prepared to cope with and adapt to some of the challenges that can arise with hybridization, but also are less amenable to searching within their existing support systems and networks for hybrid-promoting and hybrid-legitimizing solutions. In contrast, institutional actors from the GTA are both aware of the widespread adoption of this strategy by resident firms and also keen to address the localized 'sticking points' that might arise from its ever widening use. As seen above, venture capital firms are now active in promoting hybrid strategies amongst the region's dedicated biotechnology start-ups. At the same time, these organizations are careful not to overburden early-stage firms with disconnected, resource-diluting activities. Rather, they help to guide firms to revenue-generating activities that are best suited to the firm's existing skill sets, research strengths and resource availability. As mentioned above, similar support is being offered to GTA-based MAT firms by the Health Technology Exchange.

In drawing attention to these differences, it is not being suggested that other regions in North America adopt hybrid strategies and/or embrace and replicate Toronto's hybrid-favouring institutional system. After all, other life science centres in Canada, including Montreal and Vancouver, have performed well by building on their own local advantage in specialization. Rather, the goal is to suggest that Toronto's unique localized supports can be further bolstered through targeted policy such that solutions to hybrid-specific challenges are collectively analysed and addressed. While policy-makers in the GTA and Ontario are receptive to hybridization, they tend to favour one type of hybrid strategy, namely that involving technology convergence – an example of this is the above-mentioned MaRS project. What is now needed is a better understanding of the wide (and widening) range of hybrid strategies in use today, as well as the diverse institutional supports that have helped to shape these interrelated adaptive responses. Ultimately, it is through this exercise that local business practice can be better guided in ways that result not only in high firm survival rates (and thus stable regional employment), but also in a concurrent commitment by local firms to continuous product and process innovation.

A more general point also arises from this discussion – namely, that there can be more than one pathway to economic success in life science innovation, and that it makes sense for individual regional economies to develop strategies that build on their own distinctive assets and capabilities. As MASKELL and MALMBERG (1999) pointed out some time ago, a region's institutional architecture can be a key element of its asset base. Moreover, because it is slow to develop and change, it is also difficult to replicate quickly in other jurisdictions, making it a 'non-ubiquitous' characteristic. In simple terms, the drug-discovery model that is so frequently singled out in the burgeoning literature on biotechnology need not – indeed, according to the present analysis, should not – be the only model to guide the formation of regional strategies for life science development.

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NOTES

1. Included within this category are medical and assistive technologies, as well as medical and biomedical technologies used for patient and disease diagnosis and therapeutic applications. It is a broad and diverse sector that includes manufacturers of products as varied as dialysis machines, surgical instruments, visual and hearing aids, and wheelchairs.
2. In most cases, the names of individual firms have been changed in order to honour requests for anonymity. Actual names are used where information has been confirmed using publicly available and published sources.
3. HTX is a non-profit organization that was established in 2001 to help develop and promote Ontario's home-grown MAT industry.
4. This figure was obtained from MDS Inc.'s website (http://www.mdsintl.com/ir_facts.asp).
5. See http://www.protana.com/.
6. Original link: http://www.mdsproteomics.com/facs.shtml (parentheses and italics added).
7. See http://www.mtsinai.on.ca/Cord_Blood/Default.htm/.
8. See http://www.interfacebiologics.com/smm_technology.html/.
9. Data for Alberta are not reported here for 2003 as Statistics Canada indicates potential reporting problems for the province.
10. For most years between 1998 and 2003, Quebec's share of research-and-development spending for pure biotechnology activities hovered around 75%. The one exception is 2001, when pure-biotechnology research-and-development expenditures dropped to approximately 40%. While additional research is needed to explain this apparent statistical anomaly, the authors believe it reflects the fast growth (and subsequent international sale and relocation in late 2001) of Montreal-based firm BioChem Pharma, which managed to achieve global industry status between

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1999 and 2001, thereby allowing it to move quickly into more diversified areas of biomedical research and development.

11. Note that few GTA-based MAT firms rely on venture capital financing. The majority self-finance through product sales and distribution activities or rely on traditional forms of external financing, such as bank loans. The exceptions are firms that are categorized as MAT–biotechnology hybrids.
12. Ontario's population in 2001 was 11.4 million, or 38% of Canada's national population.
13. See http://www.greater.toronto.on.ca/.
14. See http://www.greater.toronto.on.ca/.
15. See http://www.canadapharma.org/.
16. See http://www.cdma-acfpp.org/en/resource_facts.html/.
17. Quebec based-scientists published 2000 biotechnology-related articles during the same period, accounting for 28% of the national total. Values for British Colombia and Alberta were 14% and 12%, respectively.
18. Phase 2 will include a 550 000-square-foot building with office space, wet/dry laboratories, and shared meeting rooms (see http://www.marsdd.com/portal/desktop/explore/phaseTwo.jsp).
19. See http://www.marsdd.com/portal/desktop/siteMap.jsp/.
20. Original link: http://www.delextherapeutics.com/news/news_03jan14.htm/.

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