Chapter 5

Geomatics as a Tool for Bridging the Cultures of Research

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Abstract. From an opportunistic venture initiated in the first phase of GEOIDE funding (2000–2002) emerged a twelve-year collaboration – ramified and open-ended – generating research approaches and GIS applications in History and in Health. From the experience the authors argue that the professional environment for scientific networking has changed little in 12 years, but suggest some "conversational" strategies for throwing bridges across disciplinary divides.

Keywords: epidemiology, urban history, health, GIS.

1 Introduction

From an opportunistic venture initiated in the first phase of GEOIDE funding (2000–2002) emerged a twelve-year collaboration on tools and strategies for research in History and Health. At the outset, two groups of scholars were seeking to take advantage of a municipal engineering GIS that epidemiologists would use to map cases of active tuberculosis 1996–2002, and historians would use to ensure a rigorous geometry for rectifying century-old maps and geocoding nineteenth-century census records.

Working in parallel, we needed precision in linking Montreal households to addresses.

As conversations proceeded – among graduate students, newly minted technician, librarians, and puzzled colleagues (the students were teaching geomatics to the professors) – common interests emerged and more daring possibilities opened up, with some practical results, funding from other sources, and discoveries no one had anticipated. As collaboration widened to include more colleagues in bioinformatics, social history, and history of architecture, we were building bridges between the "two cultures" of the sciences and the humanities. As C.P. Snow pointed out (1959, 16), "The clashing point of two subjects, two disciplines, two cultures – of two galaxies, so far as that goes – ought to produce creative chances." For us, the richest vein of discussion has been articulation of processes occurring at various scales, and a GIS feature – the on-screen zoom – was bringing us, day after day, side by side, to explore scale relationships in time and space.

Practical results for the local public health agency included innovations in data entry and contact investigation, and the spin-off of a piece of shareware for intranet mapping. A dozen joint papers spilled across academic compartments on transmission of tuberculosis past and present. Both historians and public health personnel evinced a greater appreciation of "place" and expressed some impatience to rethink research routines in their several disciplines. None of those outcomes was foreseen in the initial GEOIDE grant.

Because Canadian granting agencies are relatively short-sighted (GEOIDE 1 or 2 years, Canadian Institutes for Health Research 3–5 years, the Natural Science and Engineering Council 3 years, and the Social Science and Humanities Research Council 3 years), a twelve-year collaboration goes beyond the anecdotal. Claude Bernard, in the paper that took medical research from anatomy to physiology – from the static to the dynamic – transformed an anecdote in the digestion of a rabbit to the notion of a "found experiment" (Bernard 1865, 271f.) Here we propose to treat the 12-year process that issued from Project HSS#56 as a found experiment in scientific networking.

The chapter outlines our adventure in this order: How did we get started? Where did collaboration take us? Where will it take us next? Along these particular frontiers – between epidemiologists, architects, historians, and geographers – can we make some generalizations about the benefits of networking? Did geomatics serve as a catalyst? What personal and institutional assets proved helpful? Although we do not see a notable reduction in the obstacles to interdisciplinary networks, we can suggest some techniques for throwing more bridges across the "Great Rift" between the sciences and the humanities. Since these are conversational strategies, we allow ourselves some informality in the account, with first names and, in quotation marks, some interjections and queries we do not attribute because we can no longer remember who said what.

2 The Starting Line: An Opportunity in GIS

The spark for collaboration between Kevin's team in respiratory epidemiology and Sherry's team in urban history was the attraction of a tool of municipal engineering – the GIS of the City of Montreal.[1] From an epidemiologist's perspective, the tool would situate a Montreal TB patient or contact (at risk of infection) in a dwelling at a precise address, in relation to all the other addresses in the city.[2] From the historian's viewpoint, the city GIS would provide a rigorous and consistent ground truth for geo-referencing heritage maps and creating layers for a new "HGIS" for mapping data from nineteenth-century sources. There was no prototype at this level of precision for a Victorian city of this size.[3]

At the outset, each of the two teams had its own objectives, its own methods and habits, and its own students.[4] A group of four researchers – clinicians, epidemiologists, and laboratory scientists – were building a citywide database of cases of tuberculosis. They had no experience in GIS but had worked together since 1996 under a series of joint grants and in a variety of situations: hospital rounds, university classrooms, public health routines, and recurrent emergencies.[5] The team in urban history was a looser coalition, newly embarked on a two-year grant for a GIS project that would involve a dozen graduate students, all focussed on Montreal but variously lodged in departments of history, geography, economics, sociology, demography, and architecture. Each group was already interdisciplinary. We never intended to fuse the two teams, or to divert scholars from their original goals. But the GIS opportunity, shown as the tangent in Figure 1, represents a moment of encounter between the two teams. As the two balls rolled along, other encounters occurred; we drew other tangents and involved other people.

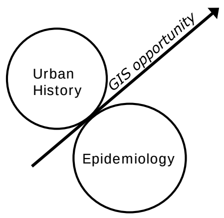

Fig. 1. Starting point: two networks seize an opportunity to exploit a geobase.

We won't say much in the chapter about the GEOIDE grant itself or the layers we created in the informal network of digital humanities known as "MAP, Montréal l'avenir du passé". The two-year grant is a mission accomplished, and we have since expanded the scope.[6] Jason and his students, with SSHRC funding, have generated an analogous project in London, Ontario, for environmental history (fire, flood, and oil); they cooperated with a team focussed on interactions of race and sex in the frontier economy of Victoria (British Columbia) in the 1880s, and the three groups jointly measured comparative evolution of segregation in the three Canadian cities 1881–1951 (http://vihistory.ca; Dunae et al. forthcoming 2011; Hayek et al. 2010). Nor will we attempt to report all of the other activities in the "TB network" such as cost-effectiveness modeling and the search for better diagnostics, with projects in India and in arctic Canada, as well as Montreal. Instead, we focus on the networking *between* our two communities.

The Challenge of Tuberculosis. To see what happened in this network, there are some things you, the reader, may want to know about tuberculosis, a costly and complicated disease. These simple facts were new to many of us.

Transmission of *Mycobacterium tuberculosis* (Mtb) occurs by airborne infectious droplets: coughing, sneezing, spitting. This usually means intimacy in confined spaces at a scale of the bedroom, sickroom, or vehicle. Most of the people infected promptly develop immunity (which can be tested); they don't get sick and are not contagious. Their infection is said to be "latent", but if the immune system is compromised by age, severe undernourishment, or assaults of other diseases (notably HIV), the infection can progress to "active disease".

Latent or active, TB can be reliably cured, but the course of antibiotics takes 6 to 12 months and sometimes has hard-to-manage side effects. For half a century after the causative bacterium was identified (1882), TB stymied the strategies of Pasteur who envisioned a live attenuated vaccine (cf. Latour 1984). In Canada today, incidence of active tuberculosis is rare (5 cases per 100,000 people, among the lowest in the world). Most persons born in Canada after World War Two have not been exposed and lack immunity. Worldwide, however, it is still one of the biggest killers (1.45 million deaths in 2010), and Canada receives more than half its immigrants from countries where most people *have* been exposed, harbour the bacillus, and therefore show an immune reaction on the tuberculin skin test (TST).

Since persons with active disease transmit infection to others, the public health department tracks every one of the 100-150 cases diagnosed on the Island of Montreal each year. Family members with latent TB infection are treated with a preventive course of antibiotics, and the nurses inquire about other close contacts. Because some strains have developed resistance to one or more antibiotics, samples of the patient's sputum are cultured and examined in a high-security lab with specific questions in mind: Is this strain known to be resistant to a particular drug? Does the genotype of the bacterium recovered from a patient match that from another case already discovered? This would imply a transmission pathway linking the two.

Initially, the two research groups shared an interest in the use of GIS to make links at the household level, but we soon recognized that we shared also a conception of the city as a system of circulation – circulation of people, the air they breathe, and microbes as fellow travellers.

3 Where Collaboration Took Us

Important in setting off new lines of questioning were the graduate students who were selected for a modicum of experience with GIS − greater than that of their supervisors. In this section we point out some of the practical results in local public health surveillance, patterns of transmission, and interpretations of how these patterns emerged.

An initial, successful grant application to CIHR allowed us to develop and pilot test a spatial approach to TB in Montreal, using previously gathered epidemiologic and bacteriological data for the years 1996-2000. Geomatics would lend itself to the data management process, but compilation of the spatial component would invite rethinking the entire chain of investigative routine: recording of data, transcription, and coding, in relation to the new tools of inquiry – both the more intensive laboratory analyses and the spatial analyses. How would we assemble the databases? How would we introduce the *Where?* and *When?* into a system designed to reference clinical observations and lab samples? The date stamp on a record was crucial: Which patient developed symptoms first? How much time elapsed? “What markers of time should go onto the computer record?” “What do we need to know about the home?”[7]

Ian, the first of the jointly supervised students, by comparing the residences of 595 TB patients with a control sample (5950 dwellings in buildings with no report of TB) uncovered higher-than-expected incidence of disease in a particular slice of the housing market (Wanyeki et al. 2006). He used variables from the city GIS: age of the building, number of storeys and dwellings, and value per square metre of land. This was the classic approach of the epidemiologist: a case-control analysis. “Why don't historians adopt case control methods?” “Can we evaluate changes in urban form from samples like this?” Even allowing for interference of confounding factors such as median income and percentage foreign-born in the census tract, Ian’s results were unexpected: Higher rates of disease were not associated with the oldest houses, as studies elsewhere had suggested, but with the high-rise apartments of the early 1970s, built with lower ceilings, smaller windows, tighter insulation, and recirculation of “reconditioned air”. His analysis pointed to a further problem: the 5- and 6- story walkups hastily built after World War II and now in need of renovation, “collectors” of families with few options in the housing market, among them refugees, recent immigrants, and large, low-income families.

A second student, by applying nearest-neighbour and spatial scan statistics to the Island-wide data, pinpointed three unrecognized “hot spots” of local transmission (Haase et al. 2007, 2008). His was also a case-control study, and he took advantage of the first batch of data from the molecular lab (816 geocodable cases) to distinguish a special group: When samples from two patients (or more) show the same bacterial “fingerprint”, it is likely that they acquired the infection in the city and were involved in a chain of transmission events. This could reflect direct transmission between the patients, or indirect transmission, where two persons have been infected by the same third party. Were cases with closely related fingerprints living closer together in the urban space than cases with unrelated strains?[8] “But these patients do not seem to be acquainted?” “There isn’t a clue in the contact inquiries.”

The pioneer physiologist mentioned earlier once described the life sciences as "… un salon superbe tout resplendissant de lumière, dans lequel on ne peut parvenir qu'en passant par une longue et affreuse cuisine" (Bernard 1865, 28). Constructing the database was painstaking but tidier work than Bernard's vivisections. From the handwritten files of the public health department nurses, we transcribed the notes they had taken for each case. Day by day or week by week, over 6 to 12 months (depending on the medication prescribed), data came in scraps: "She visited her cousin's baby in New York, and she's afraid to tell her cousin she has TB." Or a phone call to the pharmacist: "Did he come back for his refill?" At the start, all of us shared the task – not for the sake of equity, but to ensure that we would all be making the same interpretation of the protocol. "What if there's no address?" The extent of missing data for *where and when* led to elaboration of plans for a subsequent "prospective database" that Dick's team would pursue to 2012, and to design of an electronic data entry form: "Wouldn't the nurses save time if they typed it into the computer in the first place?"

The precision of Canada's 6-digit postal codes offered a convenient geocoding mechanism: 46,240 codes on the Island of Montreal, usually specific to the block-face or apartment house. But were they reliable? The postal code is hard to remember and challenges a typist. Initial checks led us to evaluate the extent of address errors in the public health databases for "reportable" diseases such as TB – over 10 per cent. We created a verification algorithm, introduced it into public health practice, and confirmed the serious implications of these errors in terms of geocoding, positional accuracy, and estimated spatial density of a disease (Zinszer et al. 2010).

In the records for contacts, information about places was alarmingly sparse. "Look at this! He works in a bar, but what bar?" Only half the recorded work locations were geocodable; three quarters of the patients were recorded as "not working", and 30 per cent were living alone. "If not at work or at home, where did the patient meet that microbe?" If we ask for details of location, how should we classify places? "Reporting of contacts was aggressive only for patients recognized as the most contagious" (Carter et al. 2009). Paul was involved in tracking one such outbreak in which 7 secondary cases of active TB arose among university students who sat (unacquainted) in classrooms in the same poorly ventilated building (Muecke et al. 2006). Re-visiting the case files made us aware of other costly investigations: 200 volunteers and personnel were tested for possible encounters with a homeless person at a shelter, and several hundred were tested after attending the same rave as a young woman with highly infectious laryngeal TB.

While we were still checking the first batch of data and tinkering with formats, Andy, the two Ians, and the two Kevins were already making maps: world maps by national rates (Figure 2), maps of "hot spots" on the Island of Montreal (Figure 3), maps of contacts reported by patients, and maps of cases that shared the same bacterial strain, such as the 20 homeless itinerants who frequented shelters and city parks (Figure 4). TB is still spread by person-to-person contact (as in Figure 5) and still treated on an individual basis (Figure 6), but intensified movement of populations worldwide means that latent infections are concentrated in neighbourhoods of recent immigrants from countries where TB is common. The "hot spots" in Montreal arise from global patterns of transmission and are revealed by the bacterial analyses (Figure

7). In other words, to uncover recent local transmission, assess local risk, and apply local remedy requires thinking at scales ranging from global to molecular.[9]

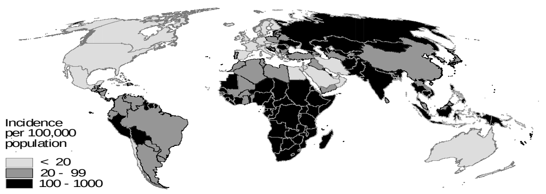

Fig. 2. Worldwide incidence of active tuberculosis. Rates are classed as light gray less than 20, gray equals 20-99, and black greater than 100 per hundred thousand people (maximum 1287). Source: World Health Organization, estimated incidence by countries, 2010, displayed in Mollweide projection.
http://who.int/tb/country/data/download/en/index

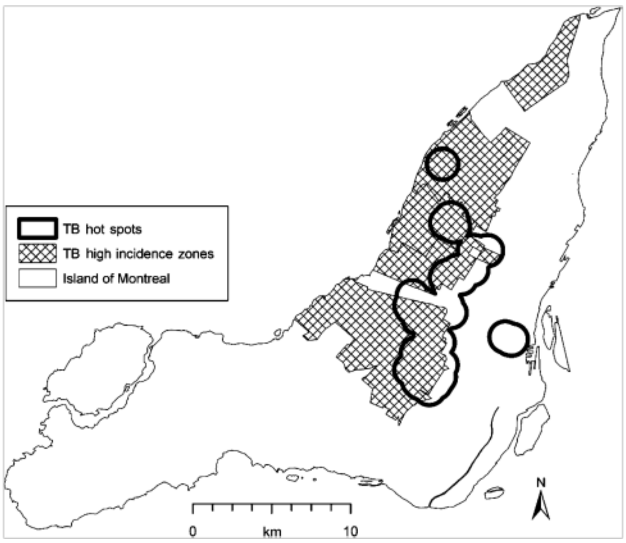

Fig. 3. Distribution of tuberculosis cases reported from Montreal Island 1996-2000. "Hot spots" – areas with the greatest number of cases - are not always those with highest incidence per hundred thousand population. Distribution reflects the concentrations of recent immigrants from countries of high incidence. Source: Haase et al. 2007, p. 636.

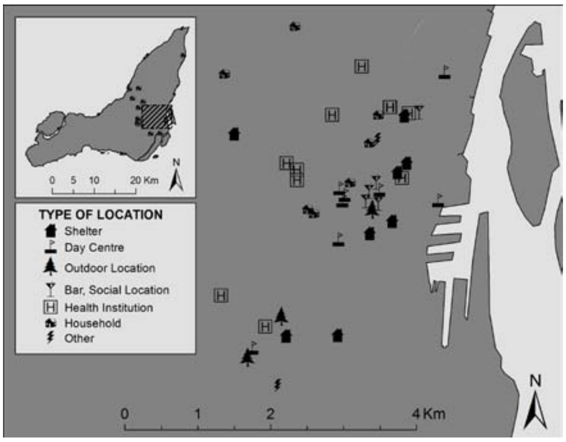

Fig. 4. Locations associated with homeless persons with TB. Of 20 homeless cases on the Island 1996-2007, 11 belonged to genotype-defined clusters (2 to 7 persons) harbouring the same bacterial agent. The high proportion indicates local transmission. The 20 individuals reported 10 shared locations. Source: Tan et al. 2011, p. 6.

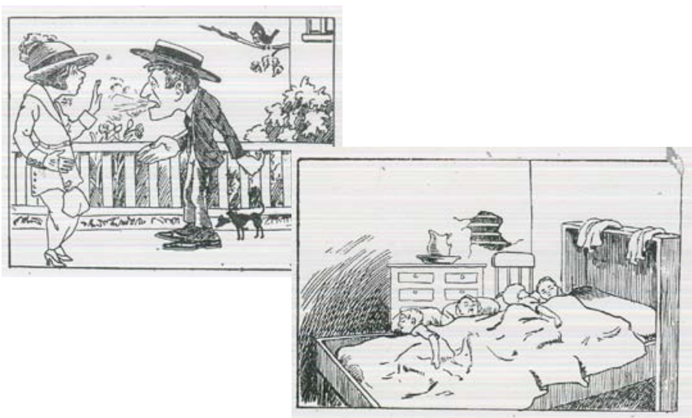

Fig. 5. The spread of infection by close contact. Public health propaganda of 1920 centred attention on personal habits and risks in the home. A particular target in Montreal was the windowless room, and the postcard urges, "This is a sure means for de-

veloping tuberculosis. Don't rent a dwelling like this." The lower postcard is titled "The dangerous cougher". Source: Bruchesi Institute, Annual Report, 1919-1920.

Fig. 6. Pneumothorax machine designed by Norman Bethune. Although the machine looks like a bicycle pump, the object was to reduce pressure, deflate the lung, and leave it at rest. Portable, it could be used in a hospital, a dispensary, or on a home visit. Bethune, after training at the Royal Victoria Hospital, introduced numerous surgical innovations at Sacré Coeur hospital, an institution managed by the Sisters of Providence for patients with advanced tuberculosis. Source: Reproduced by courtesy of the Osler Library of the History of Medicine, McGill University

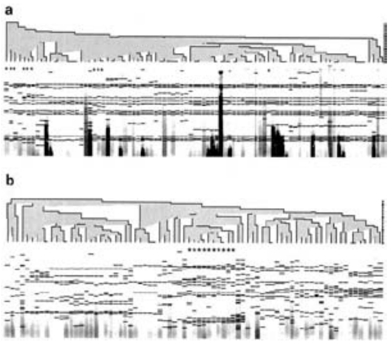

Fig. 7. Similarities in the DNA ¨fingerprints¨ of *Mycobacterium tuberculosis* organisms resistant to pyrazinamide. The dendrogram shows IS6110 RFLP patterns for the 77 resistant isolates and 10 others that were closely related. Source: Nguyen et al. 2003, p. 2880.

Since the maps were revealing, how could we make them available to the public health nurses who are the front-line investigators? How could they access the data and create their own case-and-contacts maps? When David arrived (2005), with greater experience in GIS and a focus on emergency responses in public health, he obtained a grant from Geoconnections, a federal agency intent on developing Canadian standards in geomatics. He and Christian, a newly graduated programmer, assembled a “shell” for map query by internet. The user can select records from the database and generate a map. “Are there other cases in the last month with the same bacterial fingerprint?” “What is the geographic distance between reported contacts of my patient?” Or, without a thought for the diversity of software underneath, obtain a spatial scan statistic from the proprietary SaTScan program: “Do the cases of the last 6 months add up to a cluster with higher-than-usual incidence?” Software components – PostgreSQL, PostGIS, MapServer, PHP, and JavaScript – were glued together with Python commands. The web application required secure access and insulation of users from the several agencies of public health and university research, but because the Dracones framework offered wider application and components of the shell were all open-source, Christian made it available under Open Source Initiative BSD license (http://surveillance.mcgill. ca/dracones/), and the historians are now all ears, impatient to move their own geobases to the web.

At each step, we were discovering more of what we had in common. Process makes history, and every small outbreak was a historical event. The medical researcher is used to dealing with case histories – the expected course of a fever, the normal course of a pregnancy, or, in the case of TB, the stage at which side effects of a drug may appear: How soon will the patient cease to be contagious? How soon will “feeling better” bring the temptation to neglect the medication? Because infection with TB may remain dormant for years, a search for the source of an individual’s infection demands consideration of a lifetime of personal encounters, and, as Paul’s investigation shows, incidence of infection in a population may reflect a history of interpersonal contacts over generations.

Paul had been studying an unusual strain of TB that does not respond to an antibiotic called PZA (pyrazinamide). About 100 cases turned up in the 1990s among elderly people born in Quebec. Assuming they were exposed in childhood, would tracing their ancestors pick up a historic disease event? Perhaps a mutant microbe carried by an immigrant 300 years ago? He had already arranged to track his patients through the genealogical database known as BALSAC – French Canadian marriages since the 1650s. Kevin H, who was coaching all of us in GIS, was intrigued since his own doctoral research in historical geography involved tracing surnames of those pioneer settlers into the various regions of Quebec. “Let's look at a map!” The distribution differed from that of Canadian-born patients with other strains of TB. “Why the tight little cluster around Shawinigan?” In Shawinigan itself, a small industrial centre founded in 1900, there were no such cases. “Why are most of the patients with the PZA-resistant ‘bug’ living in rural habitats?” Sherry, from earlier work in forest history, was intrigued with the map: These were villages that lived from a combination of farm and forest work.

Meanwhile, in Marcel's lab, Dao had identified a sequence of three mutations, the second of which conferred the resistance to PZA (Nguyen et al. 2003). For patients harboring each of the three bacterial mutants, and for another array with unrelated strains, Michèle, data analyst at BALSAC (in Chicoutimi) selected control groups and re-created the genealogies: Where did their grandparents live? Their great-grandparents, great-greats… ? She found no trace of a single common ancestor, but regional variations from one generation to the next. Ancestors of each patient revealed a location history much like those of Michèle's controls – people selected at random from the same small region. But geographic ranges of the several bacterial groups differed, reflecting the sequence of mutations. The BALSAC protocol had been widely applied to tracking of genetic disorders, but this was the first application to an infectious disease, and the findings pointed to a history of mobility. It looked as if the PZA-resistant strain might have spread in the Saint-Maurice valley 1840–1860 as farmers were recruited into winter logging camps on the fringe of settlement. A census of January 1861 reported the county of birth of men and boys in the logging camps, and Kevin's analysis of the surname frequencies confirmed their diversity of origins (Brassard et al. 2008a; Olson et al. 2010).

This is a small part of a story scholars are pursuing worldwide, to discover how, over thousands of years, the relationship evolved between the human organism and the bacterial organism. From laboratory analyses, a global phylogeny is established for Mtb (Mostowy et al. 2002; Gagneux et al. 2006). Which came first, tuberculosis of humans or cattle? How did TB spread in India? Did a strain spread from French Canadian fur traders (*voyageurs*) to communities of Native Peoples and Métis? In Saskatchewan, it provoked major outbreaks only when children, generations later, were gathered in large institutions like boarding schools (Pepperell et al. 2011a and 2011b).

Contemplating the big picture, we realized how little we knew about the history of the disease in Montreal. In 1880 it accounted for 30 per cent of recorded deaths of adults (ages 15–50) with puzzling interactions of gender and origins (Thornton and Olson 2011). The entire TB team was associated with the Montreal Chest Institute, initiated as the Royal Edward Institute by the anti-tuberculosis movement in 1909. This institution pioneered the local introduction of practices of open-window schooling, lung collapse, surgical thoracoplasty, and, in the 1950s, the antibiotics (first streptomycin, and then para-aminosalicylic acid and isoniazid) that changed the prospects of people with active TB.

To track those changes, we sought out additional partners – Annmarie, an architect specialized in the evolution of hospital design; Raphaël, an urban planner specialist in municipal regulations for building and zoning; Mary Anne, an experienced social historian, and their imaginative students in architecture and planning. As originally proposed, the project might sound like a conventional piece of social history, medical history, or history of architecture, but informed by Annmarie's analytic approach to *material culture*, it moved along several interfaces. From a broom closet at the Chest Institute, and a storeroom that was once the morgue, Kevin and Annmarie salvaged scrapbooks, floor plans, and photographs. In the photos, they paid attention to the equipment in the room, the furnishings, the view through the window, and the dress and pose of the figures.[10] With the introduction of chest radiography in the 1890s and computed tomography (the CT scan) nearly a century later, how did the patient experience the "visualization" of microbial invasion of his lung? These were tools analogous to the satellite photo and the layered GIS.

Meanwhile, Mary Anne was interviewing retired nurses and patients from a sanatorium that was about to be demolished. "How did the architectural design of the two sanatoria in the Laurentians reflect the practice of rest therapy?" By examining municipal spending on chronic disease among "indigents", she and Sherry uncovered the ironies of the stubborn 50-year attempt to prescribe "fresh air" for citydwellers and impose bed rest on people who could not afford to be idle (Poutanen 2006; Poutanen et al. 2009).

Networking is not new, and we uncovered extraordinary networking, both local and global, that characterizes the long struggle against TB. The Chest Hospital was networked with the two rural "sans", a school operated by the Protestant school board, and the Herzl Clinic from which sprang the Jewish General Hospital. A lone carton of social work case records Mary Anne discovered in the Canadian Jewish Archive complemented the medical case records extracted from the hospital archive, and a sample of 200 cases showed involvement of 50 local organizations, all bitterly underfunded. In the French-language community, the Bruchesi Institute initiated the city's first effective and lasting collaboration of lay leaders – doctors, volunteers, and fundraisers – with a religious community, the Sisters of Providence. The nuns, from their experience in home nursing of TB cases, articulated the problem of the stigma disease attaches to places as well as persons – to a neighbourhood, a type of housing, or a workplace.[11] Today, as a result of such circumstances, the risk of aggravating a frightening perception of the disease requires close attention to the ethics protocol, care in display of data, and constraints on the scale at which we publish our maps.

Because delay of diagnosis or treatment reduces chances of prompt recovery, health prospects are still affected by inequalities in access to care, housing, food, schooling, or sympathetic communication. In 1922, the Bruchesi Institute had identified the problem more starkly: "The dispensary, created to combat a social evil … does something to compensate for the harm done to a portion of the people by the way society is organized … For us, a motive of our duty is justice."[12]

Our mutual queries of the historical record suggest we must revise our century-old perception of the urban space. In both popular assumptions and public health practice, a "first circle" of infection is presumed to be centred on the home, a "second circle" close by (nearby work or local school), with rapid distance decay of risk. A century ago most people did work close to home; their dwellings were crowded, and they visited relatives and went to school "in the neighbourhood". Cities were built to high densities; recent immigrants were concentrated near the centre, and marriages were presumed lifelong. But urban lifestyles have changed, and today's cities are characterized by small households, rapid turnover of partners, more leisure time outside the home, and mass movements for entertainment and tourism. In Montreal, half of TB patients are traveling more than 5 km to their workplace or educational institution, and half the metropolitan population, including recent immigrants, are dispersed in suburbs beyond the jurisdiction of the Island health authority (Carter et al. 2009).

As collaboration took us in new directions, we sought other sources of support.[13] GIS was seen as a tool to answer scientific and public health questions of interest to the various group members. They came up with the questions, so that the application of geomatics was enhanced. Overall, the grants were directed to broader objectives – more efficient contact investigation, more comprehensive record-keeping, greater cost-effectiveness, or more reliable molecular markers – and most of the money went to laboratory work: storing samples, growing bacteria, and supporting graduate students in molecular research.[14] As in Pasteur's day, the cellular and molecular seemed to hold the keys to *How?* and *Why?* In the boundary layer where we were active, we addressed the common objectives by increasing attention – in both the history of Montreal and the epidemiology of TB – to cues of *Where?* and *When?*

4 Where do We Go Next?

There's no telling. The objective was not to perpetuate a particular network, but to continue opening up new options, and to diffuse the capacity for networking. The students schooled in this informal way, like the three princes of Serendip, moved into other contexts and new collaborations brought unexpected rewards.[15] The three GEOIDE students who 12 years ago were sparkplugs in conceptualization of HSS#56, have developed independent networks in Health and History. Jason's young team at Western works closely with town planners in London, Ontario, and researchers in the UWO faculty of medicine. ("He's so easy to work with!") These center on observation of children at play, factors that influence the choice of walking to school, and the effects on a child's weight, health prospects, and sense of wellbeing. Kevin Henry spent 8 years enabling GIS analysis at the New Jersey cancer database. "Why are some cancers more common in northern or southern parts of the state?" "How strong is the effect of racial discrimination in delays of diagnosis?" Now in Utah, he is making GIS the catalyst for partnership between university scholars, the libraries that house the maps, and the Utah Population Database.[16] François, as part of a heritage buildings team in Quebec City, collaborates with two religious orders (the Augustinian and Ursuline nuns) to document the evolution of their hospital and convent buildings over three centuries (http:// arc.ulaval.ca/files/1-MHDQ-03-2008.pdf). With his students in a school of architecture, he combines the tools of geomatics with architects' computer-assisted design, do-it-yourself SketchUp models, and the "space syntax" approach to analysis of circulation in the spaces of buildings and city streets (Hillier and Hanson 1984). In Montreal as well, his analyses of the temporal sequence of historic maps provides insights into undocumented portions of the urban heritage (Dufaux and Olson 2009) and the urban geometries that offer guidelines for re-design of viable neighbourhoods. Career trajectories of other trainees who worked on our joint projects show the same kind of versatility and openness to new encounters: a highly successful career in laboratory research on other respiratory pathogens; public health work in NGOs in Africa; and, in Canada, health care management and administration; and GIS applications in transportation planning.

5 The Obstacles Remain

Two emerging ventures, sidelined for a decade, will point out some of the obstacles. The "prospective" database, ongoing to 2012, includes a home visit with measurement of rate of "leakage" of air. "With Dick's expertise in ventilation of hospitals and office buildings, why did it take a decade to follow up Ian's findings of differential rates of TB in various types of housing?" "How will we obtain measures for a set of control dwellings?" Second, Christina and Kevin anticipate further research on immunity to chickenpox. In their clinical practice with immigrant patients, they are challenged by their susceptibility to many diseases that Canadians think of as having been conquered. Vaccination against chickenpox is not universal, and, in the wet tropics, the rarity of outbreaks among young children leaves them vulnerable in adolescence or adulthood. A first GIS display Andrew generated for Christina (2005) confirmed the potential for analysis of climatic factors from seroprevalence among immigrants to Canada. With the breadth of its immigrant intake, Montreal is a laboratory for global variance.

Taking a broader view, has the professional environment for scientific networking changed over the last 12 years? Despite lip service to the transdisciplinary, structures of incentive and reward in universities, public health, and research funding severely inhibit knowledge transfer. The mission of each institution – a hospital, a museum, or a library– is rigidly defined and operates under a separate chain of command. Knowledge transfer from faculties of science and engineering into corporate production often takes 8 to 10 years (Gögl and Schedler 2010, 176), and transfer into the practical settings of hospital or health department is affected by dual bureaucracies. The local public health agency, for example, in the 1990s cooperated on an early GIS application to swimming pool deaths, 15 years later on a spatial analysis of pedestrian accidents, and our own venture in reportable diseases; but each of the several teams, unaware of the others, had to reinvent the wheel. Epidemics or emergencies such as the H1N1 influenza outbreak have disrupted budgets and diverted skilled personnel rather than mobilizing new resources. "The opposite of teamwork is hierarchy" (Gögl and Schedler 2010, 11), and command structures of silo and status tend to obstruct communication.

The public health agency and the hospitals, for example, found it difficult to agree on a standard data entry format. Turnover of personnel and recurrent understaffing meant resurrecting the issue again and again for 6 years. Similar resistance, on a much larger scale, delays the "universal" system of electronic medical records on which the provincial ministry has already spent millions. And, of course, findings are not always applied by the institutions that fund the research. Cost effectiveness studies of Kevin and Dick demonstrate that it would be more efficient for the U.S. and Canadian governments to invest in diagnosis and treatment of active tuberculosis in high-incidence countries where treatment would be cheaper and yield higher in terms of improved health, as opposed to expensive and often inefficient screening of the small set of individuals who have emigrated to North America (Schwartzman et al. 2005).[17]

The Canadian granting agencies acknowledge three scientific cultures, and they are not equal. The large disparities of operating funds for research make beggars of the social scientists: 43 per cent for natural sciences and engineering, 43 per cent for medicine, 14 percent for the social sciences and humanities.[18] Is this likely to produce "informed decisions"? At the federal level, a path breaking proposal for TriCouncil collaboration and a longer horizon of funding for research on "the environment" shrank back into a joint program of accounting standards and CV formats that reduce careers and personalities to check-boxes. Continued emphasis on the paradigm and preeminence of the independent "principal investigator" running a laboratory tends to penalize other researchers who devote time to collaborative efforts. In such a context, collaboration must ensure rewards for all members such as opportunities to publish as lead author, and shared credit for successful grant applications. Styles of journals also reflect cultures of the disciplines, and many of the new "interdisciplinary" journals are tight in conception (e.g. *Environmental and Molecular Mutagenesis, Spatial and Spatio-temporal Epidemiology*, or *Emerging Infectious Diseases*), or targeted to establish new disciplines such as bioinformatics or health informatics.

At the provincial level, the University of Québec institutes (INRS), created 40 years ago to overcome a lag in the engineering sciences, and systematically neglected the social sciences and humanities where Quebec scholars shone. (Only two institutes were ever created in the social sciences, and were then forcibly merged.) The exceptional Quebec funding program known as FCAR was successful in stimulating interdisciplinary and interuniversity collaborations, but the collaborative requirement has been abandoned and provincial practice remodeled to mimic the unified federal accounting model. Canadian public agencies continue to "recover full costs" for digital maps and to turn over to private enterprise the management of data created at public expense.

The significant breakthrough in the past 12 years has been reorganization of health research in Canada, with inclusion of an Institute for Population Health and several others focussed on population components: Aboriginal people, Gender, Aging, Children and Youth. The new model favours orientation to health rather than disease, greater investment in prevention, psychology of patient self-management, and lifestyle factors conducive to health. But as soon as CIHR began providing more generously for "population health", SSHRC, under severe budget constraints, elaborated rules to restrict support for health-related research.

In universities, top managers are necessarily fund-raisers, and speak the language of "University Inc" (cf. Washburn 2005). Within the several faculties (a medieval legacy), departmental subcultures add inertia to allocation of budgets and staff positions. Snow's argument in 1959 targeted the inadequacy of British higher education to prepare the nation's intellectual leaders to manage and harness scientific knowledge. In Quebec, half a century later, the problem persists in a different form. The Ministry of Education, in order to give greater pupil-time to science, has imposed specialization from about the age of 14. Entry to university-level science programs is virtually closed to graduates of high school and college streams in *sciences humaines*; and math prerequisites at lower levels make university instruction in statistics and probability inaccessible as well as unappetizing, largely ignoring the empirical, intuitive, and graphic approaches of experimental data analysis (cf. Tukey 1977).

In addition to the hazards of academic networking between departments, each discipline presents challenges to the uptake of geomatics. To “extend techniques of GIS more widely into Canadian historical scholarship” – the first objective of the original MAP project – word-of-mouth diffusion and distribution of “demos” were not enough. Robert (at Memorial) participates in networks of “digital humanities”, and David has introduced a spatial statistics course in epidemiology, but penetration of “the spatial” into university teaching of history, statistics, or epidemiology has been very slow. GIS courses are now accessible to graduate students in the major schools of public health in North America, but are nowhere required. Teaching in history departments has not kept pace with interactive applications (Web 2.0), availability of nominal census data, record-matching experience of demographers and family history circles, and the opportunities GIS offers for more efficient sampling.[19] University-level teaching shows a 10-year lag, waiting for the arrival of students schooled in on-line banking, purchasing, gambling, and entertainment to kick-start informatics as a tool for learning, adventure and experiment.

Was GEOIDE helpful? Without the initial funding, it’s unlikely that any of these encounters would have occurred, and the GEOIDE Student Network was immensely stimulating. But the training they conceived for “HQP” (highly qualified personnel) was perceived as highly specialized and focussed on the toolkit. We had to insist that our project technician, fresh from a postgraduate certificate, be included as a student. The promotion of a new discipline seemed to take precedence over the polyvalence we needed for collaborative work. Over the last 12 years, most universities in Canada have experienced serious loss of skills in cartography, visual communication, and documentation because cartographers – as teachers, technicians, and librarians – were being replaced by specialists in remote sensing techniques or programming. Rosa is now ideally trained: a diploma in geomatics, two years with our project, and several years experience in a unique “Geographic Information Centre,” jointly conceived and funded by McGill Libraries and the Faculty of Science. Having completed a Master's in Library Science, she now heads a map library as GIS Librarian at York University. Locally, however, standardization in library organization threatens our own GIC, and across the continent the scarcity of specialist personnel in libraries and archives has not been relieved. To promote those “creative chances”, we need personnel prepared for intellectual edge-matching.

6 The Conversational Approach

It is no accident that the science society in Montreal in the 1850s organized its meetings as *Conversazzione*. The model was favoured throughout the Victorian era by the London professors of medicine, and in Montreal by fund-raisers at the YMCA, Methodist missionary ladies, and theologians of the Presbyterian College.[20] But effective dialogue is low-key and must be forged against background noise, interruptions, and divergent work schedules. “Did it make a difference to have one of us beyond retirement, no longer tuned to promotion, and with a more flexible schedule?”

Conversational skills favour bridging the several cultures: the listening skills of an experienced physician, the relatively small size of the Chest Institute; the specific demands of the two languages in the universities of Montreal. “Experienced executives know how to listen” (Stefan Arn in Gögl and Schedler 2009, 318). Paul spends some of his time doctoring in communities of the Arctic, where TB rates are 20 times those in Montreal (Brassard 2003c, Clark et al. 2002). Kevin and Christina work in teaching hospitals that function in many languages and treat people of many cultural backgrounds. These experiences prepared us for the ambiguities and difficulties of terminology and jargon between disciplines. Social skills go beyond the verbal to include Annmarie’s Christmas treats for her research team and Dick’s end-of-winter maple syrup at the seminar. According to one industrialist effective at the interface between academe and enterprise, “I’ve never done a deal … which did not first involve a significant amount of time over a beer” (Timothy Barnes in Gögl and Schedler 2009, 123).

In our 12 years of collaboration, we had no manager, no secretary, no office, no rug on the floor, no titles, no formal calendar of meetings, and no routine transfers of funds. “Such formalities would get in the way!” Conversations took place in our offices (scattered over 10 or 12 city blocks) and in the lab that our students were sharing with several PhD students in remote sensing of ground ice and marsh ecology. (They taught us a number of tricks.) Much of our conversation centred on what we were seeing in front of us on the screen, in the photographs and yellowed clippings, or on the colour-coded ground plans. For sharing an exploratory visual analysis, GIS is indeed a catalyst. Health care professionals are used to working with their eyes as well as their ears — nurses and doctors look carefully at patients and radiographic images, and epidemiologists at figures and graphs. “Are historians visually challenged?” In all these fields, there is a need for learning tools.[21]

If we look back at Figure 1, the geomatic tangent was just one more tool each team was adding to its kit, but this tangent opened up a host of new questions about space and place, distance and scale, horizons and projections, with additional sources of uncertainty and error, and with new possibilities that nourished a running conversation. With hindsight, our interactions demand a sketch more elaborate than those two simple circles. It might resemble the complicated site geometry of protein pockets, folded and crumpled, with potential for a “fit” that favours the reactivity of an enzyme, enhancer, promoter, inhibitor, or regulator.[22]

Fitting into those pockets of conversation were the graduate students. Students expect interrogation: “What is the research question?” And they expect/are expected to *ask* questions. “Why not?” “What if?” Because the techniques of geomatics were new to all of us, we were all positioned as learners, with the curiosity of the 3-year-old (Gopnik et al. 1999). The most important outcome of networking is the appearance of new questions. Kevin titled his new proposal to CIHR “*Where* is TB?”

7 The Time was Ripe

In looking back 12 years, we can see some advantages of timing of our initiative. In the 1990s, rapid expansion of “GIS for health” was oriented along two productive tracks. GIS methods for location of health facilities were driven by needs of heavy investment in hospitals and, on the supply side, by advances in operations research and the models of “shopping centre geography”.[23] Advancing alongside, wildlife biologists and veterinarians were using GIS for ecological models of animal vectors of diseases such as West Nile virus, river blindness, and malaria. (We've taken advantage of ESRI add-ons they created.) In the 12 years, new priorities have emerged. Public opinion is now tuned to the spatial gradients of environmental hazards like radiation, superfund sites, herbicides, and land mines (Beck 2008); and in medicine, top priority has moved to interactions of genetics and environment, with recognition of the micro-molecular.

Observing a project over 12 years does not tell us what to expect in the next 12. We do know that conversation across disciplines will be necessary, and it will be challenging. Ours was just one of thousands of “found experiments” in scientific networking. Such experiences provide clues to what will make those conversations productive of the “creative chances”. What if this applies to the whole of “the university”? to the whole of “the hospital” – nurses, patients, doctors, as well as research personnel and the institutions of “public health”? to the whole world of research, where the curiosity-driven, in their conversations in the corridors, are straining against the bonds of bureaucracy? The reward is in the conversations themselves, which sometimes take us to unexpected places. Conversation satisfies a thirst.

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Asterisks denote publications of the research team at the interface.

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Notes

[1] The SIURS 2000 (Ville de Montréal, Système d'information urbaine à référence spatiale) was created from airphotos and autocad files to high-precision building footprints (30cm on the ground), but as a relational database it was obsolete; the city's Service de Géomatique has since rebuilt the system for Island-wide reference.

[2] At the time we added geomatics to our toolkit, epidemiologists in the fields of respiratory and sexually transmitted infections were seeking to advance from mapping of incidence toward an understanding of transmission, its spatial contexts (Lewis et al. 2002, Zenilman et al. 2002), and the social networks in which it occurred (McElroy et al 2003, Riben et al. 2002, Munch et al. 2003). More precise geographies were required, moving from characterization of populations by states to counties, census districts (Cantwell et al. 1998), US zipcode areas (Acevedo-Garcia 2001), block groups (Barr et al. 2001), smaller Canadian postal codes, or individual buildings, and ultimately characterizing the individual patient in a household setting. For a broader literature review of earlier GIS applications to disease, see Cromley 2003.

[3] A model on paper was Charles Booth's map of London 1890; see http://booth.lse.ac.uk/

[4] The joint papers show the institutional affiliations: at McGill University, the Department of Geography (Faculty of Science), the Division of Medical Microbiology and Infectious Diseases, the Department of Epidemiology and Biostatistics, Respiratory Division (Faculty of Medicine), and the McGill Centre for Bioinformatics; research institutes of three affiliated hospitals: the McGill University Health Centre, the Montreal Chest Institute, and Montreal General Hospital; and two provincial public health agencies: the Laboratoire de Santé Publique du Québec

(LSPQ) and the Division of Clinical Epidemiology under the Direction de la santé publique, Agence de la santé et des services sociaux de Montréal.

[5] In addition to grants from Canadian Institutes for Health Research for the molecular laboratory (Behr p.i.) and Association pulmonaire du Québec for the database of cases on Montreal Island (Schwartzman, p.i.), in place prior to our networking, these scholars were supported also by salary career awards: Brassard and Behr as New Investigators from CIHR; Menzies as Chercheur National, and Schwartzman as Chercheur-Boursier Clinicien from the Fonds de la Recherche en Santé du Québec (FRSQ).

[6] The initial geobase was elaborated for 1848 and 1880; volunteer efforts have been extended to provide building footprints for 1912, a taxroll of property owners, automated address-coding for all 1901 census households, and the full census data for one quarter of them (Sweeny and Olson 2003; www.mun/mapm).

[7] This approach was built into a joint application to CIHR in 2001 (Schwartzman, p.i., MOP-53184). Using GIS for surveillance of tuberculosis, Stone et al. (2001) and Moonan et al. (2004) had identified spatial clusters of residences in Texas; and Klovdahl et al. (2001) was using GIS to infer places of contact other than residential. In addition to a higher precision of location of TB cases, ours was the first application to combine the full kit of tools: characterization of individual patients, computerized mapping of their households and contacts, the spatial scan statistic to evaluate clusters of cases, and molecular typing of the infectious agent to confirm local transmission (Haase et al. 2007, Yeo et al. 2006).

[8] Genetically “related” strains amounted to 11 or 33 per cent of cases, depending on choice of a threshold of similarity. To overcome a bias of nearest-neighbour estimates in such situations – where the number of controls is much larger than the number of cases – Kevin and a fellow student in biogeography conceived a resampling and bootstrapping method (Henry et al. 2003).

[9] For a wider perspective on spatio-temporal scales and the application of molecular tools, see Muellner et al. 2011.

[10] Adams 2005; Adams et al. 2008; Minnett 2006. David Theodore, who "managed" us, is now at Harvard doing a double-barreled doctorate in architecture and history of science. On observation of material culture, see also Swiderski 1995.

[11] Fear of TB, based on historical and foreign contexts, fosters resistance to contact investigation, notorious in workplaces. The stigma is been better recognized in the case of sexually transmitted diseases, and delays of research on HIV (cf. Brassard, Hottes et al. 2009; Macdonald et al. 2010; Shilts 1987).

[12] Institut Bruchesi, Annual Report for 1920-1922, 18, as cited in Poutanen et al. 2009, 106. « Créé pour combattre un mal social, dont la cause réside dans la Société, le Dispensaire antituberculeux est un peu le compensateur des torts causés à une portion du peuple par la mauvaise organisation de notre état social. Pour nous notre devoir a un motif de justice. »

[13] The additional grants directed to transdisciplinary objectives were these: from CIHR, Schwartzman p.i., 2002–2004 and 2004–2009, for applying GIS as an innovation in detection of TB; from Geoconnections, Buckeridge p.i., 2006–2008; from SSHRC, Adams p.i., 2003–2006. A succession of SSHRC teams (headed by Gilliland, Gauvreau, and MacKinnon) pursued the census databases for 1881 and 1901, incorporated into MAP.

[14] CIHR support was in place prior to involvement of the historical geographers: for the genealogical research, Brassard p.i. 2001–2004; for the micromolecular laboratory, Behr p.i.; and for development of the TB Keys database, Menzies p.i., 2006–2010.

[15] The notion of "serendipity" is attributed to Horace Walpole who borrowed from a Persian fairy tale; the three princes were reknowned for the happy faculty of finding things they were not looking for. See Remer 1965; Merton and Barber 2004.

[16] On the decades of residential histories, see the Utah Population Database at http://www.huntsmancancer.org/research/shared-resources/utah-population-database/overview. These take full advantage of the resources developed by the Latter Day Saints, more familiar to genealogists and historians.

[17] On resistance to epidemiological findings in workplaces, see Milham 2010; *Microwave News* 14–6 (1994), 1.

[18] Reported from NSERC, CIHR, and SSHRC in the 3 years 2007/08, 2008/09 and 2009/2010.

[19] Canadian Families Project http://web.uvic.ca/hrd/cfp/; Canadian Century Research Infrastructure http://canada.uottawa.ca/ccri/; Population et histoire sociale de la Ville de Québec http://phsvq.cieq.ulaval.ca/; Great Britain Historical GIS http://port.ac.uk/research/gbhgis/; Census of Canada 1881, http://www.prdh.umontreal.ca/census/en/main.aspx; Census of Canada 1901, http://automatedgenealogy.com; http://www.collectionscanada.gc.ca/databases/census-1901/index-e.html.

[20] For a philosophy of conversation, see Serres 2003, 266–275.

[21] For learning tools for exploratory spatial data analysis, see Robinson et al. 2011; http://geovista.psu.edu/GEX/ ; Fischer and Getis 2010.

[22] For displays of such network structures, see Feldman and Labute 2010; Liang et al. 1998; and with application to the search for drugs targeting tuberculosis, Kinnings et al. 2010, 8; Downing et al. 1995.

[23] Problems of access to health services remain important for control of TB, apparent in GIS applications in the Canadian Arctic (Clark et al. 2002), in a metropolitan area (Lewis et al. 2002), and in rural Africa where multiplication of supervision points for DOTS programs (directly observed treatment) favours completion of the full course of antibiotics, necessary to minimize emergence of bacterial resistance (Tanser and Wilkinson 1999).