1. INTRODUCTION

Late one Thursday afternoon in February 1996, I arrived in the sleepy town of Frederick in the heart of rural Maryland. As I stepped out of the car, my escort directed me towards a wholly unremarkable brown warehouse. It was a bright afternoon and, as we entered the facility, it took some moments for my eyes to adjust to the light, but as they did, I began to discern the familiar shapes of bulky machinery, equipment, and storage containers. Or at least they seemed familiar. But as my guide drew me onward, he explained that the units looming overhead and humming quietly under the florescent lights were not, as I had imagined, simple stock containers, but in fact, twenty-eight double fail-safed, double-decked, walk-in cryogenic storage chambers. Languishing in a suspended state in this technoscientific ark were more than 50,000 different samples of plants, animals, fungi and other organisms. Some of the materials would have been familiar to Noah—whole frozen starfish and yew leaves, for example—but others—thousands of tiny vials of extracted genetic and biochemical materials—would not.

What were these materials doing in the rural backwater of Frederick, Maryland? Where had they come from, who owned them, why had they been collected, and why were they being protected so assiduously? It was my desire to find answers to these questions that had bought me to this uncanny place. This particular voyage of discovery had begun for me some years earlier. Like many other researchers in the physical and social sciences, I had become fascinated, during the early 1990s, by the potential applications and implications of the development of new biotechnologies. As an economic and cultural geographer, I had long been interested in the creation, operation, and evolution of markets in materials or commodities that seem to stand outside any conventional notion of what could, or should, be tradable—carbon emissions, insurance risks, body parts, or child labor, for example. New biotechnologies, it seemed to me, could create not only new biological entities of an unprecedented kind but also vibrant new markets for those entities.

At much the same time, I also began to read about a series of new international biological-collection programs, “bio-prospecting projects,” as they were called in the press. “Bio-prospecting” was defined by Reid et al. in the early 1990s as “the exploration of biodiversity for commercially valuable genetic and bio-chemical resources.”[1] These projects were being undertaken in many tropical countries, and there was much discussion in newspapers and journals of how they would be organized, of what would be collected and where, and of whether the collection process would yield appropriate returns for supplying countries and communities. This latter question had become particularly pertinent following the ratification of the Convention on Biological Diversity of 1992, when signatory nations became obliged to ensure that all suppliers of genetic and biochemical resources receive “a just and equitable” share of the benefits arising from their utilization. Assessing whether this had happened, or was likely to happen, would, it seemed to me, necessitate establishing where the resources collected under these programs *had gone to* and how they had subsequently been used. What, in other words, had been the fate of these collections?

In answering that question, I had to consider, first, why the collections had been created. Why had there been this sudden increase in bioprospecting programs? I began by considering how the rise of this industry might be linked to other changes that had occurred in recent decades, particularly changes in the broader economy. This new industry seems to have had its genesis in a number of important technological and economic changes that occurred in the postwar period. As the world has moved from the industrial to the informational age, the economies of many of the core, industrialized countries, including the United States, have undergone a fundamental transformation. Heavy manufacturing, which once dominated economic production in advanced economies, has declined in importance, outstripped by growth in financial transactions, foreign investments, telecommunications, and other information-based services. It has been estimated that the industrialized economies’ share of the world’s manufacturing output dropped from 95 percent to 80 percent in the period from 1953 to 1995, while the United States’ relative share of world manufacturing production decreased from 40 percent in 1963 to a mere 27 percent in 1994.[2]

It is clearly evident, however, that not all forms of manufacturing are in decline. At the same time that we were witnessing the waning of heavy industrial manufacturing, we were also seeing the birth of many new, high-tech manufacturing industries. Such industries are generally understood to include those devoted to the production of computer software, aerospace and defense components, semiconductors, satellite technologies, and the like. However, they also include an industry devoted to a somewhat different type of high-tech manufacturing—the manufacture of life. The biotechnology or life-sciences industry also produces important commodities, but they are not the familiar products that are associated with manufacturing of old such as ships, steel, or textiles. They are products that are quite alien to us—transgenic organisms, cloned animals, and artificially generated biochemical compounds that have no parallel in nature—entities that are, in effect, a fusion of the organic and the technical.

We need only glance at any newspaper to be reminded of the transformative capabilities of this new industry. Every day, it seems, we are inundated with reports of new technoscientific developments: the creation of genetically engineered foods such as the Flavr Savr Tomato, which decays at half the rate of a normal tomato; of herbicide resistant crops; and of transgenic organisms such as DuPont's patented Oncomouse, an experimental mouse genetically engineered to reliably acquire cancer within a month. In California, genes for luminescence found in deep-sea marine life have been combined with regular lawn seed to create a "glow in the dark" lawn, which, the manufacturers suggest, may have important applications as a form of security lighting.[3] It is difficult to underestimate how rapidly the biotechnology and life-sciences industries have grown in recent years and what an important new source of economic productivity they are. In 1999 alone, the U.S. Food and Drug Administration approved twenty-two new biotech drugs and vaccines, while more than 350 additional drugs and vaccines were in late-stage clinical trials.[4] It has been estimated that the top five U.S. global biopharmaceutical companies now earn in excess of nine billion dollars in revenue annually.[5] The stock market's NASDAQ Biotech Index soared 102 percent during 1999, exceeding the 86 percent increase of the NASDAQ Composite Index, and rivaling the 184 percent jump recorded at the online Internet index TheStreet.com.[6] Despite the high risks and "burn-out" of many small ventures, it appears that the biotechnology industry is set for further rapid expansion. The Biotechnology Industry Association recently confirmed, for example, that the global biotech industry is still growing by 15 to 20 percent annually.[7]

The "reinvention of life" for commercial or industrial purposes seems set to become one of the most important and lucrative businesses of the twenty-first century, and the biotechnology/life-sciences industry will necessarily play a central role in that project. But how much do we actually know about how this industry functions? Take, for example, the question of raw materials. All industries require raw materials—the shipbuilding and textile industries have, for example, long extracted steel and fiber from locations across the world, creating new resource economies that have progressively shaped the economic, political, and social fortunes of source countries. There has been a growing, if peripheral, awareness that the life-sciences industry uses samples of plant, animal, and even human genetic materials as industrial commodities and raw material, and yet there has been surprisingly little discussion of where those materials have come from, who has rights in them, how they might lawfully be used, and who, if anyone should benefit from their exploitation.

The biotechnology industry has already demonstrated that it has a voracious appetite for novel biological materials that might form the basis of new proprietary products. It was precisely because demand for such materials so outstripped available supplies that large corporations, public and private research institutes, and small entrepreneurial companies began to implement new biological collection, or bioprospecting, programs in the late 1980s and 1990s. The materials that I found sequestered in the Frederick repository are the fruits of one such collecting program. Although it is one of the largest in the United States, this facility is, however, just one of many similar collections generated in recent times. Unbeknownst to most, in the quiet confines of boardrooms, laboratories, and warehouses, away from the public gaze, executives, scientists, and technicians have been involved in a worldwide collection project unrivalled in scale and scope since colonial times. A surprisingly diverse range of organizations, institutions, and entrepreneurs from large, privately funded pharmaceutical companies, publicly funded museums of natural history, small biotech start-ups, and even individual brokers have all been actively involved in systematically amassing, archiving, and storing hundreds of thousands of samples of genetic and biochemical materials extracted from species of plants, animals, and fungal and microbial organisms drawn from hundreds of localities around the globe.

Given the scale of the enterprise, it is surprising that so few people are aware of the existence of these collections and that so few questions have been raised about how they are being used. Most of the collections that have been created in recent times, including those created by publicly funded institutions such as museums of natural history, have been drawn into the service of industry. This is not necessarily problematic, as long as some proportion of the profits that are generated from this commercial use are redistributed to suppliers in accordance with the edicts of the biodiversity convention. The evidence produced from this study suggests, however, that this compensatory process is in danger of being fatally undermined by changes that are occurring in the way these biological materials are utilized within the life-sciences industry.

A clue to the nature of this change can be found in the wording of the biodiversity convention. In setting terms and conditions, the convention makes reference to the use of both "genetic materials" and "genetic resources." The decision to employ two separate terms suggests that there was, at the time of drafting, and that there remains a sense that genetic resources may prove to be separable from the biological materials in which they have conventionally been embedded. This is certainly so. Genetic resources may be considered to encompass genetic and biochemical material but also genetic and biochemical information derived from that material. Biotechnology has played a crucial role here, enabling the latter to be utilized independently of the former. Genetic resources may now be rendered in a variety of progressively less corporeal and more informational forms: as cryogenically stored tissue samples, as cell-lines, extracted DNA, or even as gene sequences stored in databases. When in these new artifactual forms, genetic resources become infinitely more mobile and hence more transmissible.

This has proven to be of great significance for life scientists. The molecularization of biological research has transformed approaches to the study of disease and pharmaceutical development. While researchers are still interested in examining specimens morphologically, these examinations are now, almost without exception, undertaken in concert with analyses of their genetic or biochemical composition. Although molecular level investigations may be conducted using minute amounts of biological material, they may still yield valuable quantities of genetic or biochemical information. In many cases, it is this genetic and biochemical information that is the commodity that is actaully sought, collected, and valued. Scientists may thus be less interested in obtaining what the historian of science Donna Haraway calls "thick messy organisms" than they are in acquiring genetic or biochemical information that can be derived from them.[8] If this information can be made available to them in a more accessible or manipulable form, this would be, for scientists, even more convenient.

The desire and ability to translate existing resources into more transmissible, informational forms is certainly not confined to the biotechnological realm. On the contrary, it can be seen in a number of other domains: in the financial sector, in publishing, and in the music and film industries. This revolution is, in fact, in keeping with predictions that have been made about the increasingly important role that information and informational resources will play in the global economy at the beginning of this new millennium. Commentators such as Daniel Bell, Alain Touraine, and, more recently, Manuel Castells have for the past two decades argued that the saturation of the market for manufactured goods will lead to the formation of a new mode of production. This mode of production, they have argued, will rely not on industrial development, but rather on the production, processing, distribution, and consumption of *information-based* goods and services. Information itself will become an important commodity, access to and control of which will increasingly provide the basis of competitive advantage in the global economy.

"Control" is the key word here. Information-based products (such as computer software, recorded music, and electronic data) are very easily disseminated and circulated through new networking technologies, but they may also be very easily replicated. This makes the task of preventing the unauthorized reproduction of these works, and the consequent loss of income, particularly difficult to prevent. It is precisely because these informational products can be so easily circulated across and beyond existing national and international jurisdictions that they have become subject to new forms of global regulation. Global regulations have had a dual and, it could be argued, conflicting role to play in this new informational economy. On the one hand, they have been introduced in order to facilitate the exchange of information-based goods and services through the development of new markets and avenues of exchange. At the same time, they are also increasingly relied upon to restrict the unlicensed use and circulation of these same resources. Research has revealed not only the emergence of new global markets and networks of exchange for computerized and digitized information, but also the difficulties of effectively regulating these new "spaces of transmission."[9]

Translating genetic resources into new, less corporeal and more informational forms might enable them to be circulated much more rapidly around avenues of exchange, but it also makes it much more difficult to keep track of where they go and who uses them. It is possible to predict that the difficulties that other industries have faced in attempting to track or control the unlicensed dissemination, uses, and reproduction of their information-based resources might now also arise in relation to the unlicensed dissemination, use, and reproduction of these bio-informational resources. Few detailed investigations have yet been conducted into the fate of collections of genetic and biochemical materials acquired under contemporary bioprospecting programs or into the efficacy of contractual arrangements or regulatory policies designed to compensate for their use. Perhaps more importantly, no investigation has sought to question what impact the ability to render genetic and biochemical materials in more transmissible and/or informational forms might have on the effectiveness of existing compensatory regimes. My intention in undertaking this research was to remedy that situation.

As most of the genetic and biochemical materials that have been collected under contemporary bioprospecting programs have been acquired for use in the American pharmaceutical industry, it seemed appropriate to concentrate most of my attention on that industry's role in the development and operation of these programs throughout the decade of 1985 to 1995. I knew that the biotechnological revolution would radically alter the way in which genetic and biochemical materials and information were embodied and presented, and I was centrally interested in describing these changes and analyzing their impact on the dynamics of biological-resource exploitation. I particularly wanted to explore the effect that these developments could have on creating new resource economies in bio-information.[10]

In undertaking this research, my aim was not just to describe the creation of this new resource economy but also to investigate the power relations inherent in its establishment and continued operation. This entailed examining how such materials are collected and used, by whom, and under what terms and conditions. I sought to establish, first, how valuable bio-informational resources were likely to become in this technoscientific age and, second, where the locus of control over these new resources is becoming centered politically, culturally, and geographically. This demanded that I also investigate how, and by whom, new global regulatory policies relating to the commodification of genetic resources have been devised. In undertaking this analysis, I gave special consideration to the role that cultural processes have played in the construction of global regulations, as these have often been misunderstood or neglected. Although often characterized as embodying universally shared beliefs or values, global regulations prove, in many instances, to have been produced out of particular, culturally specific systems of knowledge. In a work that asks questions about power and the "sociology" of knowledge, I want to illustrate how particular knowledge systems become hegemonic over space and time, creating in the process new global geographies of power and regulatory control.

At the same time, I also want to analyze the way in which power relations are played out on a much more "domestic" scale. Studying the actions and behavior of the small group of elite actors who have acquired responsibility for organizing the operation of this trade enabled me to ascertain how the terms and conditions of exchange that govern this nascent industry were established and examine whose interests they favor. By drawing out the links between these two scales of regulation, it is possible to illustrate how global regulations have been adopted and employed at regional and local levels in order to legitimate and facilitate the development of a new resource economy in bio-information.

One of the great pleasures in undertaking this project has been the opportunity that it has given me to work more closely with historians of science and with historical geographers. They sensitized me to the importance of historicizing these biotechnological advances within the long *durée* of technological development of the eighteenth, nineteenth, and twentieth centuries. In fact, one of the most complex challenges of this project proved to be teasing out what is and is not "new" about this phenomenon. The collection of biological materials has, after all, a long history, as does the applied use of genetic and biochemical material or information—in drug development or selective breeding, for example. Nevertheless, it still seems that the recent biotechnological revolution has dramatically altered our relationship to and use of collected natural materials.

In order to ascertain how this relationship has altered, I set out in chapter 2 to examine how approaches to the collection and use of natural materials have changed over time. I was particularly interested in exploring how the values that attach to particular natural objects or materials are altered through processes of collection. What may be a relatively commonplace object in one setting may become uniquely valorized as a consequence of its removal and relocation to a different geographic, cultural, or epistemological milieu. In other words, the social construction of the value of particular materials is inextricably linked to their spatial disposition. In order to draw out these interconnections, I develop a three-phased typology of what I refer to as "the social and spatial dynamics of collecting" through an illustrative, rather than comprehensive, history of collecting within natural history. My principal argument here is that the power and profit that can accrue from being in possession of a collection of natural materials derives, in part, from three factors: first, from an ability to acquire decontextualized and therefore exoticized material; second, from an ability to concentrate and control such materials within particular localities and systems of knowledge; and third, from an ability to then recirculate or redeploy these collected materials to strategic advantage over both space and time.

I then consider in chapter 3 how new, sophisticated technologies have combined with important and related economic and regulatory changes to enable a select group of collectors to *speed up* these social and spatial dynamics of collecting—to make it easier for them to collect, concentrate and control, and recirculate and regulate valuable bio-informational resources to their personal advantage. These changes are described in turn, beginning with the technological. It was suggested as long ago as the mid-1980s that biotechnological advances change the way in which biological materials are valued and that in the life sciences, at least, these materials would come to be valued more as informational resources than as material ones.[11] Several theorists made seductive, if attenuated, references to "the information embodied in living organisms" and even went so far as to suggest that biotechnology ought to be considered as a new informational technology on the basis of its ability to decode and reprogram this genetic and biochemical "information."[12] The idea that biological materials contain important and commercially valuable genetic information has quickly entered the public domain, finding expression in the development of tropes such as "genes-as-information" and "genetic software" that are now employed routinely in many newspapers, popular magazines, and science journals.

Conscious that these informational metaphors are often employed quite loosely, I begin by critically assessing something of the history of their use in the biological realm, examining how, if at all, such terms might still be usefully employed. In making an admittedly limited case for their retention, I draw the readers' attention to the creation of new bio-informational artifacts—sequences of DNA stored in databases, for example, and the development of new and lucrative markets for these novel forms of bio-information. In explaining the emergence of this new resource economy in bio-information, I link these developments in the technoscientific realm to broader changes that have occurred in recent decades—most notably, the rise of what has been termed elsewhere "the informational economy."

The final section of this chapter is devoted to an analysis of the new regulations that govern the use of bio-informational resources, including both intellectual-property-rights regulations and benefit-sharing agreements. Here, I question what it is that these regulations seek to protect, whose interests the regulations serve, and how well they serve them. I conclude the chapter by hypothesizing that these various technological, economic, and regulatory changes are together transforming trade in biological materials, altering what is collected, how it is collected, how it is then used, and how these materials are controlled or monopolized. These factors, I argue, are combining to enable a select group of collectors to exclusively capitalize on an emergent but potentially lucrative trade in bio-information.

In chapters 4, 5, and 6, I produce detailed empirical evidence to support this hypothesis. In chapter 5, I document the extraordinary resurgence of interest in biological collecting that has taken place over the last decade, contextualizing this within a longer history of collecting within the pharmaceutical and natural-products industries. I show here that although it is possible to situate contemporary bioprospecting within an apparently seamless and unchanging continuum of biological-collection practice, it would be foolish to do so uncritically. Major changes have taken place in recent years in scientific, technological, and regulatory domains that have acted to fundamentally alter the ways in which biological materials are constructed and valued as industrial raw materials within the bioprospecting and pharmaceutical industries. This has consequently affected both *what* is collected under contemporary collecting programs and *how* these materials are collected and stored. As I reveal in this chapter, these trends have allowed certain privileged collectors to acquire, collect, and concentrate increasingly valuable bio-informational resources with much greater efficiency.

In chapter 6 I explore the fate of these collections—investigating in detail how they have been used, traded, and exchanged within the U.S. pharmaceutical industry. The materials that were collected in far-flung places and later transported to private repositories in the United States have since undergone many physical transformations, existing now in a variety of more or less corporeal forms. Each of these new artifacts—cell lines, cryogenically stored tissues samples, extracted DNA, and sequenced DNA stored on databases—have been subject to many subsequent processes of trade and exchange. Rendering collected materials in these new, more purely informational forms has enabled them to be transacted in novel ways, and I provide some first evidence of these in this chapter. I also reveal how technological advances have acted to revalue existing banks of biological materials, creating an incentive for them to be illicitly "remined" for commercial or industrial purposes. The evidence presented here suggests that these new forms of commodity exchange will also speed up the social and spatial dynamics of collecting by improving collectors' ability to successively reutilize and recirculate bio-informational resources to their further economic advantage.

As I have noted, new protocols introduced under the Convention on Biological Diversity in 1992 oblige signatory states to ensure that suppliers of genetic and biochemical resources receive "a just and equitable" share of the benefits that arise from their utilization. If this commitment is to be met, suppliers should share in the profits that accrue from the commercial exploitation of their genetic resources—*no matter how constituted.* However, for this to be possible, they must necessarily be able to trace all the uses that are made of the bio-information extracted from their collected materials, for it is this, I would argue, that is *actually* the commodity that is sought and transacted for commercial gain. As I show in chapter 3, the task of tracing the successive uses that are made of information is particularly complex. In chapter 7, I expose some of the many difficulties that are inherent in regulating transactions involving forms of bio-information, and demonstrate why a failure to successfully monitor these subsequent uses will have potentially disastrous consequences for the suppliers of genetic and biochemical resources, many of whom are groups in economically vulnerable developing countries. If this outcome is to be avoided, some new and possibly quite radical approaches to the governance of this new resource economy in bio-information will have to be implemented. Some initial thoughts on what form these approaches might take are outlined in the concluding chapter.

Before any of these issues can be dealt with, it is essential to begin contextualizing contemporary bioprospecting activities within a longer history of collecting in natural history. I do so for two reasons: The first is to remind the reader that although bioprospecting is often characterized as an activity devoted to the *exploration* of biodiversity, I would argue that it is, fundamentally, about the practice of *collecting.* The second is to highlight how collecting practices relating to the acquisition of natural materials have changed over time. In order to establish what distinguishes current collecting practices from earlier ones, it is helpful to begin by first determining what they have in common—what principles unify all types of collecting practices, both historical and contemporary.