7. BACK TO THE FUTURE

As I sit down to conclude this work, I have before me copies of the daily papers, each of which makes reference to the forthcoming Earth Summit on Sustainable Development that is about to commence in Johannesburg, South Africa. As exactly ten years have now elapsed since the Convention on Biological Diversity was first implemented, it seems an appropriate, and timely moment to reflect on how the introduction of this new regulatory regime has affected approaches to the utilization and stewardship of what has become, in the course of that same decade, one of the world's most valuable commodities: genetic and biochemical material and information. Interest in the collection and use of these resources began to escalate dramatically during the early 1990s as new technologies, new global environmental and economic policies, and restructurings in the corporate and scientific realms began to create new incentives to collect genetic and biochemical materials and new avenues for their exchange. The history of the collection and exchange of biological materials is extraordinarily long, stretching back hundreds of thousands of years. Within this context, it was easy to assume—and many have—that bioprospecting is simply a new descriptor for an age-old practice.

In this work I have tried to show that there are difficulties with this assumption. Although the collection and exchange of biological materials does indeed have a very long history, the application of sophisticated, indeed, entirely unprecedented biotechnologies has fundamentally altered the ways in which these resources are now collected and used—particularly within life-science industries such as the U.S. pharmaceutical industry. The change that has occurred in the way these materials are collected reflects a broader transformation that has occurred in drug development in recent years. The progressive introduction, and later dominance, of molecular approaches to the creation of pharmaceuticals and therapies has directed

attention toward the components of living organisms. The genetic and biochemical materials and information embodied within them have proven to be extremely useful and valuable commodities, for both scientists and researchers, and interest has inevitably coalesced around the question of how to more effectively and efficiently collect and utilize these resources.

It soon became apparent to collectors that one means of improving the efficiency of the collecting process was to concentrate on collecting only those "key" or "essential" elements or components of biological organisms that were essential to processes of research and development, while divesting all other material that was considered to be extraneous or inessential. One way of achieving this was to produce a series of new engineered artifacts—such as cryogenically stored biochemical extracts and samples of tissue, cell lines, and sequence information—that could act as proxies for whole organisms. Of course, the genetic and biochemical material and information embedded in whole organisms has always been available for use; it has just not been as accessible as it is when embodied in these new forms. I have argued in this book that changing the way in which this genetic and biochemical material and information—what I have termed "bioinformation"—is rendered, or presented, has had a profound effect on the practice and politics of biological resource exploitation.

In thinking about the way in which biotechnologies have transformed trade in biological materials, I have drawn a parallel between the actions of biotechnologies and informational technologies. Both, I have argued here, are employed to act on complex phenomena in order to produce from them proxies that provide consumers with, if nothing more, then at least those "key" or "essential" elements that they most desire. In both cases, producing these proxies involves a process of distillation—a de- and rematerialization. Much of the existing material or body of the original is divested, enabling the remaining information to be rendered in new, more lightweight, mobile, and transmissible forms. Just as new informational technologies have enabled particular resources to be structured in ways that have made them easier to circulate, store, and reprocess, so biotechnology has also enabled whole organisms to be rendered in ways that make the genetic and biochemical materials and information embodied within them much easier to transmit, store, reprocess, and recirculate.

These processes are of the utmost significance, as they allow the collectors of biological material to speed up the social and spatial dynamics of collecting from which power and profit derive. As I began this work by arguing, collecting is an inherently political activity, in that it involves annexing particu-

lar materials for exclusive use. The collector's power derives from his or her ability to acquire materials of interest, to concentrate them within particular locations where they can be ordered, controlled, and disciplined, and to then recirculate them (or not) within the marketplace to strategic advantage. Any factors that allow them to speed up the different phases of this process will be all to their advantage. I have argued that the ability to create new, highly transmissible bio-informational proxies that, unlike many of their historical counterparts, actually prove fungible for them in processes of research and development has allowed a select group of collectors to acquire, concentrate, and recirculate these commodities with far greater ease. This newfound ability, as well as the creation of a new regulatory paradigm that creates conditions within which these novel commodities may be exchanged on normative terms, have together enabled collectors to create a burgeoning and lucrative market economy for these bio-informational commodities.

Almost as soon as it became apparent that the introduction of new biotechnologies would inevitably create a demand and a market for genetic and biochemical material and information, concerns were raised as to how this market would be regulated and in whose interests it would operate. Much of the collecting that took place in earlier eras was undertaken in tropical developing countries, and these countries have remained the target of collecting expeditions. Many of these states were anxious to avoid being the object of a new wave of biocolonialism, and they began to lobby intensively for the creation of new policies and regulations that might govern the collection and use of genetic and biochemical resources, hoping to ensure that these activities were carried out in a more just and equitable fashion. This pressure was, in time, translated into the regulatory protocols that were introduced under the biodiversity convention and that have created the paradigm within which approaches to the governance of these resources have been shaped. During the late 1980s and early 1990s, an elite group of senior practitioners within the bioprospecting industry began to translate these protocols into a series of novel contracts that established the terms and conditions under which these resources could be exploited. A principal feature of these agreements, and one that played a central role in legitimating this new era of bioprospecting, was the inclusion of a formal benefit-sharing regime.

Some of the most interesting and significant characteristics of this emerging trade in bio-informational resources are the modes of transaction to which it has given rise. Bio-informational proxies, as I have noted here, privilege the genetic and biochemical information embodied in whole organisms

at the expense of other attributes of the organism. This information (whether in a partially or wholly decorporealized form) may be used *successively* by a variety of consumers for a variety of different purposes. Collectors have quickly recognized that they may exploit their assets without relinquishing complete control of them. Rather than collecting and selling samples of material outright, many prefer to create an ongoing revenue stream by repeatedly selling *access*, on a short-term basis, to the genetic or biochemical information contained within them. This has given rise to forms of commodity exchange that are unprecedented in this domain, such as rental, licensing and pay-per-view. As I have illustrated here through empirical example, these resources are particularly valuable, as they can be used to form the basis of new products and processes.

If this trade is to be an equitable one, these benefit-sharing agreements must provide a mechanism that enables supplying countries to share in the profits that are generated from the many successive uses that are made of the bio-informational resources that have been collected within their borders. Agreements began with an awareness of this—the inclusion of a royalty mechanism reflected an acknowledged need to meet this aim. However, as I noted earlier, it is impossible to pay a royalty unless it is possible to determine to whom that royalty should be paid. This necessitates establishing a chain of consumption: ascertaining with certainty from whom the material was collected, by whom it has been used, for what purpose, and with what outcomes. It quickly became evident that this would require the introduction of a separate set of formal mechanisms for tracking and monitoring all of these successive uses.

This was realized through the development and implementation of a further set of contractual agreements that have become known as "Material Transfer Agreements." The use of MTAs was initially confined solely to transactions of bio-information that were understood to be commercial in nature. Almost immediately, however, it became clear that the distinction between commercial and noncommercial uses of such material and information (if it ever had existed) was being dramatically eroded by changes in the operating environment within the life sciences, particularly by the creation of a host of new dependencies and collaborations that established new links across traditional boundaries (e.g., corporate sponsorship of academic research, shared commercial and academic use of resources, and so on). Pressure thus mounted to extend the application of MTAs to *all* transactions that involve the transfer of collected biological materials. Although both corporate and scientific researchers recognize why, if MTAs are to be effec-

tive, they have to be applied uniformly, I have also detected their grave concern that extending such mechanisms to every possible exchange of material will be immensely burdensome, potentially unworkable, and, as I shall go on to suggest, morally corrosive.

This "compensatory" model is such that it also creates a need to address questions of informed consent. It has been argued that it would be unethical to change the use of collected genetic materials (for example, from a scientific to a corporate use) without inquiring whether the original provider agreed to that change of use. Every such change may yield an economic return, and as suppliers are potential recipients of a percentage of that return, it seems important that they be fully apprised of and in agreement with any proposed change of use. Although I have not addressed the issue in detail in this work, the task of securing such consents from suppliers is an immensely complicated one. Even in the most simple scenario—where a supplier provides material or information for an immediate use—it must first be possible for the collector to identify the particular individual or individuals from whom consent must be gained. This entails addressing complex and perhaps irresolvable questions about who "owns" these bio-informational resources (for example, individuals, communities, or states).

Acquiring "informed" consent also necessarily involves being able to adequately describe to such groups (once identified) how the material will be used in ways that are intelligible to them, by which I mean understandable within the context of their worldview and life experience. These difficulties multiply, first, as the numbers of transactions increase over time and, second, as the array of potential uses to which the material could be put exceeds that which any one person might reasonably be expected to comprehend or assess. At present, collectors have two choices. The first is to secure a *prior* informed consent for all potential uses; however, these consents are likely to be so broad in their compass as to lose all relevance. Such agreements are, in effect, a permission to do all things with the material even if those things cannot be specified, and in that case, to what have suppliers consented and how could their consent be said to be informed? Alternatively, collectors can insist that each subsequent user of the collected material return to the suppliers (assuming, of course, the suppliers are still there to be asked) to secure their further consent, on each and every occasion that the material is used in a fashion not previously anticipated or agreed upon. This will necessarily involve providing adequate explanations of what are, potentially, ever more complex technological applications (for example, gene splicing, nanotechnology, and so on).

Policymakers have responded to these complexities by introducing more and more layers of procedure designed to accommodate and regulate every possible eventuality, including those that cannot yet be known. Nowhere is this more evident than in the newly negotiated "Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of Their Utilization." The agreement, which represents the culmination of ten years of regulatory development within the biodiversity convention, is immensely detailed; the proposed protocols for governing access to and use of these genetic and biochemical resources now take some twenty-five pages to articulate. They include recommendations that collectors introduce, among many other things, legally consistent mechanisms for securing prior informed consents; systems for protecting and encouraging customary uses of biological resources in accordance with traditional practices; mechanisms for extending and strengthening the application of MTAs; frameworks for improving local awareness and capacity to implement benefit-sharing agreements; and, indeed, ever more complex proposals for benefit sharing, including specific provisions on type, timing, mechanism, and distribution.[1] Together they constitute a system that is, it could be argued, ever more convoluted, onerous, and unwieldy to implement, and that may, in fact, serve only to deter prospective consumers.

Despite larding up these layers of contractual and legislative requirements (royalty agreements, MTAs, informed-consent agreements) in what is an increasingly baroque regulatory framework, it remains the fact that supplying countries and communities have yet to receive any *substantial* economic returns from the exploitation of their collected materials. It could be argued that this is simply because no products have yet been developed from the material. This seems surprising, however, given that this new era of collecting and highly sophisticated investigation and exploitation of collected materials has now been underway for nearly twenty years. It is an established fact that in recent decades some 25 percent of all prescription drugs have been derived from natural products, most of which have been collected in foreign countries. Are we now being asked to believe that despite the introduction of much more sophisticated technologies, no new drugs have been developed from such materials over the last twenty years, or at least not in the last fifteen years, since access- and benefit-sharing regimes were introduced? An alternate explanation would be that these collected biological materials have, of course, formed the basis of many commercial products during that period; it is just that this has not been established factually or

acknowledged. What this suggests is that the existing regulatory system has failed to play its redistributive role, despite its elaborateness.

As I have argued here, this failure did not occur because such agreements have not been well intentioned but rather because changes in the way biological materials are rendered and utilized have combined to make the task of monitoring and compensating for their use extremely difficult. This problem is not, of course, confined to the biotechnology industry. As I have shown, the introduction of other new technologies—such as informational technologies—has created remarkably similar difficulties in other industries. The ability to transfer books, music, and films into a digital form has enabled these materials to be circulated, copied, and modified with extraordinary ease. The Associated Press reported on 21 August 2002 that it was estimated that 10 million people had tried to download the new and aptly named installment of the *Star Wars* saga, *Episode II: Attack of the Clones*, in the weekend after its release using Internet relay chat file-sharing systems, and that 4 million of them had succeeded.[2] Media executives and attorneys are so determined to stamp out these practices that they are now devoting a considerable percentage of their research and development budgets to devising new methods to prevent unlicensed replication of these products, such as encryption or hardware modification. Despite this, the industry is still finding the problem to be largely intractable. Immense amounts of time, energy, and resources are being dedicated to the task with little apparent success.

If those working in the bioprospecting industry hope to be able to trace all the uses that are made of collected genetic and biochemical materials and information over both space and time, it would seem that they too will need to employ some equally advanced technologies. Ever more elaborate and sophisticated mechanisms for monitoring and tagging the movement of genetic material and information are certainly being developed. DNA encryption, genetic fingerprinting, electronic identification (EID), molecular markers, and DNA profiling are all being promoted as the latest and most effective tools for establishing and maintaining the provenance of genetic components or sequence information as they are passed from one prospective user to another. All of which raises a question: How far down the road of tracing the successive uses of bio-information could, or should, we attempt to go?

There is no question that genetic and biochemical materials are used extensively in the biotechnology and life-sciences industries; however, they are primarily used when in these partially decorporealized or wholly

informational forms. If benefit-sharing agreements are to work, they must be able to trace and take account of all the transactions that involve the use of genetic and biochemical resources, even when they are rendered in these elusive forms. The new tracing technologies that I outlined above could be applied to this task (they are not currently), although this would be an immensely complex, expensive, and time-consuming undertaking. Even systems such as the sustainable-timber certification scheme developed by the Forestry Stewardship Council, and the livestock passport scheme introduced to trace the movement of large whole organisms (such as trees and cattle) as they are transferred from one location to another through a succession of market transactions, have been derided for regularly failing to establish an identifiable "chain of custody."[3] It is important to note that these projects have faltered even though the material that they seek to trace is infinitely larger and more stable than anything that one might attempt to trace in the bioprospecting industry.

Despite this, a large proportion of the (relatively) small amount of money that has been generated through bioprospecting ventures has been channeled into creating a flourishing bureaucracy devoted to the task of attempting to track, monitor, and secure compensation for the use of tiny fragments of genetic and biochemical material and forms of extracted bioinformation to equally questionable effect. Many of the NGOs whose principal aim is the protection of biodiversity, and many institutions in developing countries, are now devoting a considerable proportion of their operating budgets to the task of developing, implementing, and overseeing what may well prove to be an ineffectual set of procedures. Developing-state governments are not immune from this process either. Many now feel compelled to develop detailed legislative and administrative structures that, they are told, will enable them to secure ongoing returns from bioprospecting operations. Given that this regulatory paradigm may fail to deliver major returns and that the opportunity costs of directing finite resources away from other crucially important areas, such as education and health provision, are so considerable, it becomes even more important to undertake an unflinching assessment of whether such investments can be justified or sustained.

Recognizing the limits of the existing regulatory paradigm is clearly of profound importance to all concerned. However, these matters also raise a larger question: Is there a risk that the existing regulatory system may not only fail to meet its goals but may, in fact, exacerbate the very problem of mistrust that it sought to remedy? As I have illustrated here, the new era of collecting that began in the 1980s emerged in a climate of uncertainty—

there were hopes that it might provide new opportunities and returns for developing countries but also concerns that the projects might reproduce the colonialist practices of an earlier era. The new regulatory protocols that were introduced under the biodiversity convention were explicitly designed to improve relations of trust—they sought to remedy past inequities by ushering in a new regime of just distribution of gains. This original impulse has since been translated into layer after layer of ever more detailed and complex forms of contractual regulation and practical requirements for transparency and accountability that have become sedimented over the past decade into a set of practices that have now been adopted globally.

The task of conforming to these new protocols is onerous and immensely consumptive of time, energy, and resources. Many scientific research institutes and, perhaps more importantly, many companies are so constrained or wearied by the need to meet these requirements that they have elected to either abandon in situ collecting altogether or to engage in these activities illicitly. Neither course of action brings any financial benefit to source countries. Those companies, organizations, and institutions that do decide to comply are burdened by the weight of administering contacts that attempt to pin down, through ever more finely calibrated mechanisms, the whereabouts and recent uses of every last bit and byte of genetic material and information, when it must be clear to most that this is a truly Sisyphean enterprise. The structural inability of this system to produce the promised returns, will, in time, I believe, give rise to a serious, profoundly corrosive, and depressing sense of frustration in all parties.

The notion that it is possible to secure accountability and trustworthiness through the imposition of more complex systems of behavioral auditing is certainly not confined to this realm—it has been widely embraced in many areas of medicine, science, academia, and public life in recent years. As the moral philosopher Baroness Onora O'Neill suggests, "a prominent feature of this widespread movement to improve accountability has been an increasing reliance on more formal procedures, including contracts, letters of agreement and financial memoranda that impose highly complex conditions."[4] Formalization of procedure appears to have a number of advantages that are, as she suggests, "constantly mentioned by its advocates: mutual clarity of expectations, clear performance targets, defined benchmarks of achievement, enhanced accountability."[5]

What her insightful analysis highlights, however, is that the *failure* of these formal mechanisms to deliver desired outcomes may ultimately engender, rather than remedy, feelings of mistrust. Ironically, although a strict

auditing of these transactions promises to deliver accountability through transparency, in fact what it implies is that those involved in such exchanges are somehow inherently untrustworthy and must thus be subjected to continuous external monitoring. Although this may rankle, subjects might be prepared to tolerate it if they believe that the application of more detailed forms of auditing and monitoring will actually deliver equitable working relationships, standards, and outcomes. As Thompson notes, however, most eventually come to believe that such procedures in fact "only create further levels of bureaucracy and inefficiency . . . and set in motion a process that may exacerbate rather than alleviate the problems they were intended to address."[6] This may, as he concludes, contribute to deepening a culture of distrust.

This argument can, it would seem, be applied to an analysis of the development and application of regulatory paradigms in the bioprospecting industry over the past decade. These were introduced primarily to ameliorate concerns that source countries had about the inherent untrustworthiness of collectors—an attitude that had its genesis in the colonial era. In the interests of ensuring that the contemporary bioprospecting operations were carried out in a just and equitable fashion, stakeholders began to devise mechanisms that would regulate access and ensure an equitable distribution of benefits. These mechanisms and attendant procedures have become progressively more formal and more elaborate as the years have gone by, and this has, perhaps, ironically engendered further feelings of mistrust. These feelings are at risk of being exacerbated by that fact that *despite* the introduction of these increasingly complex procedures, remarkably little money has been returned to source countries from these bioprospecting operations.

Although we continue to receive estimates of the truly astonishing amounts of income that have been reaped from the sale of products developed from natural materials sourced, in most cases, from developing countries (estimated to be between $75 and $150 billion annually in the pharmaceutical sector alone), it remains the fact that none of these countries have received any significant proportion of this income—these increasingly convoluted regulatory and compensatory mechanisms have largely failed to produce the desired outcome.[7] An unfortunate consequence of this is that developing countries are being affirmed in their belief that this new wave of bioprospecting is unlikely to return the benefits it promised. Their confidence in the project has been so undermined that many are now threatening to close their borders to all collectors, including those that are undertaking collections for scientific purposes such as taxonomic identification. It

would be truly unfortunate if this were to occur, as such activities are central to the project of preserving global biodiversity.

There is also clear evidence that overregulation is deterring companies from pursuing natural-products research. Rather than opening up new possibilities for the creative and sustainable use of biological materials and information, these new multitiered levels of regulation act to progressively choke off such opportunities. There may be those who are of the view that this is no bad thing—that biodiversity is best left unexploited. However, in an increasingly globalized world, the likelihood of biodiversity remaining so is remarkably low; it would be naïve to think otherwise. The question, it seems, is not whether these resources will be exploited but rather how they will be exploited and how this market might be organized such that it operates on a more equitable basis. Given all that we have ascertained from this research, it does not seem inappropriate to propose a radical rethinking of approaches to the regulation of this burgeoning global trade in genetic and biochemical material and information. I believe that by going back to the past, it may be possible to see a new way forward into the future.

Prior to the introduction of the biodiversity convention, access to genetic and biochemical materials was unrestricted. Countries, collectors, institutions, and individuals all held an equal right to access these resources, investigate them, and employ them in any number of creative ways. There seems to be a consensus of opinion that this was generally desirable—that the ability to access them freely stimulated innovative and inventive approaches to their use. It was also evident, however, that the power to utilize these resources had historically, and would in the immediate future, continue to be concentrated in the hands of those collectors with links to the most sophisticated laboratories in the developed world. This inequity created unequal power relations and a genuine probability that most of the profit that derived from the exploitation of these materials would remain in the hands of those individuals. A property-rights war broke out as a consequence: supplying countries began to claim rights over their genetic and biochemical resources, while corporate interests began to claim rights to the engineered artifacts that they created from them.[8] The outcome was the introduction of new benefit-sharing regimes designed to ensure that a proportion of the profits that accrued from the commercial exploitation of these collected materials be returned to those countries that had supplied them.

The principle of sharing benefits with supplying countries is not, I believe, disputed by any party, even those companies that would be expected to relinquish a portion of their profits to meet this requirement. In the course of

my research, I did not find any executives who were opposed to paying a royalty of between 1 percent and 5 percent of net profits on products derived from natural materials that were not collected domestically. Most large pharmaceutical companies (those that generate large numbers of products and profits) now fully accept that they must pay for their raw materials. Ideally, they would prefer to only pay for those that prove to have some long-term utility for them, and this is understandable. They are unconcerned about the addition of this extra cost, in part because it is unlikely to be borne by them directly—it will simply be added to the sale price of the product as a production overhead, alongside costs such as advertising and packaging.

Companies are also now acutely aware of the adverse publicity that attaches to attempts to secure raw materials without paying some appropriate form of recompense to the supplier, and they have no desire to attract such opprobrium. Most are concerned to act as responsible and environmentally conscious corporate citizens. What companies emphatically *do not* wish to do, however, is to spend ever greater proportions of their operating budgets complying with an unnecessarily cumbersome and unpredictable regulatory system. Regulatory protocols (such as benefit-sharing agreements and MTAs) are being continually reworked and refined to take account of new developments. Understanding and implementing these changes is an enterprise that absorbs an increasing number of administrative and legal personnel in corporate, scientific, and academic organizations, whose services may be more usefully deployed on other tasks.

Source countries find themselves in a similar position. What they ideally want is to receive some significant and ongoing economic returns for the use of their resources, without having to commit an inordinate percentage of their extremely scarce resources to the task of developing, administering, and monitoring new policies and regulatory regimes. Although I have not had an opportunity to calculate it here, it would be interesting to conduct an assessment of how the costs that supplying countries have incurred in setting up and implementing bioprospecting legislation, policies, and agreements compare with the returns that have so far been realized from such ventures. Such an analysis would almost certainly reveal that the system is in negative equity. If the system as it currently exists does not appear to be satisfactorily meeting its aims, then other, alternative schemes must be proposed.

What I offer here is nothing more than one possible alternative derived from this detailed critique of current practice. Although radical in conception, it retains and respects the original impulses that informed the devel-

opment of new regulatory approaches to the collection and use of genetic and biochemical resources, such as access and benefit-sharing agreements. I offer it not as a fully realized proposal, for it is clearly not, but rather in the hope that it might stimulate some further debate and discussion about the shape that future regulatory paradigms in this field might take. The proposal that I intend to outline here is informed by ideas being developed in parallel domains such as the media and software industries. They have been devised in response to the need to evolve more sophisticated ways of dealing with the use, both licensed and unlicensed, of commodities and resources that have proven to be highly transmissible, readily replicable, and, as a consequence, extraordinarily slippery.

It seems to me that what matters most to collectors and suppliers in the final analysis is the question of what products are developed from collected natural materials. Samples of material and information may be used in many speculative endeavors; they may prove to be of use in some and not in others. All that really concerns people is whether those materials go on to form part of a patented or copyrighted product—such as a drug or sequence database—that is marketable and that generates profits. Suppliers have a right to expect that in such instances they would receive a small royalty for having provided the resources on which these products are based. Within the bioprospecting industry, royalties range between 1 percent for material collected at random to 15 percent for material that already has indications of proven efficacy against specific diseases. However, there is a general agreement, and evidence and probability would seem to suggest, that only a comparatively small proportion of collected samples would fall into this latter category. The majority of collected samples currently attract royalty payments of between 3 and 5 percent.

I propose that we abandon the task of attempting the trace all of the myriad uses that are made of collected genetic and biochemical materials and information and concentrate instead on working to secure a voluntary, global agreement from the pharmaceutical industry that they will add a sum of between 3 and 5 percent of their profit ratio to *all those products that they currently have in the marketplace that are based on collected natural materials*. This levy would remain in place for as long as those products are sold. In order to ameliorate some of the inequities that have characterized collection processes in the recent past, it does not seem inappropriate to suggest that this levy also apply to products, such as vincristine and vinblastine, that were derived from materials collected without recompense but which continue to generate substantial profits for drug companies.

I would suggest that a similar duty be levied on users of genetic-sequence databases and indigenous-knowledge databases. This could be easily added to the charges that institutions should, and do, routinely require to access these types of information. These levies, which would amount to not more than a few cents on most proprietary products or informational transactions, would be paid directly into a superfund that would ideally be administered by a global regulatory agency such as the Global Environment Facility.[9] Countries and communities from the developing world might then apply directly to the fund with proposals for development and conservation projects.

As I have suggested here, the task of attempting to establish the provenance of collected materials is highly problematic, and it would not be fruitful, in my view, to devote too much attention to trying to establish which countries had provided what material or information. There will undoubtedly be cries of indignation about the idea of abandoning a strict auditing of who gave what to whom and from where. Some countries will argue that they have given much more material than others, while others might argue that, while they have given less, the material that they have given has proven to be much more valuable. While such claims may well be true, it will be impossible to determine their veracity unless we are able to establish, with complete certainty, how those materials have in fact been used over time and space—a task that requires access to actuarial information that will always remain just out of reach. While we have awaited the successful completion of this potentially unworkable auditing process, years and years have slipped by without the production of any form of substantial compensation.

This scheme, might, I believe, yield a number of substantial and immediate returns for both suppliers and collectors. It is my fervent belief that what supplying countries most desire is to secure access to an ongoing income stream that they may utilize for a variety of conservation and development projects that can provide ecological, technological, cultural, economic, or social benefits. We all, collectively, live on a small and increasingly imperiled planet. As processes of globalization advance, we all become much more dependent on one another—environmental and economic collapses in one region of the world can have catastrophic consequences in another. There would undoubtedly be complexities associated with the disbursement of these funds, and I do not wish to downplay them here. The world's more biodiverse countries or those that have played host to a greater number of contemporary collecting projects may wish to argue for a greater proportion of the funds, and they may be justified in doing so. My abiding sentiment, however, is that most citizens of the world would feel that a con-

siderable gain had been made if income from the superfund were used to reverse imminent environmental destruction, *wherever that may be occurring*, and I feel certain that consumers of pharmaceuticals would consider this an extremely appropriate and welcome use of any small surcharge that had been levied upon them.

Another considerable advantage of this scheme is that it would yield an immediate, substantial, and ongoing revenue stream. Instead of having to wait twenty years or more for income that may never be realized, supplying countries would be able to make immediate application for funds for applied conservation and development projects that need to be undertaken urgently. Second, the money could be accessed directly, through existing United Nations environmental aid and donor programs, for example, without the need to generate dedicated systems of disbursement. Third, the portion of funds that is now spent on monitoring contractual agreements and tracing successive uses could also be reduced, releasing resources for other social purposes. I would not propose completely abandoning the project of monitoring the ways in which materials are used, as questions of how such materials are collected and used clearly have important social, cultural, and political implications. These tasks should continue, but they need not be seen as a necessary prerequisite for the release of compensation, as they are now.

Collecting institutions, companies, and research institutes would also benefit greatly from being released from the burden of having to account for every successive use that they make of collected material and from having to implement and monitor highly nuanced and complex access and benefit-sharing agreements. This would result in a substantial reduction of their administrative costs. The savings that are made might be used, in the corporate world, to perhaps cross-subsidize further research and development of basic drugs for use in developing countries. Scientific, academic, and other research institutes might well apply their savings to the pursuit of further basic research for which federal funds have been cut, such as species-identification programs.

All of these parties would also benefit immeasurably from a return to what might be thought of a "moderated free-access regime." The collection of species for taxonomic and other purposes would no longer be hindered, and students would be free to pursue crucial field research. This may draw attention to areas or species at risk of further destruction. Collectors from both developed and developing countries would be equally free to fully explore all the potential applications of biological materials

and to work experimentally with those materials to produce new inventions and innovations. These may, in time, become marketable products that will provide a future revenue stream. Although such a scheme may seem too revisionist, it is more likely to fulfill the shared aim of finding new, creative ways to justly and equitably develop genetic and biochemical resources and information for the broader benefit of humankind than those that we have available to us today. While the difficulties of administering such a fund may seem insurmountable, it is difficult to imagine that they would exceed those associated with the current system. As radical as it seems, this new superfund model may well act to unblock some of the obstructions that now threaten to fatally impede the operation of existing regulatory and compensatory frameworks.

Undertaking this research project has involved immersing myself in a shifting debate about how best to govern the use of a new commodity: variously embodied types of bio-information. Although we continue to imagine that biological material is the same type of resource that it always has been, this detailed research, I hope, has revealed that it is in fact a resource that is being construed, represented, and utilized in new and unexpected ways. I have argued here that we must consequently learn to evolve sophisticated and custom-made systems of regulation that might reflect the complexities that attend its changing construction and use. My motivation in undertaking this research has not been to deride or undermine the inventive approaches to the regulation of this new commodity that have been developed in the last ten years but rather to build upon and learn from such endeavors. I am indebted to all those practitioners in the bioprospecting industry whose willingness to be frank about the shortcomings of the existing system has enabled us to reflect in a much more informed way on where and how our collective approach to the uses and regulation of this new resource might be improved.

By drawing out the parallels that exist between biotechnologies and other informational technologies, I hope that I broadened understandings of how biological materials are constructed and used as commodities in the contemporary life-sciences industry and revealed the capacity that this has for creating a new and highly lucrative resource economy in bio-information. I also hope that this analysis will lead us to reflect on questions of social and economic justice and of our individual obligations to ensure that this new resource economy operates in a just and equitable fashion. While the collection of plant and animal samples for use in the pharmaceutical industry may be declining, the collection and use of human tissue and organs is on the rise. The issues that I raise in this work—questions of

what the status of various biological derivatives and "works" might be and of who should have access to them and under what terms and conditions—will have growing implications for us as the flourishing life-sciences industry pushes forward with the creation of DNA and stem-cell banks, DNA-sequence databases, and, indeed, enters other realms that remain, as yet, unimagined and uncharted. As we move into the twenty-first century, the century, perhaps, in which the engineering of life will become our central preoccupation, it seems appropriate that we continue to focus our collective attention on the question of how we, as a global community, wish to manage the commodification of life.