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If a multilateral mechanism stumbles, what then for DSI benefit sharing?

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How will countries manage their sovereign rights over the gene sequences and related information of their biodiversity? The issue of digital sequence information (DSI) is one of deciding how to apply the 30-year-old access and benefit-sharing obligations of the Convention on Biological Diversity (CBD) to the age of information. DSI has formally been on the table of the CBD for nearly six years, since a decision in late 2016. This year, 2022, may be the one in which the first significant decisions are finally made.

Large gaps remain between Parties to the CBD, and the ultimate direction of the decision remains unknown. This paper explores some of the implications of a bilateral-focused implementation of DSI access and benefit sharing. It is a road less discussed – yet becoming more likely – with major implications for both the North and the South, and which may differently impact provider countries that have significant bioinformatics capacities and those that do not.

The last two-and-a-half years have seen pandemic delays and frequent but fitful online discussions about DSI. While the interminable series of webinars were called with the best intentions, they have swirled around as much as they have clarified and moved forward. Then again, everyone knew from the beginning that an issue of DSI's magnitude – the world's sequence information is of inestimable economic and human value – wouldn't really get resolved until delegates had gone hungry and tired and spent more than one sleepless night in the negotiating room.

An indecisive initial round of in-person talks, hobbled by several key participants having to withdraw after contracting COVID, was conducted in early 2022 in Geneva. The same delegates to the CBD will next meet in Nairobi in late June, and later this year in Kunming, China, where a decision by all the Convention's members might be expected.

Third World Network (TWN) is an independent non-profit international research and advocacy organisation involved in bringing about a greater articulation of the needs, aspirations and rights of the peoples in the South and in promoting just, equitable and ecological development.

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Is hope for a multilateral mechanism failing? The present scenario

Much discussion for several years has centred on the possibility of creating a multilateral system of benefit sharing for DSI. In the view of its proponents, such a system would allow for the vast majority of DSI, now and in the future, to remain publicly accessible,[1] and for scientific uses of it, especially non-commercial ones, to proceed relatively unchanged from the present. Such a system would protect sovereign rights over DSI by requiring users of biodiversity sequence databases to agree to standardized benefit sharing as a precondition to database access. This could be implemented through something resembling the familiar "click wrap" agreements attached to computer programs, telephone software, and other encounters in modern life that include "code", which DSI at least superficially resembles.

In such a multilateral system, benefits paid for commercial use of DSI would be pooled and then distributed by an international entity, with the financial and other obligations satisfied either directly by users, for example through a specified collective financial obligation divvied amongst them [as is the approach of the World Health Organization (WHO)'s Pandemic Influenza Preparedness (PIP) Framework], or through taxation or other levies managed by governments to reach or exceed an agreed annual minimum.

Importantly, a multilateral system would not require tracking and tracing all sequences because benefit-sharing obligations could be met without needing to know the details of every use of every sequence. This latter feature is much more efficient and practical as it vastly simplifies the system and responds to concerns about the high degree of complexity that would be required in a track-and-trace system, given the reality that a single query by a single user – one of many millions to happen every year – might bring back "hits" from dozens of countries. In other words, a single search query might potentially require tracking of hundreds or even thousands of sequences.

And then there are the companies and large research institutions, and there are many, that don't use public web interfaces but instead swallow large data sets whole. They do so by downloading entire databases or large portions thereof (see illustrations), including the largest DSI databases maintained by the International Nucleotide Sequence Database Collaboration (INSDC).

There is no tracking system, nor can one be realistically envisaged, for such use of DSI, which is likely to become more prevalent in the future as more and more users purchase or develop proprietary analytic systems (or implement the equivalent of publicly-available systems behind closed doors, where their use of DSI cannot be tracked by competitors or for the purposes of benefit-sharing claims).

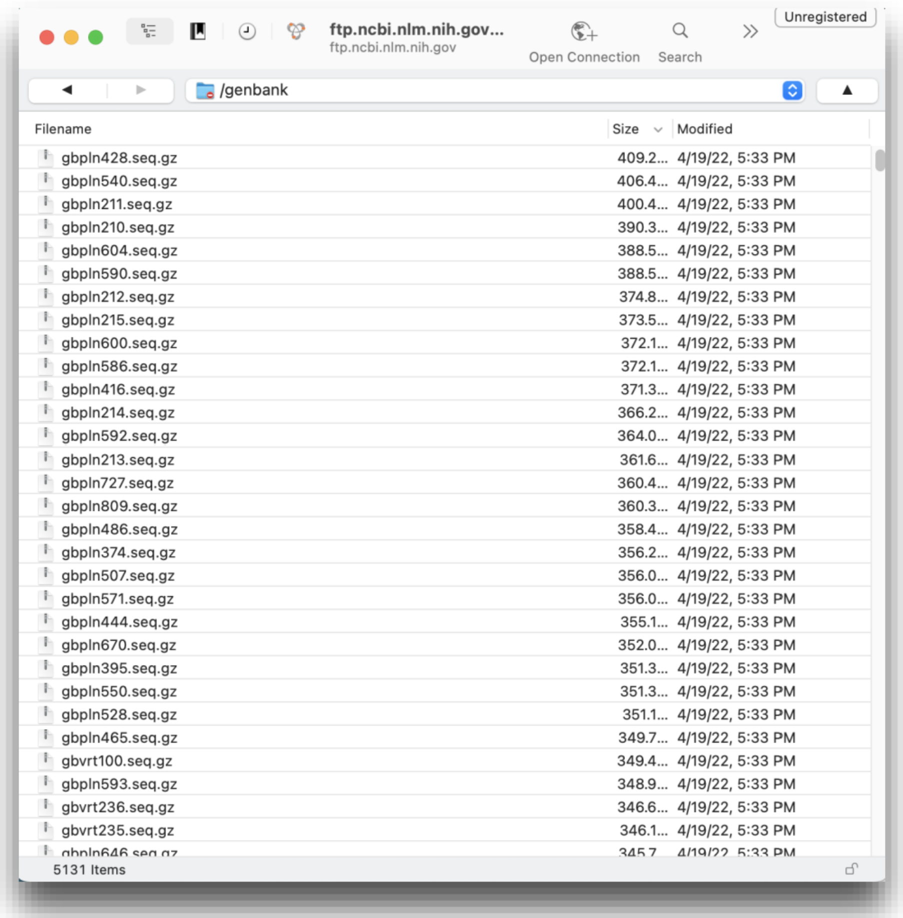
But the ideas of the multilateralists have run into strong countercurrents in recent months.

Academic denialists

An honest appraisal of where things stand requires acknowledging that the current system, dominated by the EU, US, and Japan-controlled INSDC "open access" databases, is built to subsidize Northern life sciences multinationals. It is a system structured to provide free access to the world's sequenced biodiversity, without restrictions or compensation when it is used for commercial purposes.

Sometimes obscuring that reality, unwittingly or not, are academics. Academic scientists interested in open access to DSI typically pay lip service to global equity but eschew personal responsibility in a solution to the DSI problem, even as they seek funding to sequence more and hit "upload" to add more information to the system they (usually) acknowledge is unfair.

1 "Publicly accessible" is functionally similar to, but not the same as, "open access", insofar as public accessibility may be governed by a user agreement, or other terms and conditions that are generally absent from open access databases.



THE US GENBANK'S FTP SITE CONTAINS THE ENTIRE INSDC DATABASE IN SO-CALLED "FLAT FILE" FORMAT. THE FLAT FILE DIVIDES THE DATABASE INTO OVER 5,000 GZIP ARCHIVES THAT SUM OVER 15 TERABYTES OF COMPRESSED DATA. THE TOTAL NUMBER OF DNA/RNA BASES IN THE FILES IS BEYOND MEANINGFUL HUMAN COMPREHENSION AND IS GROWING QUICKLY.

Free access to DSI is useful and customary for academic scientists, and the subtext of their arguments tends to be that it's more important to preserve their own free access to DSI than it is to take the benefit-sharing obligations of the CBD seriously. In other words, "leave us alone, fairness and equity may be a problem but it's not mine".

Some of the INSDC's defenders in academia have sought to muddy the economic reality by applying a dubious veneer to the system. These efforts include a misleading veneer of statistics about INSDC web users which do not include use of the "flat file" (see illustrations). And which, due to the way internet addresses work, are not necessarily reliable to begin with. Statistics put forward by scientists involved in DSI discussion on scientific publications that cite INSDC sequence information are similarly canted in a way that shades underlying commercial use of open access DSI.

But recasting the fundamental inequity of the open access system as being less unacceptable because of the claim that "not only Northern scientists use the INSDC", has convinced few.

Steaming into the storm

Though the nakedness of its self-interest in working to perpetuate the INSDC is embarrassing, the North would still rather look greedy than change. Why start paying if you're currently getting sequences for free? Especially if, as the German government has, you can quietly hire political consultants and recruit

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gbpln181.seq
GBPLN181.SEQ          Genetic Sequence Data Bank
                             April 15 2022

                NCBI-GenBank Flat File Release 249.0

                         Plant Sequences (Part 181)

  135630 loci,   149,863,966 bases, from   135630 reported sequences


LOCUS       KP717007                 630 bp    DNA     linear   PLN 25-JUL-2015
DEFINITION  Colletotrichum sp. 34409 calmodulin (CAL) gene, partial cds.
ACCESSION   KP717007
VERSION     KP717007.1
KEYWORDS    .
SOURCE      Colletotrichum sp. 34409
  ORGANISM  Colletotrichum sp. 34409
            Eukaryota; Fungi; Dikarya; Ascomycota; Pezizomycotina;
            Sordariomycetes; Hypocreomycetidae; Glomerellales; Glomerellaceae;
            Colletotrichum.
REFERENCE   1  (bases 1 to 630)
  AUTHORS   Arzanlou,M., Bakhshi,M., Karimi,K. and Torbati,M.
  TITLE     Multigene phylogeny reveals three new records of colletotrichum
            spp. and several new host records for the mycobiota of Iran
  JOURNAL   Unpublished
REFERENCE   2  (bases 1 to 630)
  AUTHORS   Arzanlou,M., Bakhshi,M., Karimi,K. and Torbati,M.
  TITLE     Direct Submission
  JOURNAL   Submitted (27-JAN-2015) Plant Protection Department, University of
            Tabriz, Iran
COMMENT     ##Assembly-Data-START##
            Assembly Method       :: Mega v. 6
            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
FEATURES             Location/Qualifiers
     source          1..630
                     /organism="Colletotrichum sp. 34409"
                     /mol_type="genomic DNA"
                     /strain="CCTU 1051"
                     /host="Viola sp."
                     /db_xref="taxon:1684292"
```

The header of one of the 5,000+ gzipped parts of the flat file. Decompressed, this 59 megabyte (MB) file grows to 500 MB and includes 150 million DNA/RNA bases. Sophisticated DSI users, particularly companies, can download the flat file and use in-house tools for queries and analysis.

This private use of DSI is not recorded by the INSDC. Therefore, statistics about how the INSDC is used that are based on queries submitted to its web interface – for example, statistics on the origin of INSDC users based on IP address (data which already fails to account for VPNs) – are misleading because they exclude flat file use.

a cadre of self-interested scientists to generate confusion around the economic realities of your self-serving arrangement?

Thus, the greatest obstacle to the advancement of a multilateral option so far has been that, even as the sea of discontent keeps rising, the North is locked on course to preserve the status quo or, more cynically, rebrand the status quo “multilateral” (as in “we fund the INSDC, and we think the INSDC is beneficial, ipso the INSDC is a benefit-sharing system”).

In either case, the North won’t signal a willingness to seriously fund a multilateral system that generates financial benefits to support biodiversity conservation, even as its companies derive many billions of dollars in profits from products developed using DSI every year. Northern countries could plot a route around the storm, but instead they insistently steam straight into the eye, blinded to deteriorating conditions by a determination to save on fuel (i.e., $) and avoid the trouble of turning the wheel.

But the South too has those that are dubious about a multilateral system for DSI, and who can blame them? If sequence information is the fuel for the “bioeconomy” in which countries North and South clamour to be major players, then doesn't it seem plausible that countries that retain national control over their DSI may prove to have a leg up? Especially if they are very biodiverse?

In addition, the experience of the multilateral system for crop seeds of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has been, to be blunt, rather unfortunate. Could anyone take seriously the multinational seed companies' proposal to value access to seeds and DSI of most of the world's major food crops as being worth about $50,000 a year, which is what the $40-billion-per-year seed industry effectively proposed in the dying days of pre-pandemic efforts to fix the Treaty?

In reality, that cynical proposal was simply sabotage, even if its US Trump administration proxy proponents feigned earnestness. The negotiation collapsed, and what the ITPGRFA debacle showed is not that DSI isn't valuable, but rather that industry isn't going to pay unless it is forced to. But at ITPGRFA, developed countries' corporate-obeisant agriculture diplomats were absolutely not going to twist seed companies' arms.

In the late 2010s, the North at ITPGRFA steered straight into the storm, like it does today at the CBD, refusing to seriously contemplate anything that would fundamentally change the DSI status quo, or even to really discuss charting a new course at all, except possibilities of making the unjust system even larger.

The North survived its cavalier stance at ITPGRFA, but there is a crucial difference between ITPGRFA and the CBD. ITPGRFA is a flawed treaty that protects the North's interests by default on the pretence of being an agreement for CBD implementation adapted to the "unique characteristics" of the agricultural sector. Such a safe harbour does not exist for the North in the CBD, a more balanced treaty that offers developed countries fewer anchorages favourable to avoidance of benefit sharing.

If not deterred from DSI multilateralism by "bioeconomy" aspirations or the depressing spectacle of ITPGRFA, some in the South appear interested in pursuing a bilateral path for still more reasons. These are rightly informed by a sense of historical injustice, that is, a determination to cease being "open veins" for Northern economic domination. And in some cases they also relate to concerns about traditional knowledge, for fear that a multilateral benefit-sharing arrangement may not protect indigenous peoples' interests.

Whatever the motivations, however, some South Parties interested in a bilateral path are better positioned to implement it than others, but it's hard for any to go it alone.

What could a bilateral system look like?

While much of the oxygen in virtual and physical meeting rooms over the past several years has been consumed by talk of multilateral benefit sharing, the idea currently has less momentum than it needs to succeed as a decision nears. Considering the headwinds discussed in the previous section, it is very possible that no agreement on a multilateral approach to DSI will emerge by the time the CBD Conference of the Parties convenes.

What, then, could a more bilaterally-focused system look like, and what are its implications?

A key assertion of this paper is that, despite technological changes underway in artificial intelligence and computer-aided design, in order to substantively benefit from bilateral benefit sharing for their DSI, developing countries will have to develop and operate their own information systems that replicate features of the INSDC, albeit at a national level.[2]

2 It should be noted that DSI-focused companies like Basecamp Research are proposing a relatively new avenue for Parties to manage large portions of their DSI, or manage use for specific purposes of their DSI, which is to, in effect, outsource the job to companies en masse. This paper does not consider this idea in detail, as there is not a deep well of publicly-available detail about such arrangements. It is not obvious how the approach supports the development and conservation goals of some Parties. In principle, this type of arrangement could be compatible with different international approaches but a better public understanding of its details and implications is needed.

But can't Parties manage DSI with bilateral bioprospecting contracts?

In one-off situations, yes they can, but in the absence of a multilateral system, bilateral contracts are unlikely to replace the need for nationally managed DSI sets.

Countries can and should place provisions on DSI into access contracts for physical specimens. These terms can prevent bioprospectors from mismanaging the DSI that they generate. But they will not replace the need for national DSI management if bilateral approaches are to create significant and reliable revenue for biodiversity conservation.

DSI generated under bilateral contracts will be oriented towards the needs of the entity requesting access and, as such, even if that DSI is controlled by the provider (or eventually returned to it), reliance on foreign bioprospectors to build DSI resources won't result in a national information resource that systematically represents a country's biodiversity, nor will it likely exist in a form attractive for subsequent commercial use.

Further, unless a bioprospector is seriously engaged in R&D and manufacturing inside the providing country, bilateral contract provisions on DSI generally won't contribute in a significant way to the domestic economic goals (e.g., "bioeconomy" development) influencing some countries that favour bilateral elements in the CBD's DSI approach.

In a bilaterally-tilted world, countries that are unable to acquire and systematically curate their DSI will face a heightened threat of being undermined from outside. Efforts like the Earth BioGenome Project to sequence large swathes of biodiversity from samples in natural history museums and other *ex-situ* repositories will impair a country's ability to capitalize on its DSI to fund conservation and sustainable use.

Some larger developing countries like Brazil may be able to restrict access to their markets to punish companies making uncompensated use of their DSI, but a "market denial" strategy is not available to countries that lack the leverage of a relatively developed economy of over 200 million people.

Put differently, if countries want to manage their DSI bilaterally, then they will have to manage their DSI themselves. This is a simple idea, but is also new for many countries and will prove challenging in resource-limited environments. Builders of national DSI systems will face many obstacles stemming from the need to preserve their control over its economic value.

Countries that bilaterally restrict access to their DSI at a legal level but that do not properly collect and curate it won't bring any "product" to the bilateral DSI marketplace, leaving them as physical resource providers and likely gaining little added value for their efforts.

The "hybrid" systems presently being discussed by some Parties would formalize a situation wherein two DSI access systems coexist. The first would be an open access DSI system, likely global in scope, and exemplified today by the INSDC. In parallel, national counterparts comprised of bilaterally restricted DSI (bDSI) would exist. These would, presumably, be primarily composed of DSI of endemic species and other biodiversity that has very significant variation within a country's borders (e.g., a secondary centre of origin of a crop).

National authorities would select what DSI to withhold from open access systems, or perhaps withhold by default and authorize release to open access systems in specific instances. In keeping with the approach of the Nagoya Protocol, access to and use of bDSI would require terms mutually agreed between the user and the providing country. Thus, to effectively exert rights to bDSI, each country would need its own access system tailored to DSI.

INSDC: Don't expect serious change

Some in the South seem to take courage in the hope that a CBD decision could result in the INSDC being changed so as to accommodate their bilateral interests.

Unfortunately, this is wishful thinking. The INSDC is well adapted to erase sovereign claims over DSI while simultaneously preserving the right, using intellectual property laws, for users to assert proprietary claims over its contents (e.g., patent a sequence for a set of purposes) or the results of using aggregated information (e.g., synthesized gene variants whose design was informed using INSDC DSI).

Accommodating the bilateral interests of developing countries would require a major transformation of the INSDC to implement a track-and-trace system.

Hopes that the INSDC's funders will agree to change the open access system to enforce sovereign claims are ill-placed. The US is not a CBD Party and other developed countries, such as Japan, also a funder, are reluctant to accept that DSI benefit sharing is an obligation; much less are such INSDC funders prepared to upend the system they have built and that serves their economic and scientific interests quite well as it is.

Further, the INSDC has an advantageous structure, from the North's perspective, that co-opts developing-country scientists into open access systems. The INSDC induces Southern scientists to prioritize career interests over national interests through the ways in which it (and research funding) is linked – by policies – to scientific fundraising and publication. South scientists are effectively forced to use the INSDC in order for their work to appear in leading journals. And many types of funding from Northern governments and philanthropic groups are conditioned on use of open access.

The funding and publishing situation can place a South scientist's career ambitions in opposition to her country's national interests. This coercive aspect is, in the view of open access advocates, a feature and not a bug. And it will likely remain problematic for countries managing DSI bilaterally.

This implies a number of needs in each country seeking to manage a significant part of its biodiversity bilaterally, such as:

- National capacity to collect and curate bDSI
- Secure national bDSI storage and hosting
- An access portal with basic query tools
- Legal resources (laws and lawyers) in place to execute and potentially enforce mutually agreed terms (MAT)
- Reckon with the impacts on scientific collaboration and have a strategy to respond to unauthorized bDSI release
- Have a strategy for issues raised by open access to DSI from *ex-situ* specimens
- Ability to pay for the above and, for the effort to be economically sensible, ensure that the system will generate additional revenues to support national conservation efforts.

Each of these aspects of implementing an effective bDSI management system is discussed below.

National capacity to collect and curate bDSI is variable. Some developing countries, particularly larger ones, have significant expertise and relevant resources. Many others do not. The ability to collect bDSI at scale requires a domestic sequencing capacity, or trustworthy foreign service providers under contract. In the context of a bilateral system, an effective collection system will need to extend to most, maybe all, persons in the country performing biodiversity sequencing (and their collaborators). This growing (in most countries) number of persons will need to have authority to place DSI in the system, understand applicable protocols, and have a willingness to follow them, bearing in mind that bDSI, at present, cannot be published in major journals (a disincentive to international academic collaboration) without being deposited in an open access database (which defeats the bilateral purpose).

The collection of sequences, however, may not be as hard as curation of bDSI at a level that will make it an attractive resource for commercial users. Effective curation is a massive problem of making sense of the order and then the function of billions of sequence reads that usually come, at least initially, in a disorganized jumble of tiny pieces. Doing so well may require international cooperation among groups sharing knowledge, for example among experts in the genomic structure of a particular genus. National researchers may sequence an organism, or part of it, but only be interested in or able to fully assemble part of it… what happens to the rest?

Bioinformatics tools are poised to, over time, lighten the load of assembly and annotation, but countries wishing to pursue bDSI collections should consider if they have the requisite national technical and scientific capacities to collect and organize their bDSI well enough for their resources to attract enough value in benefit sharing to make the effort worthwhile.

Countries that seriously pursue bDSI policies will require secure national bioinformatics facilities. Economic espionage is a reality, and governments at all levels are routinely targeted by electronic attacks, for example so-called “ransomware”, seeking to extort payment to restore access to, or prevent publication of, important government information resources.

There is reason to believe that bDSI sets could be the target of such attacks, particularly if the bDSI is known to be economically valuable. Keeping a backup won’t help in the case of bDSI, because its publication (due to inability or unwillingness to pay a hacker ransom) will impair its economic value for the country. A few keystrokes and a darkweb page could undermine many person-years of effort.

Quantum computing even threatens to bring about an age, maybe only a few years from the present, in which a handful of countries and well-equipped companies will have unprecedented access to the secrets of others. But air gapping a bDSI collection – that is, maintaining it disconnected from the internet for security reasons – would present an insurmountable panoply of practical problems for using it to support conservation and sustainable use.

Some developing countries may have national bioinformatics resources presently able to protect bDSI from attacks, though none is 100% secure, while other countries have no such capability. There will always be a degree of vulnerability of bDSI to hacking, and all countries that pursue a bilateral access model will need to develop the means to protect bDSI from unauthorized access. Countries should consider the relevant capacities and costs.

bDSI collections will require an access portal with basic query tools, which isn’t as easy as it might sound. Though some claim artificial intelligence will change this, at least for the time being, every information set needs an index so that it is a collection rather than an accumulation. Few customers will pay much for an unknown item. So where to draw the line on what information to provide about bDSI prior to requiring a user to enter into a binding commitment? And will your line be one the potential user will accept?

A feature of relevant emerging technologies is that value in DSI is frequently unlocked through broad comparison. That is, the answer to a problem in one location might be found by looking in completely unanticipated places, or might be devised by learning from a large and disparate set of information sources. One organism's solution to a problem in one context might be a basis – in a way not anticipatable by conventional wisdom – to a different problem in a separate context. If your solution might be found anywhere, it may affect the cost and restrictions you'll accept on a particular data set.

By the same token, it remains entirely possible to make commercial discoveries by a more traditional path, e.g., "let's look for resistance to disease, or other useful traits, in the sequence information of a diverse set of relatives of this plant".

Tools can make a database. For instance, GISAID, the influenza and coronavirus sequence database that is not open access, has become popular among academics and public health labs not only for its terms and conditions designed to protect the personal career interests of depositors, but also because of the analytic tools it offers. It is no accident that GISAID's management aggressively confronts any other public genomic tool that uses information from the database with strident demands that GISAID be prominently recognized. If GISAID were to decisively lose the "tool war", then its stature and attractiveness to users would decline.

The above hopefully illustrates the contradictions that bDSI managers will face. Value becomes apparent through tools and broad comparison, but once bDSI hits those tools, at least some of its value can't be recalled. At the same time, bDSI's value isn't apparent when it stands alone in a silo. And as "open" data grow, all the while being sucked up into private analytic systems (e.g., use of the "flat file"), large-scale bDSI users will be primed to argue that the gain of adding relatively small national bDSI data sets to the whole is marginal, trying to leverage bDSI access on the cheap.

Opening access to a large amount of metadata about bDSI may be tempting, as it could imply value, but could also impair the rights of indigenous peoples, as information about locations (e.g., soil type) and morphological characteristics, for instance, might reveal traditional knowledge. It might also facilitate the location of similar bDSI from alternative sources.

Yet if little or nothing is revealed about bDSI, and particularly if it cannot be used with analytical tools without a benefit-sharing commitment, and still further if there are concerns about its curation, then the value of bDSI to a potential user will be unclear, and this may reduce demand for access.

Pursuing bDSI policies means that **legal resources must be in place to execute and potentially enforce MAT**, in other words, laws and lawyers. This may be one of the lesser hurdles for bDSI, particularly executing access contracts, a matter which many countries now have experience with, but enforcement for bDSI, as opposed to physical genetic resources, may be trickier. If a patent is derived from use of thousands of disparate sequences, might it not be relatively easy for the patent holders to persuade a court that any single one was trivial to the process? Or that the value of an invention is imparted by a proprietary analytic tool and not the DSI that the tool uses as its fuel?

And while there are exceptions, if one looks in general at the history of the ability of developing-country courts to effectively impose, and ultimately enforce, sanctions against multinationals in the realm of ecological and biodiversity crimes (think of the oil industry, for instance), the track record is not encouraging. And this is assuming the crime is detected in the first place, which is far from a given considering how DSI is used.

Related to MAT enforcement, and to curation, **countries will need to reckon with the impacts on scientific collaboration and have a strategy to respond to unauthorized bDSI release into open access databases.**

Contemporary science often involves collaborations across borders, and funding for studies from Northern sources encourages or even mandates (through contract obligations) the placement of DSI into open access databases. This is a problem for developing countries' regulation of bDSI because it may limit the ability of national scientists to participate in international collaborations, and/or reduce the attractiveness of a country's scientists and scientific institutions as partners.

Countries wishing to exert bilateral control over large parts of their DSI will face internal pressures to reverse course as their scientists seek collaboration, and feel pressure to waive bDSI controls in the interest of acquiring research funding, which will generally be consumed in the course of the activity itself. (This is arguably a benefit, but one unlikely to have broader conservation and sustainable use impacts, and which probably won't capture a share of any related commercial benefits.)

Separately from the question of DSI from *ex-situ* collections (see below), countries will need a strategy to deal with unauthorized release of bDSI into open access databases, or even privately to foreign users. Of note, this will require monitoring of open access databases in order to identify problems.

Countries will need a strategy for issues raised by open access to DSI from *ex-situ* specimens. By restricting bDSI for endemic species, and likely species with diversity that are more widespread but are especially interesting within their borders (for example, tomato wild relatives aren't unique to Ecuador, but collections from the Galapagos Islands have yielded a variety of valuable genes), countries will encourage the sequencing and placement in open access databases of specimens of their diversity found in *ex-situ* collections. Why pay if it's available somewhere else for free?

Importantly, DSI may come from "dead" sources, such as herbaria and entomology collections, where some preserved specimens, while not viable, contain recoverable whole or partial genomes. Thus, the problems posed by *ex-situ* collections, which are familiar to anyone that follows access and benefit-sharing issues, are substantially bigger for DSI than for physical genetic resources because of the ability to extract sequences from non-living samples.

The plans of the Earth BioGenome Project (EBP), which aims to sequence every eukaryotic species, are indicative of the threat. Seeking money from funders to get underway in earnest, the EBP does not describe having entered into agreements with providers, but rather, it touts its intent to mine *ex-situ* collections, including "hundreds of thousands of samples, maintained with the latest genome-preservation technology, 'shovel-ready' for this project", that are held by the Smithsonian Institution, a US government entity. And the EBP is prepared to fund sequencing of these samples by giving the work to a private company, and to give that private company a right of refusal on commercial applications (an arrangement sought by sequencing companies elsewhere as well).

Other natural history museums and *ex-situ* collections, like the Australian Museum, Kew Gardens, and the University of Florida (specialist in the neotropics), are joining the EBP's effort. Not all but some of the potential economic value of endemic species' DSI will be erased by projects like the EBP that sequence *ex-situ* genomes and place them in open access databases.

How to deal with the particular problems *ex-situ* collections pose? In a purely bilateral system, there are few options. If CBD Parties opt for a "hybrid system", this will be a particularly thorny problem that must be addressed for bDSI systems to be successful.

Finally, for the effort to be sensible at a level beyond assertion of national pride or neocolonial resistance, **bDSI systems must be able to pay for all of the above and generate additional revenues to support national conservation efforts** – which is the objective, in line with the CBD, after all. This observation needs little explanation. Managing DSI bilaterally will generate significant costs and ongoing administrative and technical burdens for developing countries, and the benefits derived from doing so need to outweigh the costs.

The Smithsonian Institution's Entomology Collection contains more than 33 million specimens, only about 1% of which appear in its online inventory. Due to age and storage conditions, not all will yield DSI, but technology to extract such information is improving. Years ago, Natural History collections began to deliberately preserve some specimens in ways that facilitate DSI extraction.

It might be argued that non-monetary benefits would be significant in a hybrid system, for example, bargaining for access to analytic resources in return for bDSI. But such access would be very unlikely to include cutting-edge bioinformatics used by corporations, and it is very hard to quantify such benefits, the value of which ultimately may depend on other national policies (i.e., how well a country's scientific establishment is oriented to support national biodiversity conservation).

Similarly, restricting access to DSI could be interpreted as a policy with parallels to that of keeping oil in the ground, with a goal of preventing damage now and preserving a national resource until a time when it might be better used to benefit a country, if ever. It might even, for biotechnology skeptics especially, be part of a broader statement about the relationships between technology and conservation. But "keeping DSI in the forest" means it can't be utilized to generate revenues for conservation.

Such motivations are an incomprehensible calculus to those with implicit faith in technology, but even technophiles should admit that there is no evidence that biotechnology has solved or will solve the world's biodiversity loss problems in any significant measure. In fact, one of the few bright spots in biodiversity conservation, that of indigenous peoples' lands, depends on almost wholly different knowledge systems, values, and technologies than those that impel projects to sequence the world. Maybe it is those systems that should be most strongly supported by DSI monetary benefit sharing.

Conclusion

The author hopes it is clear that it is quite uncertain if many developing countries will be able to effectively implement bDSI systems whose benefits outweigh their costs. In this light, it would be best to pursue a multilateral benefit-sharing system for DSI that directs its monetary benefits to indigenous peoples and local communities and that is substantially governed by them, in collaboration with national governments.

Such a system should be based on fixed, periodically revisable, contributions summing several hundred million US dollars in annual monetary benefit sharing paid to an international fund, which would be directed towards fortifying and deepening the development of the knowledge systems and practices that are proving most effective in biodiversity conservation and sustainable use.

But if bilateral management of DSI, including hybrid systems, is to be the result of the CBD's work on DSI, then what would a developing-country bilateral agenda look like at the CBD?

At a technical level…

- Development of model contracts and options for terms and conditions for access to bDSI.
- Identify / develop / adapt curation practices for use by developing countries and that are, preferably, technically compatible with those of potential users.
- Identify / develop / adapt basic search and analytic tools for national bDSI sets that enable "showing off the wares" without "spilling the beans".
- Review and advise on information security practices for bDSI.
- Study potential interoperability of bDSI systems among provider countries.

In the policy realm…

- Urgently initiate consideration of the access and benefit-sharing issues posed by DSI from *ex-situ* collections, including the larger set of non-living collections that have previously scarcely been considered in this context.
- Evaluate the benefit-sharing impacts of the lack of controls on provenance of DSI uploaded into INSDC and similar databases.
- Develop guidance for international science funders on avoiding incompatibility between research they sponsor and the national bDSI policies and laws of provider Parties.

Thus a bilateral agenda will be difficult and challenging for developing countries, especially smaller countries with fewer resources and capacities. A multilateral system with an agreed minimum fixed annual financial benefit, substantially directed to indigenous peoples and sufficient to effect real change in conservation outcomes, is still preferable as well as "efficient, feasible and practical" as Parties have discussed.

But if countries want to pursue a bilateral DSI agenda, they should go in with eyes wide open, and be fully cognizant of the substantial demands that such an agenda entails.

For the North, a shot of transparency about the economic value of DSI would be helpful for the honesty that it would hopefully engender, as would being more forthright about the inequities of the status quo. It is plain to see that those inequities threaten to create a world in which a large proportion of DSI is locked behind "paywalls," which isn't in the long-term interest of the North's corporations or of its scientists.

Short-term thinking, stimulated by a self-interested industry with undue influence on Northern policy, encourages postponing or even altogether avoiding, if possible, acceptance of the need to provide truly substantive financial benefit sharing so that DSI can remain publicly accessible and all three objectives of the CBD are served. But by refusing to change course now and come to the table with a serious offer, the North takes a grave risk of accelerating bilateral processes that may end with a chaotic DSI access and benefit-sharing situation which will benefit few over many and which is unlikely to have the conservation – and economic – benefits that serious funding of a multilateral system could.

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