Fairness, Equity and Efficiency for the Convention on Biological Diversity and the Nagoya Protocol:

Analysis of a Rodent, a Snail, a Sponge and a Virus

Sociedad Peruana de Derecho Ambiental (SPDA) / Peruvian Society for Environmental Law
The ABS Capacity Development Initiative

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To friends and family
who succumbed to COVID-19

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Disclaimer

The opinions expressed herein do not necessarily reflect institutional affiliations of the authors of the case studies or the position of The ABS Capacity Development Initiative.

Executive summary

"No matter how long you have gone down the wrong road, turn back", says a Turkish proverb. The pivot for "access and benefit sharing" (ABS) of the Convention on Biological Diversity (CBD) was the First Global Dialogue on Digital Sequence Information on Genetic Resources, held from 6-8 November 2019 in Pretoria South Africa. Some 65 participants from 27 countries met to discuss alternative modalities to bilateralism. A ground rule for the discussion was that no topic would be taboo. We interpret the rule as applicable to a multilateral benefit sharing proposal already in the literature.

At the Dialogue, anxiety ran high among those who identified with either Users or Providers. The bilateral approach of ABS to dematerialized genetic resources would severely encumber both public and private science. Yet non-compliance with the CBD would gut ABS and frustrate conservation and sustainable development. With 1600 + databases extant worldwide, participants realized that "digital biopiracy" was as easy as a click

Breathtaking has been the pace of the larger discussion which led to Pretoria. "Digital Sequence Information" (DSI) was first uttered in 2015 and only debuted at the thirteenth Conference of the Parties (COP13) in 2016. By 2018 at COP14, the Parties had institutionalized the placeholder as the subject for commissioned studies on Traceability and Databases (denoted #2&3) and on Domestic Measures (#4). The original quotation marks around DSI vanished in texts as did the modifier "placeholder" in speech. The cart was not only in front of the horse, but out of sight. Much of this Report reigns in that horse and repositions the cart. Stakeholders, Parties and the AHTEG have rejected DSI on solid grounds; yet the term is strangely resilient. We reject DSI for the same reasons as has everyone else plus a simple Darwinian one: a broader yet more discriminating term exists for the object of access in R&D. We shall address that point in detail.

The timing of our Report is fortuitous. The psychology of *stare decisis* – stand by precedent – has lost its grip on ABS. How should reasoning proceed in interpreting and drafting treaty language? To date, the COP has endorsed the inductive method, where successful cases of bilateral agreements are sought. Hope remains perennial that cases can be found and lessons learned for replication elsewhere. The method has failed spectacularly, but not for lack of effort. Deductive reasoning explains the impossibility of the endeavor. Even the best case for bilateralism supports the need for a Global Multilateral Benefit-Sharing Mechanism, which was the title of the view submitted by the Sociedad Peruana de Derecho Ambiental (SPDA) to the UNSCBD in 2019.

After the historic pivot in Pretoria, what should be the next step forward? We recommend that the Parties reaffirm the nature of the CBD and Nagoya Protocol (NP) as framework agreements. Decisions made at the COP can be revisited and reversed. The adoption of an alternative modality to bilateralism could even include a return to the "Common Heritage of Mankind" (Modality 5), which is just as much an expression of sovereignty as is the bilateral approach.

On the road back to treaty language, theory is fuel. The objectives of the CBD and NP lend themselves to economic thinking, which is not evident in the Decisions on ABS. The main reason lies in something seemingly small: the interpretation of "material" as matter in Article 2 of the CBD. Economists who have deferred to that misinterpretation must own up to their mistake (e.g. TEEB: The Synthesis Report). Treating intangibles as tangibles has led to competition, and the competition to "peanuts" being paid in agreement after agreement for almost 30 years. The object of access for R&D is natural information, even when the genetic resource cannot be dematerialized. The abstraction of economics becomes powerful.

This Report rests on correcting the category mistake over the interpretation of "material". The correction is, however, just the beginning of where economics can take us. A triad of abstractions justify multilateralism. They are "rents, excess burden and fungibility". Most readers will now pause. These terms require an understanding beyond what can be gleaned from the Lexicon to this Report (Appendix IX). They require stepwise explanation. How do we entice the reader to read the Full Report?

No one picks up an Economics textbook for fun. The challenge has been to write a narrative about ABS while applying "rents, excess burden and fungibility". We want the story to entertain. Partly for that reason, we have adopted cases despite our original disinclination to do so. We were pleased to discover that the cases can fire imagination and provide insights. We recall that division of labor was the first chapter of *The Wealth of Nations* (Adam Smith 1776). The authors of the four studies (Appendices I – IV) have distilled facts about each case according to a template (Appendix V). The SPDA Research Team then explored three or four ABS issues for each case in the Full Report. Patterns emerged for cases as wildly diverse as the naked mole-rat, sea snails, a Caribbean Sea sponge and the Ebola virus.

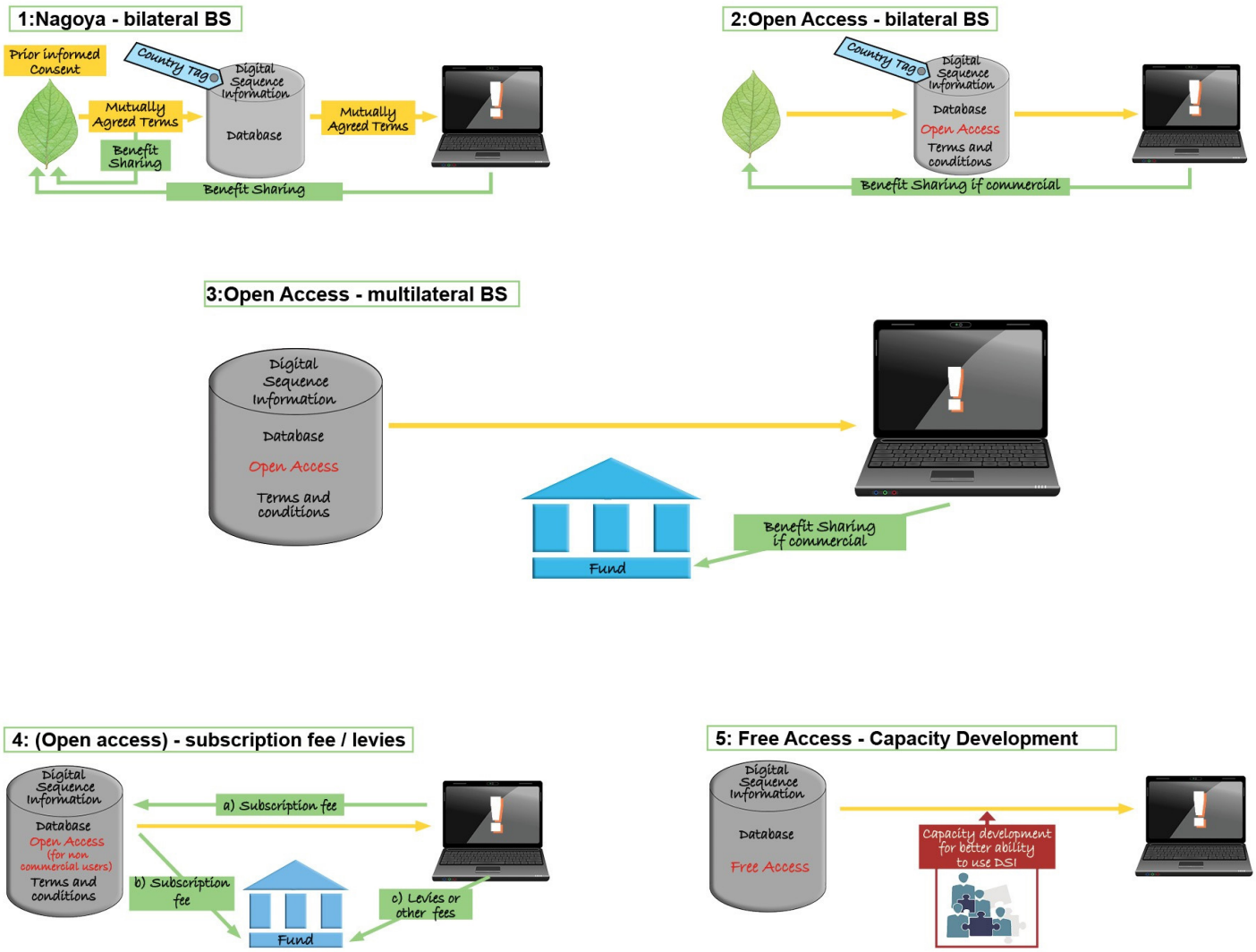
For the rat, snails, sponge and virus, the best modality turns out to be the same one. In other words, one modality meets the criteria of efficiency and equity. This modality is Variant Two of Modality 3 "Open Access – Multilateral", known in the literature as "bounded openness over natural information".

A caveat is in order which provides a preview of our general thesis. Comparisons are necessary. Other variants of Modality 3 exist. They include: "common pools", "Mare geneticum" and Option 2 of "Finding Compromise on DSI & ABS" of the WiLDSI Project. None of the variants contemplates the fairness and equity of rents, which is core to our argument. "Common pools" allows competition among the pools. Mare geneticum imports the royalty percentage observed in bilateral agreements. And Option 2 suggests royalties as low as 0.01%. Crunch the numbers: on the rare, blockbuster, billion dollar-a-year biotechnology product, the royalty would be a paltry $100,000. Why bother at all with ABS?

The asymmetry of fixed and marginal costs for information justify rents, which are payments beyond what would occur in a competitive market. Proposals on ABS which do not address rents are unfair, inequitable and inefficient. A royalty of 0.01%, 0.1% or even 1% does not incentivize conservation. How much should the percentage be? Public Finance deals with that question by examining the price elasticity of demand and deploying the Ramsey Rule to minimize excess burden. If the sentence you just read seems esoteric or abstruse, the Full Report explains the economics step by step. Likewise, we broach one topic which is never discussed at the COP: fungibility. Again, the Report explains technical terms by bridging law, biology and economics. Psychology is also not left out.

In the end, the whole point of this Report is to change the system (the enduring advice of a German philosopher who will go unnamed). Policy implications must be rendered into recommendations and the recommendations, into legislation. Appendix VI is a "Legal Elements for the 'Global Multilateral Benefit-sharing Mechanism' as contemplated in the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization".

Policy Options
Center front is the ABS modality which best achieves fairness, equity and efficiency



The needle has moved. The five images above are reproduced from the Report of the Global Dialogue on Digital Sequence Information held in Pretoria, South Africa from 6-8 November 2019. The original representations were equally sized. Economic analysis has demonstrated that the most unfair and inefficient is the "Nagoya – Bilateral Benefit Sharing" bilateral approach of Figure 1. "Open Access – Bilateral" of Figure 2 is slightly less unfair and inefficient. "Open Access – Subscription Fee / Levies" of Figure 4 would improve fairness but is highly inefficient. "Free Access – Capacity Development" of Figure 5 does not adress the opportunity costs of conservation.

Only "Open Access – Multilateral BS" of Figure 3 leaves hope. Fairness and efficiency can be coincident if and only if economic rents are designed into the modality. Its variants currently number four: "bounded openess over natural information", "common pools", "Mare Geneticum" and "Option 2 of the WiLDSI Project". Only boundet openness is grounded in rents.

Recommendations

Equity is not in tradeoff with efficiency. The fortuitous outcome is reason for hope. An alternative modality to "Nagoya-Bilateral BS" can achieve both equity and efficiency. An overarching recommendation is education of economic concepts, which may be novel to stakeholders and delegations. Capacity building should also be redirected away from implementing the bilateral approach and to discussion of the *status quo* vis-à-vis the alternatives. Everyone should give pause to ongoing endeavors of implementation. The existence of national legislation regarding "Nagoya-Bilateral BS" only means that the treaty is in force. Operability remains elusive.*

a. A multilateral ABS regime must be informed by peer-reviewed literature just as the peer-reviewed literature is itself informed by the peer-reviewed literature. Rather than a brokered policy riddled with gaps, loopholes and contradictions, the framework should address the two dozen issues identified and tabulated in this Report.

b. Application of the inductive method to design the ABS Modality is a fool's errand. Relevant experiences do not exist for genuine inspiration much less simulation. ITPGRFA, UNCLOS and WHO reflect distinct trajectories, which also struggle with ABS.

c. Cases tweaked into thought experiments illuminate the advantages and disadvantages of alternative modalities to "Bilateral – Nagoya Protocol". Recalcitrant Parties, institutions and stakeholders should contemplate royalty percentages of 0.1% in the most biodiverse country on the planet. Biotechnology is an almost trillion USD/year global industry. Why does the academic literature characterize the benefits as "peanuts"?

d. The choice of modality should not require exactness in either the valuation of genetic resources or the costs of implementing an alternative modality. Two crucial questions suffice: Does probable cause exist that a given modality will cover the costs of implementation? Which modality will most likely achieve the first two objectives of the CBD?

e. Only Modality 3-II (Bounded openness over natural information) and Modality 4 (Open access – subscription fee / levies) afford rents. However, the latter generates heavy excess burden. Two tasks await Modality 3-II: identification of the classes of utilization and estimation of the elasticities for each of the most revenue-generating utilizations. The Ramsey Rule of Public Finance becomes the ideal for the minimization of excess burden. However, under Modality 3-II, the royalty percentages are negotiated by Users and Providers as groups. Once Providers are no longer atomistic suppliers of genetic material, the economist can bow out.

f. Retroactivity is the Gorgon we must look in the face. Modality 3-II requires a grand bargain whereby all collections prior to the 1993 ratification of the CBD hold a status equivalent of one Provider in the benefit-sharing of royalties for specimens.

g. The Nagoya Protocol should be amended.

*Our interpretation disagrees with the Global Biodiversity Outlook whereby Aichi Target 16 is "considered partially achieved" and that the NP is "now fully operational", UN CBD Secretariat (2020): 11. Available at www.cbd.int/gbo/gbo5/gbo-5-embargo-en.pdf

Full Report

Fairness, Equity and Efficiency for the Convention on Biological Diversity and the Nagoya Protocol:

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Sociedad Peruana de Derecho Ambiental (SPDA) / Peruvian Society for Environmental Law

Prepared for The ABS Capacity Development Initiative

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List of Acronyms

ABS	Access and benefit sharing
ABNJ	Areas beyond national jurisdiction
AZD	Azidothymidine
BSA	Benefit-Sharing Agreement
CBD	Convention on Biological Diversity
CML	Chronic myeloid leukemia
COP	Conference of the Parties
DAA	Data Access Agreement
DNA	Deoxyribonucleic acid
DSI	Digital sequence information
EEZ	Exclusive Economic Zone
GISAID	Global Initiative on Sharing All Influenza Data
GMBSM	Global Multilateral Benefit-Sharing Mechanism
GS	Gene sequences
INSD	International Nucleotide Sequence Database
IP	Intellectual property
IPFMA	International Federation of Pharmaceutical Manufacturers Association
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
MAT	Mutually agreed terms
MTA	Material Transfer Agreement
NDC	Nationally determined contributions

PIP	Pandemic Influenza Preparedness Framework
PLS	Public Library of Science
RCP	Regional common pools
R&D	Research and Development
TKI	Tyrosine kinase inhibitors
TRIPS	Trade related Aspects of Intellectual Property Rights
SPDA	Sociedad Peruana de Derecho Ambiental (Peruvian Society for Environmental Law)
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
ZVD	Zidovudine

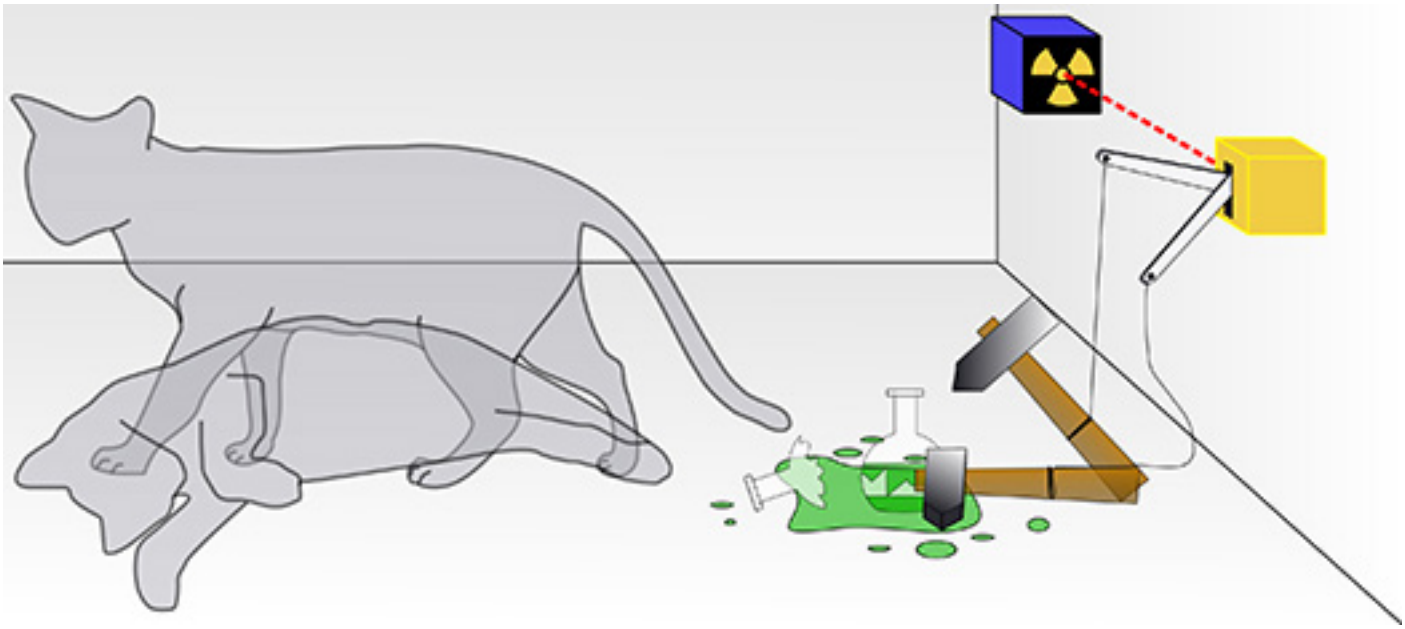
Foreword

Our intended audience are stakeholders and delegates to the Conference of the Parties to the Convention on Biological Diversity and Nagoya Protocol (COP). Few are degreed economists; yet economics is fundamental to resolving "access to genetic resources" and the "fair and equitable sharing of benefits arising [from their] utilization" (ABS). The naturalist E.O. Wilson has quipped that physics is difficult even for physicists. We would claim that something similar holds for economics. In this Report, we have tried to make the economics as simple as possible, which is no mean feat. As readers will see, economists can hold opposite opinions about ABS. The opposition can be traced to distinct premises, which thus makes philosophy a prerequisite for the discussion. To deploy deductive reasoning, we tweak cases of access and utilization with what could have been. Information about what actually happened can be found in the case studies of the Appendices. We repeatedly ask "What if?" The thought experiments enable analysis.

In the continuum from a popular account to an academic paper, this Report tilts toward the latter. Our justification is practical. To persuade the Conference of the Parties that modalities must be vetted for fairness, equity and efficiency, a modicum of rigor is indispensable. Nevertheless, we recognize that the abstractions can scaffold and the supporting information, overload. We felt that a lexicon was necessary for technical terms with non-obvious meaning. These terms appear in bold with their first use. The highly abstract concept of excess burden even warrants its own box. We also felt that a filmography would help the reader contextualize the issues. Analysis of each case is preceded by six key messages in bullets.

The Executive Summary compresses the thesis of the Full Report: fairness, equity and efficiency are fortuitously coincident. The Recommendations are written to stand alone. The framework nature of the Convention on Biological Diversity and the Nagoya Protocol makes possible the amendments proposed in Appendix VI.

The SPDA Research Team, 18 October 2021



What could have been: Schrödinger's cat

Source: Dhatfield, CC BY-SA 3.0 via Wikimedia Commons)
https://common-s.wikimedia.org/wiki/File:Schrodingers_cat.svg

Abstract

Fairness, Equity and Efficiency for the Convention on Biological Diversity and the Nagoya Protocol: Analysis of a Rodent, a Snail, a Sponge and a Virus

Peruvian Society for Environmental Law / Sociedad Peruana de Derecho Ambiental (SPDA)

Analogical, inductive and deductive reasoning are applied to "access and benefit sharing" (ABS) in the 1992 United Nations Convention of Biological Diversity and 2010 Nagoya Protocol. Presented are the implications of economic reasoning, largely deductive, for five distinct modalities for the Global Multilateral Benefit-Sharing Mechanism. To illustrate the implications for "digital sequence information", case studies about a rodent, a snail, a sponge and a virus are tweaked into thought experiments. The modality of "bounded openness over natural information" best achieves fairness, equity and efficiency for ABS. Recommendations include language for a twenty-five-article amendment to the Nagoya Protocol.

Keywords: Access and Benefit-Sharing, Global Multilateral Benefit-Sharing Mechanism, Digital Sequence Information

French

Justice, équité et efficacité pour la Convention sur la diversité biologique et le protocole de Nagoya : l'analyse d'un rongeur, d'un escargot, d'une éponge et d'un virus

Peruvian Society for Environmental Law / Sociedad Peruana de Derecho Ambiental (SPDA) /Société Péruvienne de Droit de l'Environnement

Résumé

Un raisonnement analogique, inductif et déductif est appliqué à "l'accès et au partage des avantages" (APA) selon la Convention des Nations unies sur la diversité biologique de 1992 et le protocole de Nagoya de 2010. Les implications d'une analyse économique, principalement déductive, sont présentées pour cinq modalités distinctes du Mécanisme mondial multilatéral de partage des avantages. Pour illustrer les implications relatives au "séquences numériques d'informations", des études de cas ont été conduites sur un rongeur, un escargot, une éponge et un virus. Elles servent ensuite à des expériences de pensée. La modalité de "l'ouverture limitée sur l'information naturelle" est celle qui permet le mieux d'atteindre l'équité, la justice et l'efficacité en matière d'APA. Les recommandations correspondantes comprennent la proposition d'un amendement de 25 articles au protocole de Nagoya.

Mots-clés : Accès et partage des avantages, Mécanisme multilatéral mondial de partage des avantages, séquences numériques d'informations

Portuguese

Justiça, Equidade e Eficiência para a Convenção sobre Diversidade Biológica e o Protocolo de Nagoya: Análise e estudos de casos de um roedor, um caracol, uma esponja e um vírus

Peruvian Society for Environmental Law / Sociedad Peruana de Derecho Ambiental (SPDA) / Sociedade Peruana de Direito Ambiental

Resumo
Raciocínio analógico, indutivo e dedutivo são aplicados ao "acesso e compartilhamento de benefícios" (ABS, em sua sigla em inglês) da Convenção da Diversidade Biológica das Nações Unidas de 1992 e ao Protocolo de Nagoya de 2010. Apresentase neste estudo as implicações do raciocínio econômico, em grande parte dedutivo, para cinco modalidades distintas do Mecanismo Global Multilateral de Partilha de Benefícios. Com o objetivo de ilustrar as implicações referentes à "informação digital sobre sequências", em estudos de caso sobre o roedor, o caracol, a esponja e o vírus em questão, realizaramse afinados exercícios intelectuais aplicados a esses organismos. A modalidade de "abertura delimitada sobre informação natural" surge então como melhor alternativa para alcançar a justiça, equidade e eficiência para ABS. Incluemse neste estudo recomendações para a alteração da linguagem presente em 25 artigos do Protocolo de Nagoya.

Palavras chave: Acesso e Compartilhamento de Benefícios, Mecanismo Global Multilateral de Partilha de Benefícios, Informação de Sequência Digital

Spanish

Justicia Equidad y Eficiencia para el Convenio sobre la Diversidad Biológica y el Protocolo de Nagoya: Análisis de un roedor, un caracol, una esponja y un virus

Sociedad Peruana de Derecho Ambiental (SPDA)

Resumen
El razonamiento analógico, inductivo y deductivo se aplican al "acceso a los recursos genéticos y participación en los beneficios" (ABS) del Convenio sobre la Diversidad Biológica de 1992 y el Protocolo de Nagoya de 2010. Se presentan las implicaciones del pensamiento económico, mayormente deductivo, para modalidades diferentes para un Mecanismo Mundial Multilateral de Participación en los Beneficios. Para ilustrar las implicancias para las "información digital sobre secuencias" secuencias genéticas digitales", estudios de caso sobre un roedor, un caracol, una esponja marina y un virus se manipulan para generar experimentos mentales. La modalidad de "apertura delimitada sobre la información natural" es la que alcanza la equidad, justicia y equidad para ABS. Las recomendaciones proponen una modificación de 25 artículos al Protocolo de Nagoya.

Palabras claves: Acceso a los recursos genéticos y participación en los beneficios, Mecanismo Mundial Multilateral de Participación en los Beneficios, información digital sobre secuencias

Introduction

The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD, 1992) and the Nagoya Protocol (2010) will determine the modality for "access to genetic resources" and the "fair and equitable sharing of benefits arising [from their] utilization" (ABS). The choice of modality will be expressed through a Decision by the COP. Because both treaties are framework conventions, previous Decisions can be revisited and even reversed. Reasoned arguments should drive the open-ended discussions forward. [1]

At COP14 in 2018, many Users insisted that genetic resources are tangible in the legal context of ABS.[2] Providers and stakeholders disagreed and some, vehemently. Scientists who enter the discussion *in media res* may have been left non-plussed. As a matter of science, Research and Development (R&D) adds value to the informational dimension of genetic resources, whether the resource was dematerialized or not.[3] A trend, however, is clear: genetic resources are increasingly dematerialized.[4] Some 1600 biological databases now exist and more will appear in the near future.[5] Some Providers decry that open access to all this data constitutes "digital biopiracy"[6] (Box 1). The Users shudder.[7] Will **Prior Informed Consent** (PIC) and Benefit-Sharing Agreements (BSA) be required for every sequence downloaded?[8] What should be the modality of ABS? Perhaps no issue before any of the COPs has ever been more consequential for the CBD. Resolution of the controversy requires that all options be vetted.

Box 1.

"Digital biopiracy"

"While biopiracy has conventionally meant the physical removal of a material from a community into private hands, synthetic biology enables digital biopiracy, where the DNA of an organism is sequenced *in situ*, uploaded to the Internet as information, and then transferred digitally to a DNA synthesizer so that copies can be rebuilt elsewhere. Such digital transfer of DNA 'code' does not even require a Material Transfer Agreement (since no material is transferred). Yet, the technology allows corporations, governments and individuals to take genetic information and use it to create new synthetic organisms, which can then be patented as inventions. While synthetic biologists talk of inventing DNA from scratch, in reality, most genetic parts developed for synthetic biology are derivatives of natural stretches of genetic code that are then 'evolved' through computer models".

Source: ETC Group, Synthetic Biology: Creating Artificial Life Forms - Briefing and Recommendations for CBD Delegates to COP10 (October 2010): 3. Available at http://www.etcgroup.org/files/publication/pdf_file/ETC_COP10SynbioBriefing081010.pdf.

To begin the process of vetting, one may start with Article 1 of the CBD.[9] The three objectives of the treaty are conservation, sustainable use and the fair and equitable sharing of benefits arising from the utilization of genetic resources. They are interrelated in a fashion that is largely unappreciated. Appearing as the third objective, benefit

1 Under Article 23 (Conference of the Parties) of the CBD, the COP may not only "(d) consider and adopt, as required, in accordance with Articles 29 and 30, amendments to this Convention and its annexes"; but also "(i) Consider and undertake any additional action that may be required for the achievement of the purposes of this Convention in the light of experience gained in its operation." Interpretations thus evolve according to circumstances and COP Decisions, primarily guided by the recommendations of the SBSTTA and SBI.

2 See, for example, International Chamber of Commerce, Digital Sequence Information and Benefit Sharing, ICC Submission to the CBD (2019). Available at https://iccwbo.org/content/uploads/sites/3/2019/06/icc-submission-to-cbd-digital-sequence-information-benefit-sharing.pdf

3 S. Laird, et al., "Re-thinking the Expansion of Access and Benefit Sharing," *Science vol*. 367, issue 6483 (13 March 2020): 1200-1202. DOI: 10.1126/science.aba9609.

4 The World Economic Forum classifies the current era, in which data and technology capabilities combine the digital, physical and biological realms, as "The Fourth Industrial Revolution". See, World Economic Forum. Harnessing the Fourth Industrial Revolution for Life and Land. Towards and Inclusive Bioeconomy, Fourth Industrial Revolution for the Earth Series, (January 2018): 2. Available at http://www3.weforum.org/docs/WEF_Harnessing_4IR_Life_on_Land.pdf

5 D.J. Rigden and X.M. Fernandez, "The 26th Annual Nucleic Acids Research Database Issue and Molecular Biology Database Collection", *Nucleic Acids Res* vol. 47, issue D1 (2019,): D1-D7. DOI: 10.1093/nar/gky1267.

6 E. Hammond,"Gene Sequences and Biopiracy: Protecting Benefit-sharing as Synthetic Biology Changes Access to Genetic Resources." Third World Network Briefing Paper (August 2017). Available at https://www.twn.my/title2/briefing_papers/No93.pdf

7 See, for example, "Response by the Wellcome Trust and Wellcome Trust Sanger Institute to the Call for Information by the CBD Secretariat: The Use of Digital Sequence Information in Genetic Resources" (8 September 2017). Available at https://wellcome.ac.uk/sites/default/files/the-use-of-digital-sequence-information-on-genetic-resources.pdf

8 K.D. Prathapan, R. Pethiyagoda, K.S. Bawa, and P.H. Raven and P.D. Rajan, P.D. and 172 co-signatories from 35 countries, "When the cure kills – CBD limits biodiversity research", *Science vol* 360 issue 6396 (2018): 1405 – 1406. DOI: 10.1126/science.aat9844

9 Article 1 of the CBD establishes that: "The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the *fair and equitable* sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding" (italics added). Available at https://www.cbd.int/convention/articles/?a=cbd-01

sharing is ostensibly an end. However, it is also a means to the first and second objectives.[10] Should the modality of ABS also show **efficiency** in the sharing of benefits, incentives could begin aligning between utilization of genetic resources and land use, i.e., for conservation rather than conversion.

Frustrating alignment are misconceptions: Users and Providers have long considered the **bilateral approach** as non-negotiable. Times have changed, however, with the advent of **"digital sequence information"** (DSI).[11] The consideration of a Global Multilateral Benefit-Sharing Mechanism (GMBSM) under Article 10 of the Nagoya Protocol now puts multilateralism on the table.[12]

The academic disciplines of negotiators matter in the discussions of ABS. Delegates and stakeholders are largely drawn from the legal and biological professions. After fourteen COPs and almost thirty years, the lawyers have become conversant in the language of biology, and the biologists in the language of law. Rarely are economists present.[13] Fortunately, most of the tools to grapple with ABS correspond to what is covered in introductory economics, which is often a prerequisite course in the law curriculum and an elective for biologists interested in policy.[14] Inasmuch as such exposure was probably a long time ago, most likely forgotten was the reason for studying economics: to hone critical thinking about efficiency.

10 Separation of the objectives leads to undesirable tradeoffs. For example, one could clear cut a rainforest to facilitate sampling of the canopy, thus forgoing conservation and sustainable use for benefit sharing. Independence of the objectives is not a reasonable interpretation of Article 1. Attempts to separate the objectives are an attack on the objectives themselves. The fact that all three objectives do not appear in distinct articles supports the interpretation of their interrelatedness.

11 Decision 14/20 of the CBD COP notes that "DSI" will be used as a placeholder until a better term is found. See, document CBD/COP/DEC/14/20, November 30, 2018. Available at https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-20-en.pdf. The placeholder status implies that the undefined DSI should not be used without quotation marks. However, aesthetics intervenes to remove them and biases discussion toward acceptance.

12 Article 10 of the Nagoya Protocol, Global Multilateral Benefit-sharing Mechanism, determines that "Parties shall consider the need for and modalities of a global multilateral benefit-sharing mechanism to address the fair and equitable sharing of benefits derived from the utilization of genetic resources and traditional knowledge associated with genetic resources that occur in transboundary situations or for which it is not possible to grant or obtain prior informed consent. The benefits shared by users of genetic resources and traditional knowledge associated with genetic resources through this mechanism shall be used to support the conservation of biological diversity and the sustainable use of its components globally". Available at https://www.cbd.int/abs/text/articles/?sec=abs-10

13 The 1996 Decision 391 of the Andean Community was the first ABS legal framework ever enacted. Available at http://www.sice.oas.org/trade/JUNAC/decisiones/DEC391e.asp. One suspects that less than a dozen of the 200 participants in the negotiations would have had a university degree in economics. The absence of economists is common. For example, of the 36 participants and 3 presenters at the Ad Hoc Technical Group on DSI (2020), not one was an economist. Among thousands of attendants at any given COP, the number of economists engaged in ABS discussions can be counted on one hand with fingers left over.

14 Most were probably taught from one of the nineteen editions of Samuelson, P. and Nordhaus, W., *ECONOMICS* 19th ed. (New York: McGraw Hill, 2009).

Box 2.

Reasoning in the Intertwined History of Thought in Economics and Biology

Inductive and Analogical:

Carl Linnaeus (1707-1778) demonstrates the enduring value of inductive reasoning. His *Systema Naturae* (10th edition) established the binomial system of nomenclature and hierarchical classification. Success in classification depends on identifying whether similarities among specimens are analogous or homologous.

Analogical and Deductive:

Charles Darwin used the metaphor "economy of nature" some thirteen times in *Origin of Species*.[a] Although inspired by economics, Darwin did not reason analogously. The relationship of biology to economics is homologous. Darwin credits "the doctrine of Malthus [*Essay on the Principle of Population*], applied to the whole animal and vegetable kingdoms".[b]

Inductive and Deductive:

John Maynard Keynes, the veritable Darwin of Economics, famously rehabilitated Malthus' observation of stagnation. But Keynes-first-the-mathematician was not satisfied with Malthus' induction. From observing that prices were rigid in the downward direction and that savings did not equal investment, Keynes deduced an equilibrium of unemployed resources.

Deductive and Reduction:

Paul A. Samuelson took the mathematics of post-WWII Economics to dizzying heights. Diminishing returns have long set into such micro-manipulations. The frontier of the discipline now goes "From Homo Economicus to Homo Sapiens."[c] Patterns of non-rational behavior are premises for which falsifiable hypotheses are constructed and tested. Should the new premises be deduced from evolutionary psychology, biology will also become the anti-discipline of economics. E.O. Wilson has advocated for just such reduction ever since Chapter 27 of the watershed *Sociobiology* published in 1975. One recalls that Keynes quipped that "animal spirits" explained the instability of investment.[d]

a Charles Darwin, *The Origin of Species* (London: John Murray, 1859). Available at http://www.gutenberg.org/files/1228/1228-h/1228-h.htm

b Ibid. "The doctrine of Malthus" appears, appropriately, in the Introduction and again in Chapter 3: Struggle for Existence.

c Richard H. Thaler, "From Homo Economics to Homo Sapiens", *Journal of Economics Perspectives* vol. 14, issue 1 (Winter 2000): 133-141. DOI: 10.1257/jep.14.1.133

d John Maynard Keynes. *The General Theory of Employment, Interest and Money* (London: Macmillan 1936): 161-162.

Wilson reminds us that enjoyable activities today are also those which were done for millions of years in our hominid past.[15] Doing Economics was not one of them. But narratives were. Hence, policymaking-by-case-studies is more enjoyable than policymaking-by-Economics. Case studies are essentially stories. We find them instructive for exploring the economic consequences of the five possible modalities of ABS as well as affording insights. Thought experiments illustrate the advantages and disadvantages of each proposed alternative modality.

Methodology

Analysis allows three types of reasoning: the analogical, the inductive and the deductive.[16] The three are not mutually exclusive. Analogies are inspirational en route to either meticulous inductive or rigorous deductive reasoning. Induction can also enable identification of new premises for deductive reasoning.

The history of thought in biology and economics provides examples of the interrelationships among analogical, inductive and deductive reasoning (Box 2). However, the institutional context for ABS has been neither biology or economics, but law. Decisions to the COP have also enjoyed protection through precedent, which is both a doctrine and a mindset typical of law. Precedents in Decisions are hard to overturn. Yet to move forward, as repeatedly urged by the Secretariat and the COP, one must step back and examine premises. Is genetic-material-as-tangible the wrong premise? To entertain the question, Parties must compare analogical, inductive and deductive reasoning (see Table 1).

Moving forward also means identifying where one last left off. COP14 commissioned four studies on DSI and a fifth, on transboundary situations. The commissions were completed in late 2019 and early 2020.[17] Informing the Methodology of our Report are peer reviews to those studies as well as the Report on the First Global Dialogue on Digital Sequence Information, held in Pretoria, South Africa from 6 to 8 November 2019.[18]

We believe that the word "material", left undefined in the CBD and Nagoya Protocol, is the linchpin to resolving ABS. Section 1 reviews the controversy. Should the interpretation of "material" include "information", the policy implication is multilateralism, which can be accommodated through Article 10 of the Nagoya Protocol. Possible modalities for

Table 1. Validity of Conclusions in Analogical, Inductive and Deductive Reasoning

	Analogical	Inductive	Deductive
Use	Despite prevalence in legal argumentation, only inspirational for inductive and deductive reasoning in science.	Common in human affairs and in science where phenomena seem irreducibly complex.	The hallmark of science. Despite strength of inference, application is difficult due to complexities of the phenomenon under study.
Premise	Patterns are observable between distinct phenomena.	Cases can be systematized,	Certain facts are foundational.
Conclusion	Similarities in some aspects carry over to other aspects and are assumed to dominate differences.	Relations exist that can be generalized.	Application of logic to fact(s) yield implications not necessarily obvious; hypotheses can be constructed and tested
Validity	Risk of affirming the consequent. Differences between the phenomena analogized may be sufficient to warrant refusal of generalization.	Conclusion is probably true.	If premise is true and logic applied, then conclusion is true.

15 E.O. Wilson, *The Meaning of Human Existence* (New York: W.W Norton and Co, 2014).

16 For a discussion about analogies, metaphors and forms of reasoning, see A.S. Reynold, *The Third Lens: Metaphor and the Creation of Modern Cell Biology* (Chicago: University of Chicago Press, Chicago, 2018).

17 See, "Studies on Digital Sequence Information on Genetic Resources,2019 – 2020 Intersessional Period" and "Global Multilateral Benefit-Sharing Mechanism". Available at https://www.cbd.int/dsi-gr/2019-2020/studies/ and https://www.cbd.int/abs/art10.shtml#tab=4

17 4

18 The Report of the First Global Dialogue on DSI, 6-8 November 2019, Pretoria, South Africa (ABS Capacity Development Initiative, the South African National Department of Environment, Forestry and Fisheries, and the Norwegian Government, 2019). Available at http://www.abs-initiative.info/fileadmin//media/Events/2019/6-8_November_2019__Pretoria__South_Africa/Report-First-Global-DSI-Dialogue-SouthAfrica-201911_EN.pdf

the GMBSM must compete for the objectives of fairness and equity in ABS. Although not an explicit criterion in either the CBD or NP, efficiency should be welcome. Section 2 offers a menu of modalities.

What if each of the modalities had been operative for any given utilization of genetic resources? Four cases have been selected for their complementarity in Section 4 and are organized by a template (Appendix V). They are about a rodent, a snail, a sponge and a virus. Background information for the cases appear in Appendices I-IV. By applying the menu of modalities in Section 2 to the cases, thought experiments ensue. Section 3 provides a brief comment on the advantages of alternative modalities to "Nagoya-Bilateral".

During the intersessional periods 2016 – 2018 and 2018 – 2020, Parties and stakeholders expressed dissatisfaction with the *status quo.* The First Global Dialogue identified alternatives to Nagoya-Bilateral ABS Modality, which are analyzed in this Report. Twenty-four issues exist which constitute distinct problems for ABS (Table 2). Analysis of the cases illustrate the advantages and disadvantages of the modalities for the issues tabulated.

Overlap exists among the issues which impact the cases. For example, the analytical tools presented in the first thought experiment, the naked mole-rat, also apply to the conus snails and the sea sponges, respectively the second and third experiments. To enhance complementarity, we have selected different issues from Table 2 or different aspects of the same issue. The fourth case is the Ebola virus and was chosen as a capstone. Despite being counter-intuitive, the fourth integrates with the other three and reveals the robustness of the economic approach. None of the thought experiments relate precisely to what actually happened, which may be found in the Appendices I – IV. The experiments capture what could have happened in a narrative that facilitates comprehension of the policy analysis. We reiterate: they are mental exercises.

Because the language of various disciplines may be unfamiliar to the reader, a lexicon appears in Appendix IX. Terms defined in the lexicon appear in bold with their first use in the text. Legal elements for a GMBSM are proposed in Appendix VI. Discursive footnotes throughout the text suggest where one may further explore the literature.

Table 2. Issues and Problem(s) of Nagoya-Bilateral

No.	Issue	Problem(s) rendering Nagoya-Bilateral disadvantageous
1	Country of origin and fairness and equity	Inefficiency due to transaction costs. Competition among Providers eliminates rents (see Jurisdiction shopping by Users)
2	Sovereignty and ownership	Cosmopolitan species mean competition among Providers and elimination of rents (see Jurisdiction shopping). To the extent legal title does not correspond to control over land use, incentives not aligned between utilization and conservation
3	Jurisdiction shopping for countries of origin by Users	The resultant elimination of rents violates fairness and equity as only Users enjoy rents on value added through time-limited monopoly IP. Legal uncertainty ensues even in simple ABS frameworks
4	Jurisdiction shopping for site selection of capital investments	Countries choose the non-party
5	Transparency	Conceals royalty concluded in contract, which is essential to evaluate fairness and equity
6	"Material" in Article 2 of the CBD	Object of access for R&D is information. Evasion of ABS through disembodiment of genetic resource
7	"Digital sequence information" (DSI)	Manifold shortcomings repeatedly identified by Users and Providers since debut of neologism in 2015
8	Scope of ABS (collections)	Transaction costs exceed expected benefits, rendering ABS uneconomic for Provider. Taxonomy is encumbered

No.	Issue	Problem(s) rendering Nagoya-Bilateral disadvantageous
9	Scope of ABS (value added but not protected by IP)	Users may seek IP in order to pay for ABS obligation
10	*Ex situ* materials collected prior to the CBD	Scope depends on institutional policies of collection and national legislation
11	Material collected in a "Transboundary Cooperation"	"Cooperation" according to Art 5 of CBD and Art 11 of NP has not eventuated. Unfeasible where relations scaled-back, impossible where suspended
12	Non-commercial research (including taxonomy)	Distinction cannot be made in practice as non-commercial blurs with commercial
13	Changes in use of genetic resources and derivatives during R&D or change of intent	Not realistic to predict how and when changes will occur in R&D environments, which span jurisdictions, actors and time frames
14	Multiple sources of genetic resources and derivatives	Monitoring and tracking multiple contracts and R&D streams from multiple sources
15	Materials under Annex 1 of ITPGRFA for uses other than those stated in the treaty	Monitoring and tracking complex contracts and R&D streams from multiple sources
16	Calculation of monetary benefits	Besides elimination of rents, asymmetries in expertise and negotiating power between Users and Providers. Potential values often impossible to calculate *ex ante* conclusion of agreement
17	Calculation of non-monetary benefits	Because difficult to quantify, magnitude easily over- or understated by User or Provider, respectively
18	Trigger for benefit sharing	Monitoring R&D outside jurisdiction of Provider becomes impossible (or excessively costly) with successive transfers. Excessive reliance on good faith of Users despite well publicized cases of biopiracy
19	Fungibility	To the extent that earmarked funds displace funds allocated or to be allocated, benefit sharing swaps the source of finance without increasing the finance. Art.21 CBD may be interpreted to address fungibility, but its language may also be reasonably interpreted to the contrary
20	Checkpoints and monitoring	Reluctance of institutions (e.g. IP institutions, commercialization points, research institutions, funding agencies) to assume responsibility
21	Compliance	National legislation of Providers are slow to regulate as deemed of low economic importance, largely due to elimination of rents
22	Institutional Arrangements	Inadequate capacity of authority, especially in developing countries
23	Areas beyond national jurisdiction (Antartica, deep seabed, etc.)	Cooperation or a GMBSM suggested
24	Human pathogens	Eradication of pathogens *in situ* runs counter to a literal interpretation of the objectives of CBD

1. "Material" as Linchpin to ABS

Article 2 of the CBD defines "genetic resources" as "genetic material of actual or potential value" but does not define "material".[19] The *lacuna* is not the problem that it may appear. Article 31.1 of the 1969 Vienna Convention establishes that "[a] treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose".[20] English is the official language of the CBD and *The Oxford Dictionary*, the usual source for ordinary meanings.

Users who interpret "material" as only physical matter generally do not explain their interpretation. Instead they invoke the legal doctrine of ***stare decisis***, albeit not always explicitly. They are essentially saying that the interpretation is settled, so let's move on.[21] Besides being anti-scientific, the argument must first establish that precedence was actually established. Providers rejoin that scientists have always interpreted information in the "actual or potential value" of genetic material.[22]

As long as the information could not be separated from the physical medium, conflating the tangible with the intangible was a tolerable indulgence. Scientists were always well aware of the difference. Jack R. Kloppenburg's 1988 landmark book is *First the Seed: The Political Economy of Plant Biotechnology*. The title could have been *"First the DNA"* but was not.[23]

One can take the argument further. Thinking abstractly, scientists drew the distinction between medium and information even prior to the 1953 discovery of DNA.

Erwin Schrödinger's 1943 lectures *What is Life?* spoke of "code-scripts".[24] Because the implications of the **economics of information** are opposite to those of physical matter, interpreting "material" correctly is the linchpin to ABS.

Since Francis Crick's 1970 publication of "The Central Dogma of Molecular Biology", the immaterial nature of "genetic resources" has become a commonplace, particularly in the context of R&D. "Genetic information" is now ubiquitous in molecular biology literature. For the purposes of ABS, the economist can do Crick one better and suggest **natural information** thereby sweeping in molecular structures, epigenetic phenomena and genetic sequences *inter alia*. Biologists should not object. Reductionism is "the virtually unchallenged linchpin of the natural sciences."[25]

Application of economics to ABS depends on correctly identifying the object of access as intangible for purposes of R&D. The deductive argument can be communicated by analogical reasoning:

> For material goods, competition promotes efficiency and equity; for information goods, competition promotes neither (Samuelson & Nordhaus, 2005). The exception of information goods from the standard economics analysis inheres to the high fixed costs of research and development and the low marginal costs of reproduction. Without protection from competitors, creators cannot recoup the fixed costs of their creations. Why spend vast sums to create something if everyone can cheaply copy it? Time-limited monopoly rights are the solution.
>
> Inasmuch as genes are information – a sequence of nucleotide bases that can be copied – the analogy with intellectual property is really a homology. Conservationists cannot recoup the opportunity costs of conservation if anyone can trade freely in the same natural information, usually geographically dispersed. Why conserve a vast habitat if you can take out a few samples? Oligopoly rights over natural information are the analog to the monopoly rights over artificial information. Such framing of ABS also extends to enforcement. Similar to

19 Text of the CBD. Article 2: Use of Terms. Available at https://www.cbd.int/convention/articles/?a=cbd-02

20 Vienna Convention on the Law of Treaties (with annex) (23 May 1969): 340. Available at https://treaties.un.org/doc/Publication/UNTS/Volume%201155/volume-1155-I-18232-English.pdf

21 As of this writing, the latest manifestation may be found in UK Parliament Post, "Digital Sequence Information", PostNote Number 630, September 2020. Available at https://post.parliament.uk/research-briefings/post-pn-0630/ "Defining what is meant by DSI: While the current definition of genetic material is confined to physical biological material...", p. 3

22 Richard Dawkins, popularizer of evolution, describes genes as "pure information". *River out Of Eden: A Darwinian View of Life* (Basic Books, London: Basic Book, 1995): 19

23 Jack R. Kloppenburg drew the title from the motto of the American Seed Association.. *First the Seed: The Political Economy of Plant Biotechnology,* 2nd ed. (Maison: University of Wisconsin Press, 2004): 4

24 Erwin Schrödinger, *What is Life?* (Dublin Institute of Advanced Studies, Trinity College, 1944). Available at http://www.whatislife.ie/downloads/What-is-Life.pdf Watson and Crick cite Schrödinger as inspirational. See Joachim Pietzsch, "What is Life?" NobelPrize.org. Nobel Media AB 2021. https://www.nobelprize.org/prizes/medicine/1962/perspectives

25 E.O. Wilson, E.O. *Naturalist* (Washington D.C.: Island Press, 1994): 345

> artificial information, the illicit flow of natural information cannot be impeded physically. The fence around information must be metaphorical, i.e., a legal instrument. So the economics-of-information narrative ends with analogous institutions: intellectual property has TRIPs [Trade Related Intellectual Property Rights] and WIPO [World Intellectual Property Organization]; genetic resources should have an International Regime on ABS under the Secretariat to the UN CBD [aka Global Multilateral Benefit-Sharing Mechanism].[26]

Adherence to material-as-only-physical-matter is increasingly untenable as the cost of sequencing decays exponentially. The "-omics" revolution of the 1990s (viz., genomics, proteomics and so on) puts into high relief the category mistake. In the new millennium, databases of genomes, etc., are now just a click away. This reality penetrated the CBD discussions of **synthetic biology** where the neologism "digital sequence information" (DSI) appeared in 2015.[27]

DSI soon migrated from synthetic biology to the ABS discussion and took off. Objections soon followed as did alternative terms. The SPDA has long advocated "Natural Information" as the object of access but had not yet defined the term,[28] considering it as self-evident.[29] Clarity is now needed. So, for the purposes of the CBD and NP: "Natural Information: Any unintentional distinction, non-uniformity or difference extracted from matter that is living or was once alive."

Competing terms from other Parties and stakeholders lend themselves to the Venn diagrams of formal logic. The set Natural Information is represented by the large teal-green oval in Diagram 1, where "The Phenom" is the desired scope of ABS. N[ucleotide] S[equence] D[ata] lies within natural information (biotic) as do tangible genetic material, biochemical compounds and other expressions like biomolecular structures, biomimicry and non-human cultures. NSD, TGM, BioCmpd, etc., are represented by small grey ovals, some of which intersect one another. Such conceptualization allows for still unidentified expressions, represented by the grey oval of a question mark, as long as they meet the definition of biotic natural information. Out of scope are artificial information and abiotic natural information, represented by the blue-grey ovals.[30] Diagram 1 yields a dispiriting interpretation: the mustard-yellow oval of DSI partially intersects NI (biotic), NI (abiotic) and AI. In other words, DSI excludes what should be included within the scope of ABS and includes what should be excluded.

Natural information (biotic), hereafter just "natural information,"[31] invites the relevant economics, which is the economics of information.[32] As will be argued throughout this Report, the policy implication is that multilateralism supplant bilateralism for ABS.[33] The entrée for reform is the GMBSM, which is Article 10 of the Nagoya Protocol. The handle for the modality of the GMBSM is **"bounded openness"**,[34] whereby natural information flows unencumbered by ABS procedures for R&D. Openness would be the default position whereby bounds are only imposed should they enhance efficiency and equity. In 2016, the SPDA launched the following definition:

> Bounded openness: Legal enclosures which default to, yet depart, from *res nullius* to the extent the departures enhance efficiency and equity, which must be balanced when in conflict.[35]

26 J. H. Vogel, et al. "The Economics of Information; Studiously Ignored in the Nagoya Protocol on Access and Benefit Sharing." *Law, Environment and Development Journal* vol. 7 issue 1 (2011): 52-65. Available at http://www.lead-journal.org/content/11052.pdf

27 Edward Hammond, "Comments of Third World Network on Digital Sequence Information", SCBD/NPU/DC/VN/KG/RKi/87804 (1 June 2019): 3. Available at https://www.cbd.int/abs/DSI-views/2019/TWN-DSI.pdf

28 Peruvian Society for Environmental Law / Sociedad Peruana de Derhecho. Lawful Avoidance of ABS: Jurisdiction Shopping and Selection of non-Genetic-Material Media for Transmission. Proposals for new and emerging issues for consideration received after COP-13 (2 May 2017). Available at https://www.cbd.int/emerging/

29 J.H. Vogel,"The Intellectual Property of Natural and Artificial Information", *CIRCIT Newsletter*, Melbourne, Australia (June 1991): 7.

30 Examples of abiotic natural information would be the topology of a stalagmite or the porous structure of a crystal. See, for example, J.T. Prabhakar, "Five Ways that Natural Design Could Inspire Human Nanotechnology." *Nanowerk* (13 August 2018). Available at https://www.nanowerk.com/spotlight/spotid=50869.php

31 Given that the discussion occurs in context of a treaty on biological diversity, "biotic" is tacit when discussing natural information

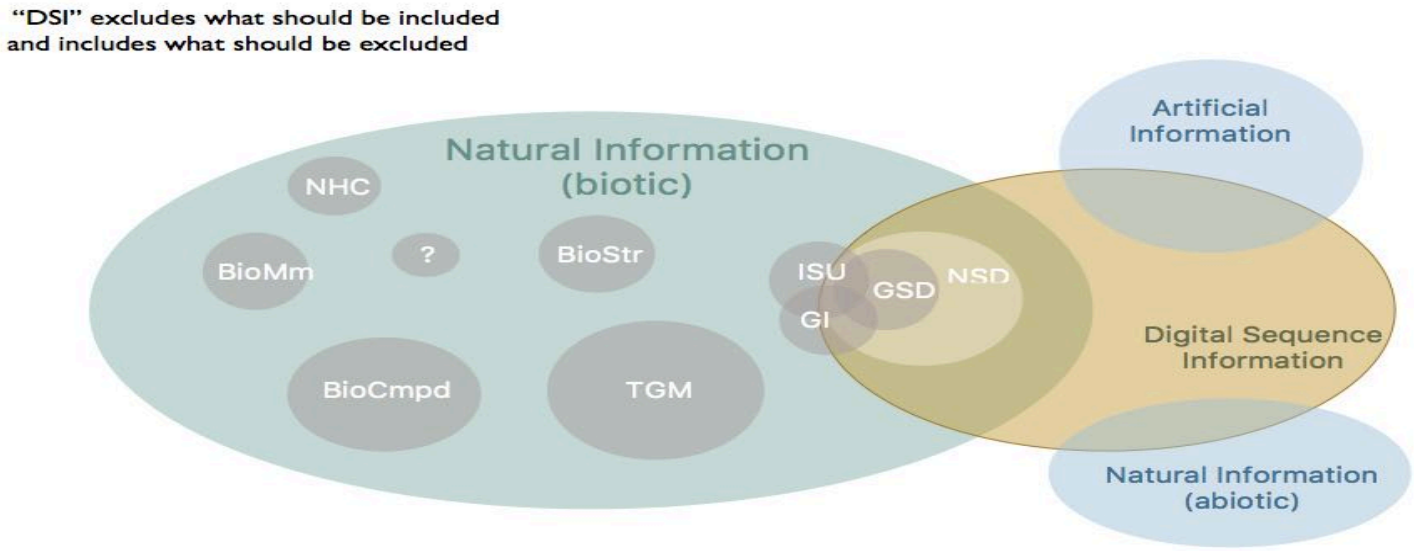
32 As a corollary, any term for the desired scope of ABS which does not include "information" does not imply the relevant economics *prima facie*, e.g., NSD, GSD, ISU.

33 J.H. Vogel, "Reflecting Financial and Other Incentives of the TMOIFGR: The Biodiversity Cartel" in M. Ruiz and I. Lapeña (eds), *A Moving Target: Genetic Resources and Options for Tracking and Monitoring their International Flows* (Gland, Switzerland, IUCN: 2007): 47-74 . Available at http://data.iucn.org/dbtw-wpd/edocs/EPLP-067-3.pdf

34 "Bounded openness" was coined by the political scientist Chris May in reference to man-made or artificial information. The concept proves robust. See, C. May, *The Global Political Economy of Intellectual Property Rights*, 2nd. ed (London: Routledge, 2010): 142-146

35 Sociedad Peruana de Derecho Ambiental, Submitted view for the Updated report and synthesis of views in response to paragraph 7(b) of Decision XII/24 (2016): 2, fn 2. Available at https://bch.cbd.int/synbio/peer-review/2015-2016/.

Diagram 1. "The Phenom"



KEY

Natural Information (biotic)	=	Any unintentional distinction, non-uniformity or difference extracted from matter that is living or was once alive.
Natural Information (abiotic)	=	Complement of Natural Information (biotic) with respect to that which is not living and was never alive.
Artificial Information	=	Any human-made distinction, non-uniformity or difference that is intentional.
Digital Sequence Information	=	Placeholder for the "Phenom"
NHC	=	Non-human cultures
BioStr	=	Biomolecular structures
BioMm	=	Biomimicry
BioCmpd	=	Formula of biochemical compounds
TGM	=	Tangible genetic material
GI	=	Genetic information
GSD	=	Genetic sequence data
ISU	=	In silico utilization (of genetic resources):
NSD	=	Nucleotide Sequence Data

Image Credit: Valeria M. Berríos-Arroyo

Source: Adapted from J.H. Vogel, Peer Review of the "Combined Study on Traceability and Databases" (19 November 2019): 4. Available at https://www.cbd.int/abs/DSI-peer/2019/Study2-3/JosephHenryVogel.pdf

2. Menu of Modalities

The Report of the First Global Dialogue on DSI illustrates five modalities for ABS with clip art.[36] Transversal to the alternatives to the Nagoya-Bilateral approach is open access of some type, which in turn requires clarity for what is meant by "open access". The publisher Springer-Nature defines the term as "… free, unrestricted online access to research outputs such as journals, articles and books... open to all, with no access fees."[37] The success of open access as a concept is evidenced by the 2002 Budapest Open Access Initiative, the 2003 Bethesda Statement on Open Access Publishing, and the 2003 Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, among others.

Many participants to the Dialogue may have associated open access with "the common heritage of mankind", which inspired the 1983 International Undertaking on Plant Genetic Resources.[38] Such "open access" ended *de jure* for almost all genetic resources with the ratification of the CBD in 1993.[39] The argument in favor of open access, nevertheless, remained vibrant. The *Harvard Law Review* published in 1998 "The Tragedy of the Anti-commons: Property in the Transition from Marx to Markets". The author, Michael A. Heller, warned that patent thickets could thwart R&D, as scientists become increasingly encumbered with licenses.[40] Although that prediction did not eventuate,[41] an analogous prediction for ABS seems more fruitful.[42] Inasmuch as the anti-commons movement led to the 2001 Creative Commons licenses, could similarly layered protections be designed for ABS?

Many participants in the Dialogue distinguished "open access" from "free access", where only the latter would mean "unrestricted…with no access fee". Unfortunately, "free" lends itself to equivocation. Does "free" mean "free[ly available]", "free [of charge]" or "freely available and free of charge"? Although participants voiced the last option, non-participants might not agree. In common usage, "open access" also means "freely available and free of charge".

36 See Report of the First Global Dialogue on DSI, Note 18.

37 Springer Nature, What is Open Access? Accessed 26 August 2020. Available at https://www.springernature.com/gp/open-research/about/what-is-open-access

38 FAO Resolution 4/89 (Agreed Interpretation of the International Undertaking), adopted on 29 November 1989, clarified that "free access" to plant genetic resources under the common heritage principle, does not mean free of charge. Available at http://www.fao.org/3/x5588E/x5588e06.htm

39 The exception being the human genome and the 64 crops and forages listed in Annex 1 of the "FAO International Treaty on Plant Genetic Resources for Food and Agriculture" (Rome: FAO, 2001): 44-49. Available at http://www.fao.org/3/a-i0510e.pdf

40 G. Dutfield and K. Sideri, "Openness, Innovation, and Science Policy in the Age of Data-driven Medicine." *Science and Public Policy* (2020): 1–3. Available at https://doi.org/10.1093/scipol/scaa009

41 W. Lesser. "Whither the Research Anticommons?" *AgBioForum* vol. 19 issue 1 (2018): 1-9. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7121752/

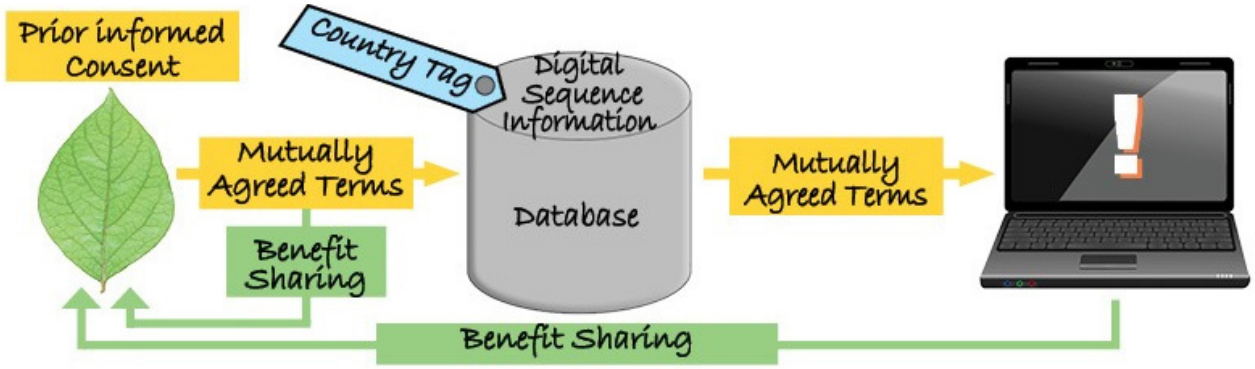
42 G. Dutfield, *Intellectual Property Rights and the Life Sciences: Past, Present and Future*, 2nd ed. (Singapore: World Scientific Publishing, 2009).

2.1. Modality 1: "Nagoya –Bilateral Benefit Sharing"

"Nagoya – Bilateral Benefit Sharing" describes the *status quo*. Should DSI be interpreted as within the scope of "genetic resources", then "Nagoya-Bilateral" is the default position for ABS. Benefits are shared through contracts which set **Mutually Agreed Terms** (MAT) in some type of Material Transfer or Benefit-Sharing Agreement (MTA/BSA). The agreement would be signed by the Provider and the first User, leaving the daunting task of enforceability along value chains. Third-party provisions regarding downstream use would have to bind Users through a country tag to the DSI. Current templates do not allow parallel uploading of DSI and a corresponding MAT.[43] Model clauses would only reduce the **transaction costs** of the agreements as legal fees would remain.[44]

Interpretation of the modality in Fig. 1 requires careful examination. Subtle is the meaning of a single leaf in the icon. For DSI diffused among species whose range overlaps jurisdictions, competition would go digital. The sole leaf could be reasonably interpreted as the winner-who-takes-all in the **race to the bottom**. Competition will drive down the monetary benefit, precipitously. Thus the Provider first to upload the DSI only enjoys a small advantage. And should the MTA/BSA be considered onerous, Users can always turn to other Providers or even resort to physical specimens. Much of this Report will elaborate the justification for preventing such competition and institutionalizing **economic rents**, which we will explain in detail. The arrow extending from the personal computer to the leaf should be interpreted as vanishingly thin, disappearing completely whenever the country tag or the database are from the non-Party.

Figure 1. Nagoya-bilateral BS



2.2 Modality 2: "Open Access – Bilateral"

Terms and Conditions of the database would regulate benefit sharing for commercial use of DSI. "Open Access – Bilateral" requires a country tag for DSI so that the User can remit benefits to the country of origin. The modality is known in law as an adhesion agreement.[45]

Interpretation of the modality in Fig. 2. builds upon the reconciliation of "Nagoya – Bilateral Benefit Sharing" with Fig. 1. Departures from the *status quo* are (1) elimination of the transaction costs involved in the yellow boxes "Mutually Agreed Terms" of Fig. 1 and (2) introduction of the transaction costs associated with the "Terms and Conditions" of the database, represented by the cylindrical tank. Whether the transaction costs of Modality 2 are less than those of Modality 1 depends on the number and complexities of competing "Terms and Conditions". Inasmuch as only one tank is illustrated in Fig. 2, when over a thousand could exist, the tank depicted should be interpreted as the one which won the race to the bottom, i.e. the minimum royalty percentage. Like "Nagoya – Bilateral Benefit Sharing", competition eliminates rents. Also like "Nagoya – Bilateral Benefit Sharing", Users will prefer the non-Party whenever available.

43 See *Report of the First Global Dialogue* on DSI, Note 18, 17.

44 For example, Gerd Winter and Evanson Chege-Kamau preface nineteen suggested clauses with the recommendation that " a lawyer who is familiar with ABS issues should be consulted before an agreement is signed. Research institutions will need to ensure that appropriate advice is made available". See "Model Clauses for Mutually Agreed Terms on Access to Genetic Resources and Benefit Sharing". *Law, Environment and Development Journal* vol. 12 issue 1 (2016): 18-34, 20. Available at http://www.lead-journal.org/content/16018.pdf

45 This paragraph is paraphrased from the Report of the First Global Dialogue on DSI, 17, Note 18.

Figure 2. Open Access-bilateral BS

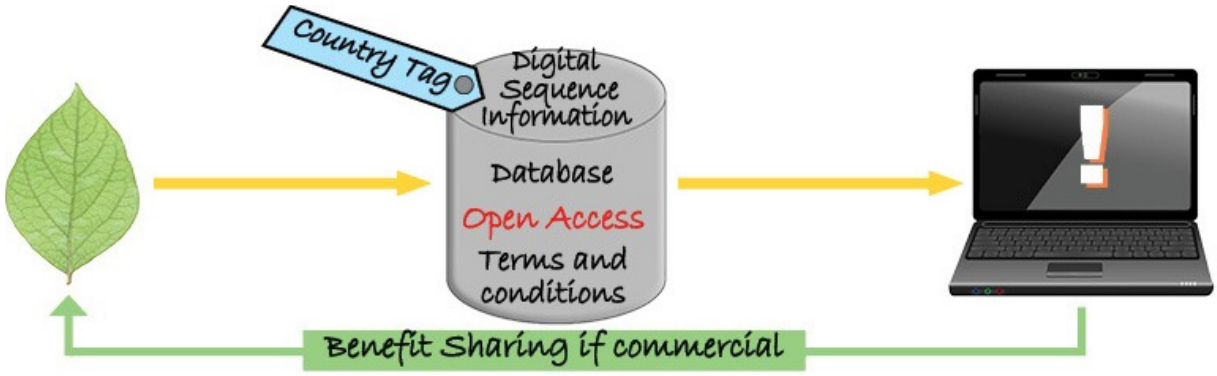
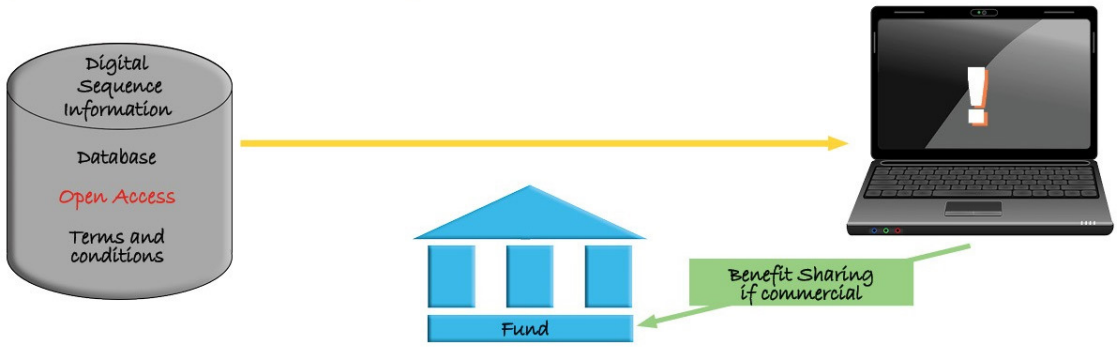


Figure 3. Open Access-multilateral BS



2.3. Modality 3: "Open Access – Multilateral"

A multilateral regime regulates the commercial use of DSI rather than contracts and other agreements. Two main variants can be found in the literature. Neither requires a country tag as monetary benefits remit to a Global or Regional Fund. Openness is bounded by the obligations of the regime. Either the regime or the Secretariat would notify Users.[46] "Open Access-multilateral BS" has been the least discussed over the COPs. Elaboration is now required.

Variant One "Open Access-Multilateral BS" (3-I) derives from the literature on common-pool resources by Elinor Ostrom, who co-shared the 2009 Nobel Memorial Laureate in Economics.[47] The application is most associated with the work of Evanson Chege-Kamau and Gerd Winter.[48] The application to DSI is an extension of historic practices of related user groups, viz. *ex situ* seed collections, culture collections and database conglomerates. Variant One would reduce the transaction costs of ABS agreements through integration, harmonization and streamlining. Because the benefits would go to the regional pool rather than to one provider, distributive justice is enhanced but not achieved: other pools could form among neighboring Providers and face no barrier to compete.[49]

46 This and the previous four sentences are almost verbatim from the Report of the First Global Dialogue on DSI, 18, Note 18.

47 E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (United States and United Kingdom: Cambridge University Press, 1990). See also Evanson Chege-Kamau and Gerd Winter, "Streamlining Access Procedures and Standards", pp. 365-379 in E. Chege-Kamau and G. Winter, eds. *Genetic Resources, Traditional Knowledge and the Law* (London: Earthscan, London, 2011): 365-379; Tom Dedeurwaerdere, "From bioprospecting to reflexive governance", Ecological Economics volume 53 (2005)": 473-491

48 E. C. Chege-Kamau and G. Winter, *Common Pools of Genetic Resources: Equity and Innovation in International Biodiversity Law* (London and New York: Routledge, 2013).

49 The phenomenon of "jurisdiction shopping" predates the 1993 CBD (SPDA, 2015). An example is the US National Institutes of Health whose "frog alkaloid program would eventually become global in reach. ... Not surprisingly, [chemist John] Daly's group preferred collection of species with ready access and stated so frankly: 'The research has been hindered by difficulties in obtaining permits to collect any amphibians for scientific investigation, especially in neotropical countries of Central and South America, where the alkaloid-continuing dendrobatid frogs are found. For this reason, in the past decade our research has shifted to bufonid frogs of Argentina and to mantellid frogs of Madagascar' (Daly 2003, p. 449)". See, Klaus Angerer, "Epipedobates anthonyi under 'bounded openness' " in M. Ruiz Muller, *Genetic Resources as Natural Information* (London and New York: Routledge, 2015): 98-109, 102

Chege-Kamau and Winter reject modeling regional common pools (RCPs) on existing pools, such as the Multilateral System model under the FAO International Treaty on Plant Genetic Resources for Food and Agriculture.[50] They seem to prefer deductive reasoning and suggest a dozen features that should be incorporated into the design. The last feature listed is the briefest "RCPs should be integrated on a global level".[51] However, Kamau and Winter's approach allows competition, not among individual Providers but among pools. They do not address the elimination of rents.

The absence of rents in a multilateral BS system most distinguishes 3-I from Variant Two (3-II). By the criterion "rents or absence thereof", 3-I also includes *Mare geneticum* for marine genetic resources[52] and Option 2 of "Finding Compromise on ABS and DSI".[53] *Mare geneticum* imports the royalty percentage observed in bilateral agreements. The authors of Option 2, ostensibly inspired by ITPGRFA, contemplate royalties as low as 0.01%, which, as we will analyze in Section 5, is a full order of magnitude below the Brazilian lower bound.[54] The title "Finding Compromise" also suggests a zero-sum situation between Users and Providers.

Variant Two (3-II) affirms that any elimination of rents violates **fairness and equity** in the CBD and Nagoya Protocol. "Bounded Openness over Natural Information",[55] shortened to "bounded openness" in the context of ABS, derives from the economics of information.[56] Under "bounded openness," natural information flows unencumbered. Monetary benefit-sharing obligations are triggered by the successful commercialization of value added through time-limited monopoly intellectual property (IP).[57] Like "Finding Compromise", traceability in 3-II begins with a Yes/No disclosure of use of natural information in an application for IP, undertaken *ex post*. Through negotiation between Users and Providers as *organized* groups, the regime sets royalty percentages according to combinations of characteristics in utilization, which include industrial sector and type of IP. Salient among those characteristics is the **elasticity** of demand, which will be discussed in the analysis of the cases.

The mechanism just described requires disclosure of revenues on specific products that derive from genetic resources. Such a requirement is analogous to disclosure of minerals extracted from State-owned lands.[58] Distribution of royalty income would be proportional to the geographic range of the species, strains or populations from which the natural information could have been accessed.[59] The terrestrial biomes of Figure 3a is a first approximation of who would often be commoners. Table 3 explores the homology between intellectual property and bounded openness.

50 Chege-Kamau and Winter, see Note 47, 30.

51 Ibid, 32.

52 Classification is an art. The authors of Mare Geneticum classify their proposal as multilateral but do not rule out bilateralism: "To reduce the transaction cost and to maximize predictability, which are necessary to attract investments from the private sector, a fixed percentage would be preferable over case-by-case negotiations." A. Broggiato, T. Vanagt, L.E. Lallier, M. Jaspers, G. Burton and D. Muyldermans, "Mare Geneticum: Balancing Governance of Marine Genetic Resources in International Waters", *The International Journal of Marine and Coastal Law* vol. 33, issue 1 (12 March 2018): 3-33. Available at: https://doi.org/10.1163/15718085-13310030

53 A. Scholz, U. Hillebrand, J. Freitag, I. Cancio, C. dos S. Ribeiro, G. Haringhuizen, P. Oldham, D. Saxena, C Seitz, T. Thiele and E. van Zimmeren, "Finding Compromise on ABS and DSI in the CBD: Requirements & Policy Ideas from a Scientific Perspective" WILDSI (October 2020). Available at https://www.dsmz.de/fileadmin/user_upload/Collection_allg/Final_WiLDSI_White_Paper_Oct7_2020.pdf

54 Ibid, 21.

55 "Bounded openness" was first used as a handle for a modality of the GMBSM in J.H. Vogel, et al, ""The Economics of Information; Studiously Ignored in the Nagoya Protocol on Access and Benefit Sharing," see Note 26.

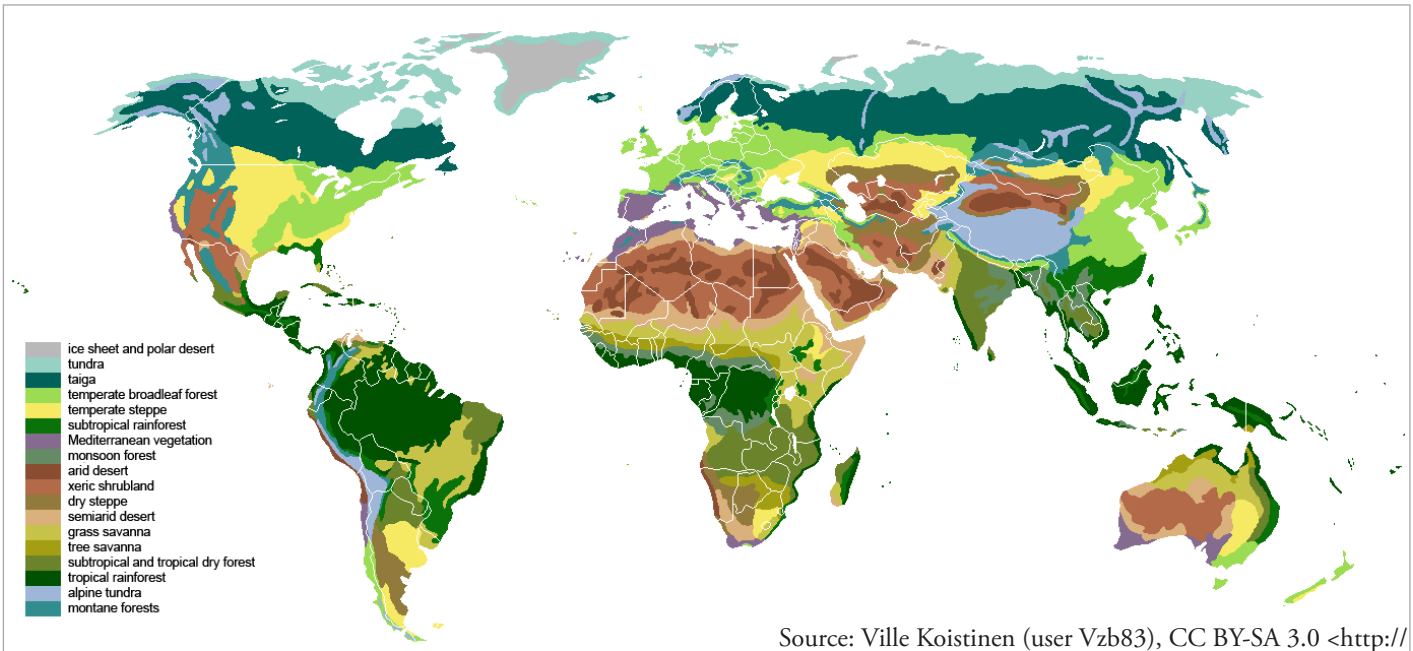
56 The orthodoxy of the economics of information is evidenced by Memorial Nobel Laureates who have pioneered the field: Friedrich Hayek (1974), George Stigler (1982), Ronald Coase (1991) and Joseph Stiglitz (2001). Available at https://www.nobelprize.org/prizes/lists/all-prizes-in-economic-sciences/

57 The word "monopoly" fires different neurons depending on whether one is an economist, a lawyer or a social activist. In economics, the term describes a market structure for which barriers to entry result in one firm providing a good or service for which no close substitute exists. Connotations are not intended. Thus, the GMBSM is classified as an oligopoly or cartel in Table 2 without pejorative intent. See J. Thomas McCarthy, Roger E. Schechter and David J. Franklyn, *McCarthy's Desktop Encyclopedia of Intellectual Property*, 3rd ed. (Washington, DC: Bureau of National Affairs, 2004): 384-385.

58 The COP would have to anticipate resistance to disclosure of revenues on specific products. See Matt Apuzzo and Selam Gebrekidan,"Governments Sign Secret Vaccine Deals. Here's What They Hide", *The New York Times* (29 January 2021): A10.

59 The application of the economics of information to genetic resources predates the 1992 CBD. However, "bounded openness" as the handle for the policy implications only appeared in 2011. See Notes 26 and 33. Five years prior to the launch of "Finding Compromise", non-obvious institutional details such as (Y/N) were elaborated in Ruiz, M. *Genetic Resources as Natural Information: Implications for the Convention on Biological Diversity and Nagoya Protocol* (New York: Routledge, 2015).

Figure 3a. Terrestrial Biomes



Source: Ville Koistinen (user Vzb83), CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons

Table 3. Intellectual Property Rights vs Bounded Openness in the Economics of Information

	Intellectual Property Rights	Bounded Openness over natural information (Modality 3-II)
Economic Rationale	Allows innovator to recoup the fixed costs of innovation and capture economic rent	Allows State or holder of land title to offset opportunity costs of conservation through the capture and sharing of economic rents
Vehicles	Various including patents, copyrights, trademarks, trade secrets	Global Multilateral Benefit-Sharing Mechanism (GMBSM)
Geographic scope	International and national	International and national
Right holder	Legal or natural person(s)	Countries of origin of species or populations which are the media of natural information utilized
Nature of right	Limited-time Monopoly	Limited-in-time Oligopoly (cartel)
Subject matter	Artificial information	(biotic) Natural information
Trigger for benefit (sharing)	Royalty payment and/or licenses	Commercial success of intellectual property over value added to natural information
Rights granted	Exclusion of non-authorized persons from using, commercializing, copying and so on, of protected creation or innovation	Claim of countries of origin to share royalty income according to percentage of global range of species. Income insufficient to cover costs of such determination is applied to fixed costs of GMBSM
Benefits (monetary)	Negotiated royalties and licenses	Royalties set according to a combination of characteristics including industry classification and type of intellectual property
Timing of monetary benefit sharing	*Ex post* protection of innovation through IP and commercialization or licensing	*Ex post* commercial success of IP

Negotiator of royalty	Holder of intellectual property right	Conference of the Parties of the CBD and NP
Impact of protection	Allows for financial sustainability of innovation. Through possibility of profits, incentivizes creativity	Offsets the opportunity costs of land use conversion and abates green house gas emissions. Through possibility of significant rents, incentivizes conservation
National complementary measures	Specific national intellectual property laws and regulations	Incentives could be devolved to local levels and holders of land titles
Expectations	High rate of IP applications despite few commercial successes	Low probability of commercial success despite high expectations from a few well known blockbusters
Transaction costs	High. Self-financing	Low. Self-financing

Interpretation of Fig. 3 "Open Access – Multilateral" is challenging. Digitization is just one of several media to communicate natural information. Others are print, film or the physical specimen. Competition is not just among databases but also among media (digital, print, etc.). A reasonable interpretation of the clip art must also reconcile "commercial" with the icon of the personal computer. Variant One (3-I) does not discriminate commerce on the basis of IP. Variant Two (3-II) does: obligations arise only for activities which enjoy commercial success through time-limited monopoly intellectual property. Because 3-II differentiates royalty percentages according to a set of characteristics in utilization, the thickness of the arrow of benefit-sharing in 3-II does not correspond to that of any of the proposals associated with 3-I. For 3-II, royalty income is distributed to the Parties proportional to the geographic range of the terrestrial species, strains or populations.[60] Variant One (3-I) would distribute income for conservation projects of high priority in developing countries. This difference between 3-I and 3-II raises the issue of fungibility, i.e., financing something which would have been financed anyway.[61]

The problem of fungibility is abstract but no less real. A mundane example may clarify. In an effort to reduce CO2 emissions, imagine a State institutes a nationwide policy to subsidize street arborization for all municipalities. However, some municipalities have always planted trees and others were already budgeting to begin planting. The money granted in the subsidy is fungible. For the aforementioned municipalities, the trees will be planted as always and the subsidy will be used elsewhere. Benefits shared under 3-II are at lower risk of a fungibility problem than are those under 3-I. [62]

Under 3-II, when natural information is ubiquitous across species or jurisdictions, and the transaction costs of disbursement exceed the royalty income, then the benefits remit to taxonomic endeavors or related public goods, including the databases. Given the cosmopolitanism of most of the species which result in patents, the occurrence will be common.[63] The fungibility problem resurfaces but with an ameliorating twist. Any reduction in government financing of databases due to the royalty income will diminish international freeriding.[64]

The preceding paragraphs explain Modality 3-II in terms of rents, elasticity and fungibility. Due to the power of these and other economic abstractions, we reject the classification of "bounded openness" as a "compensatory liability regime".[65] The alternative nomenclature shifts emphasis away from rents, etc. and thereby undercuts the analysis of efficiency and equity.

60 M. Ruiz Muller, *Genetic Resources as Natural Information. Implications for the Convention on Biological Diversity and Nagoya Protocol* (London and New York: Routledge, 2015).

61 Economists usually address the problem of "fungibility" as one of "adverse selection". See, Joshua Linn "Cash for Clunkers 2.0: Targeting Scrappage Subsidies to Cut Costs" Resources. 22 December 2020. "Of the $3 billion that the federal government spent implementing Cash for Clunkers, most went to households that would have bought new vehicles, anyway – a phenomenon economists refer to as 'adverse selection'". https://www.resourcesmag.org/common-resources/cash-clunkers-20-targeting-scrappage-subsidies-cut-costs/

62 For royalties on ubiquitous genetic resources remitted to taxonomic institutions, then fungibility does becomes a problem for 3-II if the State concomitantly reduces a financial commitment that seemed perennial. However, fungibility is less of a problem in 3-II than for 3-I, where the problem pertains to all benefits earmarked for conservation.

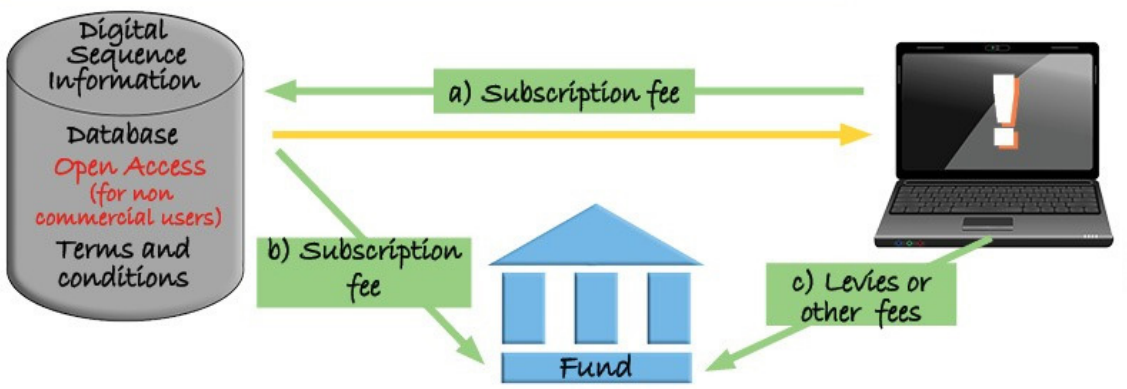
63 "As the lists of species presented above reveal, the bulk of patent activity is concentrated around a small number of well-known and cosmopolitan species". P. Oldham, S. Hall, and O Forero,"Biological Diversity in the Patent System", *PLOS One* vol. 8, issue 11 (12 November 2013): 1-16, 6. Available at https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0078737&type=printable

64 For example, Felicity Keiper of BASF reminds Parties and stakeholders that "The substantial cost involved in running and maintaining the INSDC [International Nucleotide Sequence Database] is conservatively estimated at USD$50-60 million annually but its use is unconditionally free." See submission of peer review, "A compilation of comments received and how they were addressed", regarding Draft of Study on Traceability and Databases. Fabian Rhoden, Sixing Huang, Gabriele Droge and Amber Hartman Scholz, (2019): 17. Available at https://www.cbd.int/abs/DSI-peer/2019/Study2-3/BASF.pdf

65 Elisa Morgera, Stephanie Switzer and Miranda Geelhoed, "Study for the European Commission on 'Possible Ways to Address Digital Sequence Information – Legal and Policy Aspects", Consultancy project conducted for the European Commission: ENV.F.3/SER/2019/6175145 (August 2020): 42-44. https://ec.europa.eu/environment/nature/biodiversity/international/abs/pdf/Final_study_legal_and_policy_aspects.pdf

2.4. Modality 4: "Open Access – Subscription Fee / Levies"

Figure 4. Open Access – Subscription Fee / Levies



"Open Access – Subscription Fee / Levies" joins the sharing of benefits to the value added. The modality does not require a country tag to the DSI. Access is bound only by subscription fees or levies paid into a Global Fund, where disbursement is according to a mechanism to be negotiated. Subscription fees are disclosed through the Terms and Conditions of the database and could differ for commercial or non-commercial use. As an alternative to subscription fees, levies could be placed on equipment purchased for the use of DSI (e.g., sequencers and related robots).

The tools of Economics are unavoidable for any fruitful analysis of Modality 4. They will be elaborated in the analysis of Case Study 1 on the naked mole-rat. Suffice to say here that subscription fees are similar to a specific excise tax. Revenues from the fees would transfer some **consumer surplus** from the Users to the General Fund. Because demand is downward-sloping, a higher price ($0.00 plus the subscription fee) means fewer Users. An **excess burden**, also known as a **deadweight loss** is the value forgone for would-be Users of DSI who desist when a subscription fee is charged (see Box 3).

Is the deadweight loss from subscription fees greater or less than the deadweight loss from a tax on equipment? The answer lies in the respective elasticities of demand for DSI and demand for equipment. The "high level of dissatisfaction" expressed by scientists during the Dialogue indicates that they believe that the incidence will fall on them.[66] The model is a familiar one in academic publishing. For example the Public Library of Science (PLOS) charges fees tiered according to the economic development of the author's country of residence. Elsevier seems to charge the heftiest, ranging up to $5000.[67]

To the extent that the databases do not discriminate subscription fees by type of user, excess burden will be experienced in commercial or non-commercial sectors for which demand is more elastic (Box 3). To capture rents, the subscription fees would have to be high which would result in lower use and greater elasticity of demand.

Interpretation of Fig. 4 turns on the thickness of the green arrows. Should the modality attempt to capture rents, then alternative media of natural information become attractive for commercial users, viz., print, film or the physical specimen. High fees would push non-commercial users into the elastic zone of demand. The deadweight loss and concomitant dissatisfaction would be notable.

66 Report of the First Global Dialogue on DSI, Note 18, 19.

67 For comparison of open-access fees, see Sherpa Romeo. Available at https://v2.sherpa.ac.uk/romeo/

Box 3.

Excess Burden: A Mundane Example of a Highly Abstract Concept

The newspaper *The Guardian* sells quarterly subscriptions for $75 but also allows free access. Such generosity is possible because the **marginal cost** of a page view is near zero. Nevertheless, the **fixed costs** of the news organization are high. Lemon-yellow pop-ups ask readers to donate one dollar. Should enough readers free ride, management may end up charging the dollar.

Imagine the responses of three typical readers to a dollar charge. Page Viewer X desists as he is indifferent to reading *The Guardian* or some other news source. He enjoyed no consumer surplus when access was free. Viewer Y desists because he is not willing to pay one penny more than $0.50. Viewer Z purchases. She derives utility equivalent to what would be generated from $3 spent elsewhere. The values of the same news article for X, Y and Z are respectively, $0.00, $0.50 and $3.00. The values are subjective and independent of the cost of production or the price charged. At a price of $1, page views drop from 3 to 1 and consumer surplus, from $3.50 to $2.00. However, one dollar of the former surplus is now revenue for *The Guardian*. Thinking abstractly, the total value of the news article for X, Y and Z was $3.50 under free access and is now $3.00, due to the deadweight loss of non-consumption by Viewer Y. The loss is also called excess burden. As we shall see, excess burden is crucial for a judicious choice of an ABS modality.


Cillian Murphy
From Peaky to the apocalypse
Film & Music G2
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Friday 28 May 2021
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From £1.75 for subscribers
The Guardian
For 200 years
Pressure on Hancock over failure to protect care home residents
Health secretary rejects Cummings claim that he lied about Covid testing
Aubrey Allegretti
Political correspondent
Matt Hancock was under mounting pressure last night to explain why the government had failed to protect care home residents at the outset of the Covid pandemic, as he sought to salvage his reputation after Dominic Cummings accused him of lying.
The health secretary claimed for the first time that it "wasn't possible" to test all care home residents for Covid before they were discharged from hospital last March, because the testing capacity was not yet available.
But the shadow social care minister, Liz Kendall, said that explanation "simply doesn't stack up".
"There were over 530,000 tests carried out in the UK by 20 April, yet they couldn't test 25,000 people discharged from hospitals to care homes, after we saw it sweep through care homes in Italy, France and America?" she said. "The reality is, they wanted to free up the beds and they didn't prioritise older people."
She accused Hancock, who previously claimed to have thrown a "protective ring" around care homes, of changing his story to "wriggle out" of responsibility.
On Wednesday, during seven hours of evidence to MPs, Cummings accused Hancock of promising ministers that all residents were tested before being discharged back to care homes and then lying about this. Hancock denied the claim, and a No 10 spokesperson said last night: "The prime minister has full confidence in the health secretary and will continue working with him to protect public health and save lives."
The UK has one of the world's worst coronavirus death tolls: more than 127,000 people have died including in excess of 40,000 care home residents.
New data from Public Health England (PHE) released yesterday found that the transfer of patients with Covid from hospital to care homes resulted in 286 deaths. It said 96 outbreaks in care homes were related to this problem - about 1.6% of all care home outbreaks
6
'The reality is... that they didn't prioritise older people'
Liz Kendall
Shadow social care minister
China fury at broader US inquiry into Covid
Vincent Ni China correspondent
Julian Borger Washington
Joe Biden's decision to expand the US investigation into the origins of the Covid-19 pandemic, with one intelligence agency leaning towards the theory that it escaped from a Wuhan laboratory, has opened a new divide in his administration's already tense relationship with China.
Biden said yesterday that he would publish the results of the 90-day inquiry, which he has made a priority for the intelligence agencies. The move represents a dramatic turnaround from the administration's policy of leaving the investigation to the World Health Organization.
The US called on the WHO to carry out a second phase of its investigation into the origins of the new coronavirus, with independent experts given full access to original data and samples in China. "It is critical that China provide independent experts full access to complete, original data and samples relevant to understanding the source
28
Clever as Einstein
But did he get his celebrated theory wrong?
News Page 17 →
£11bn: cost of repairing schools in England
Richard Adams
Education editor
Schools in England face a repair bill of more than £11bn, nearly double some previous estimates, according to a long-awaited national survey completed by the government.
The survey confirms years of complaints of crumbling and leaking buildings, in some cases riddled with asbestos, and of "temporary" cabins still in use despite exceeding their lifespan.
Meanwhile, the Department for Education's consultation on fire safety in schools was criticised yesterday for only recommending that sprinklers should be installed in any new builds over 11 metres (36ft) high, in effect at least four storeys.
The results of the repairs survey, which involved
4

Source: *The Guardian* front page on 28 May 2021

Figure 5. Free Access – Capacity Development

2.5. Modality 5: "Free Access – Capacity Development"

No specific benefit-sharing obligations for DSI exist under the fifth and last modality considered at the Dialogue. Benefits are assumed to be diffused through commercial and non-commercial use of DSI. Participants who advocated "Free Access – Capacity Development" spoke of benefits "trick[ling] down into socIety", apparently unaware of the pejorative connotations of "trickle down" in economics.

The value rendered through technological advance is indisputable. However, quantification is thorny. Multipliers come into play when resources are under- or unused. An overarching benefit is capacity development for Users in developing countries and, much overlooked, the eventual public-domain status of patented biotechnologies which added value to genetic resources. The finance of training in capacity development is assumed to accompany growth in associated activities. Bounds on openness imposed by the CBD or NP would be zero.[68] Interpretation of the modality illustrated in Fig.5 is challenging due to the static nature of the image. Imagination helps. If Fig. 5 were a film short, then the yellow arrow would be pulsating with repeated access. The box of people who enjoy capacity development would enlarge with every pulse.

68 See *Report of the First Global Dialogue on DSI,* Note 18, 20.

3. Advantages of Alternative Modalities to "Nagoya-Bilateral"

Defense of "Nagoya–Bilateral Benefit Sharing" can no longer count on *stare decisis* or **cognitive dissonance** of the alternative modalities. Multilateralism was on the table at the Dialogue. The last of the five alternatives discussed,"Free Use–Capacity Development", is the "common heritage of mankind". The suggested rehabilitation of the pre-CBD doctrine should give the COP pause.

The push-back by participants against bilateral ABS in Pretoria in 2019 has prestigious antecedents. *Nature* reported the ratification of the Nagoya Protocol in October 2014 with the provocative title "Biopiracy ban stirs red tape fears".[69] *Science* published in 2018 an article whose title is essentially a denunciation "When the cure kills–CBD limits biodiversity research".[70] The authors amassed 172 co-signatories from 35 countries. At COP14, 77 notable Users issued a Joint Statement that "genetic resources" be interpreted as only tangible.[71] Users also look at the non-Party with a certain envy and resentment: envy because access is unencumbered; resentment because a safe haven exists.

User dissatisfaction is mirrored by that of Providers, whose advocates characterize unauthorized access as digital biopiracy (see Box 1). As if all this were not sufficiently disquieting, calls for a review of the treaty are made in earnest.[72]

Summing up the period 2015 – 2020, one can say that the disadvantages of Nagoya-Bilateral Benefit Sharing can no longer be dismissed. Discontent is palpable. With utmost urgency, the alternatives must be fleshed out. While the First Global Dialogue attempted to identify the possibilities, any choice requires deep reflection of all the attendant issues. Table 2 lists twenty-four. How do the alternatives fare for each issue?

69 D. Cressey, "Biopiracy Ban Stirs Red-Tape Fears", *Nature* vol. 514 (2014): 14-15

70 K.D. Prathapan, et al, Note 8.

71 CIOPORA and 77 signatory organizations, "Promoting sustainable use and conservation of biodiversity through open exchange of Digital Sequence Information" (November 2018). Available at https://www.cbd.int/doc/c/e5c6/e8e7/f0aab5ae9fad61a2f7ff9094/np-mop-03-dsi-other-01-en.pdf

72 K.D. Prathapan and P. Dharma Rajan, "Convention on Biological Diversity: Need for a Review." *Economic & Political Weekly* vol. 1IV issue 3 (2019): 60-62.

4. Foundations and Applications

Unwieldy would be a pairwise comparison of the alternative modalities and Nagoya Protocol-Bilateral for each issue identified in Table 2. Information would quickly overload: Six modalities and 24 issues generate some 720 combinations. Theory affords compaction.[73] The solution is much facilitated when the theory is already constructed and the audience, amenable to its application. One gleans such disposition from the participants of the Dialogue.

The Report for the Dialogue lists "information creates value" as the last point in the discussion of "Commercial and non-commercial use of DSI".[74] No three words hold more potential for elucidation or hazard more potential for misunderstanding. Parsing the sentence can address how each modality of ABS *creates* and *distributes* value. Although the analysis is economic, formal education in economics is not necessary to fully grasp the argument to follow.

Information creates value

Information: According to the *Oxford Learner's Dictionary*, the scientific definition is "what is represented by a particular arrangement or sequence of things [e.g. digitized facts and data]." Left unqualified, "information" includes what is artificial, i.e., human made (e.g., sequence music from an electronic keyboard). To be within the scope of the CBD and the Nagoya Protocol, the provenance of information must lie in what is or was alive. Analogous to the distinction between artificial and natural selection, the COP must distinguish between artificial and natural information. The formal definition of information from the *Oxford Learner's Dictionary* can be easily qualified: "what is represented by a particular arrangement or sequence of things *that evolved without intentional artificial selection*".

Albert Einstein famously advised to keep things as simple as possible but no simpler.[75] The parsimony of the qualified definition for "natural information" is perhaps too simple. Because the ABS discussion conflates information with its medium of transmission, a less parsimonious definition is preferred. We repeat here the definition from Diagram 1:

Natural Information: Any unintentional distinction, non-uniformity or difference extracted from matter that is living or was once alive.

Create: The *Oxford Learner's Dictionary* defines "create" as "to make something happen or exist." However, information-creates-value does not make literal sense. *The use* of information *with other factors of production creates value.*

Value: The *Oxford Learner's Dictionary* defines "value" as "how much something is worth in money or other goods for which it can be exchanged" (price) and "how much something is worth compared with its price" (satisfaction or utility). Economists emphasize that the utility derived from any purchase can exceed that derivable from a different purchase at the same price. The difference between one's willingness to pay (utility) and what was paid (price) is the consumer surplus. Fully assimilating the difference between one's willingness to pay for a good and the price of that good is essential to analyze the five alternative modalities of ABS.

Classical argumentation

Pluralism in modalities is not an option for ABS.[76] The COP must decide which is best. To do so, Parties must first agree on *whether benefit-sharing is worth the effort*. What is the value of genetic resources? The question is extremely difficult, even for economists. Do opposing answers reflect different philosophies within the discipline? Or are some economists right and others wrong? The non-economist must take stock.

Two OP-EDs with opposing views on valuation appeared in 2019. The articles are "The Problem with Making Nature Pay for Itself: Trying to Make Nature Pay for Itself has a Disappointing Track Record"[77] by R. David Simpson and "Access to Genetic Resources and Benefit-Sharing" in the

73 G. Hardin, *Living within Limits* (New York: Oxford University Press, 1993): 102

74 Report of the First Global Dialogue on DSI, Note 18, 10.

75 What Einstein actually said was more loquacious: "It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience." "On the Method of Theoretical Physics", The Herbert Spencer Lecture, delivered at Oxford (10 June 1933), *Philosophy of Science* vol. 1, no. 2 (April 1934): 163-169, 165.

76 Bruce S. Manheim, "The Quid Pro Quo Failing Biodiversity and the Discovery of New Products", *BioScience* vol. 69 issue 11 (November 2019): 856-857.

77 R.D. Simpson, "The Problem with Making Nature Pay for Itself: Trying to make nature pay for itself has a disappointing track record", *Anthropocene Magazine* (7 July 2019). Available at www.anthropocenemagazine.org/2019/06/the-problem-with-making-nature-pay-for-itself

Post-2020 Global Biodiversity Framework"[78], authored by Ruiz Muller et al. (all of whom are collaborators of the present Report).

A few select sentences from each OP-ED can throw light on "information-creates-value" and assist in comparison of the ABS modalities. Readers are highly encouraged to download the sources and verify that the quotes are not taken out of context. The articles are open access and the latter, also available in French and Portuguese.

A Category Mistake

Simpson relates the heady world of conservation in the 1980s. Hopes were high that bioprospecting would save the rainforest. He remembers how "[a]t the start of [his] career", he arrived at an "epiphany",[79] which was mundane nonetheless. "How much would you pay for something whose supply seems 'unlimited'? Probably not much. Things that are in short supply command high prices; things that aren't, don't".[80] The explanation about "short supply" and "high prices" is commonsensical. Considering the meaning of "something" and "things" in "How much would you pay for something", the audience most likely hears "How much would you pay for a *tangible* whose supply seems 'unlimited'?" But, alas, the "something" is *intangible*.

Simpson's query begs revision. Substitution of a few words will do. "How much would you pay for *the right to use information* whose supply seems 'unlimited'"? The answer can be gleaned by the 164 members to the World Trade Organization,[81] and the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), whereby societies grant limited-in-time monopolies to holders of IP.[82] How much would you pay for the *right to use information*? The answer: Probably a lot. One sees why we insist that the interpretation of "material" is linchpin to ABS (see Section 1). The category mistake extends to the valuation of genetic resources.[83]

Equivocation of tangibles with intangibles is not the only fallacy seeded in Simpson's prose. His voice is one of authority, which is fitting for the lead author in the *Millennium Ecosystem Assessment*.[84] The readers may thus be susceptible to the fallacy of authority: reliance on the opinion of an authority *in lieu* of the merit of the argument. Simpson fertilizes the field by chastising conservationists for not appreciating "basic economics".[85] He indicates matter-of-factly that "Economists argue that value is determined by scarcity."[86] The assertion hinges on the meaning of value. A low price does not equate with low value as Adam Smith pointed out in *The Wealth of Nations* (1776):

> The word VALUE, it is to be observed, has two different meanings, and sometimes expresses the utility of some particular object, and sometimes the power of purchasing other goods which the possession of that object conveys. The one may be called "***value in use***" and the other "***value in exchange***". Nothing is more useful than water; but it will scarce purchase anything. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequent be had in exchange for it (bold added).[87]

Nobel laureates Paul A. Samuelson and William D. Nordhaus explain the paradox to first-year students: "the total utility from water consumption does not determine its price or demand. Rather, water's price is determined by its *marginal* utility, by the usefulness of the *last* glass of water" (italics in original).[88] The explanation requires expansion. The marginal utility of water combined with an abundance of water results in a low price and a large consumer surplus, i.e., the utility derived beyond that attainable from other goods at the same price. Should part of that value be extracted as rent?

Context matters. Nothing is more contextual than the environment. Given the hydrologic cycle and a stable human population in pre-industrial 18th century England, extraction was not then needed to assure a future supply

78 M. Ruiz Muller, J.H. Vogel, K. Angerer and N. Pauchard, "Access to Genetic Resources and Benefit-Sharing" in the Post-2020 Global Biodiversity Framework", Op-Ed, *Enhanced Integrated Framework* (EIF) (11 December 2019). Available at https://trade4devnews.enhancedif.org/en/op-ed/access-genetic-resources-benefit-sharing

79 R.D. Simpson, Note 77, 2.

80 R.D. Simpson, Note 77, 4

81 Members and Observers, World Trade Organization (25 May 2020). Available at https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm

82 Who we are, World Trade Organization (25 May 2020). Available at https://www.wto.org/english/thewto_e/whatis_e/who_we_are_e.htm

83 A "category mistake" is defined as "the mistake of applying a predicate appropriate to a certain kind of object to an object of a different (and inappropriate) kind". J. Woods, *The Death of Argument: Fallacies in Agent Based Reasoning* (British Colombia: Springer Science + Business Media Dordrecht, 2004): 306.

84 Patrick ten Brink incorporates Simpsons' empirical results in Chapter 5 of TEEB-*The Economics of Ecosystems and Biodiversity for National and International Policy Makers*. "To the dismay of those who believe that genetic resources are a global resource of high value, these estimates come out rather low. A key earlier study (Simpson et al, 1996) calculated values of genetic resources in 1996 prices at between US$ 0.2/hectare (California) and US $20.6/hectare (Western Ecuador) and argued that these estimates could be on the high side. Other studies making the same point include Barbier and Aylward (1996) and Firn (2003)", "Chapter 5: Rewarding benefits through payments and markets", TEEB – The Economics of Ecosystems and Biodiversity for National and International Policy Makers, (2009): 35. Available at https://www.cbd.int/doc/case-studies/inc/cs-inc-teeb.Chapter%205-en.pdf

85 R.D. Simpson, Note 77, 74.

86 R.D. Simpson, Note 77, 74.

87 Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Vol. 1, Chap. 4:29. Edited by James E. Thorold Rogers 1869 [1776]. Available at https://archive.org/details/inquiryintothena030768mbp

88 Samuelson and Nordhaus, Note 14 , 95

of water. The consumer could rightfully enjoy the surplus. But the validity of a conclusion depends on the conditions of the premise being true (Table 1). Are genetic resources today like water in 18th century England, i.e. essentially a **free good**? Mass extinction in the 21st Century warrants extraction of rents to incentivize conservation. The case for rents is not just about "who gets what?" It is also about "how much will there be?"

Rent is payment in excess of the price that would obtain if markets were perfectly competitive. The delegation of Ecuador proposed the issue of rents at COP9 in 2008. Rents formally entered Decision IX/12 but vanished en route to COP10 in 2010.[89] The most recent iteration of the economic argument is the aforementioned OP-Ed from Ruiz Muller *et al*:

> When competition ensues over information, many would-be innovators wait to copy what others have invented. The strategy avoids the fixed costs associated with creation. Should enough suppliers so free ride, the market price will plummet and innovators will not be able to recoup the fixed costs of the invention.
>
> Recognizing the inefficiency and inequity of such outcomes, governments institutionalized monopolies over human-made information – i.e. artificial information – through limited-in-time intellectual property rights.
>
> The same logic can apply to genetic resources. Just as governments incentivize the creation of artificial information—for example innovations and creations—through intellectual property rights, governments can incentivize the conservation of natural information through ABS. Because natural information is diffused across jurisdictions, the protection must be oligopolistic rather than monopolistic.[90]

The Naturalistic Fallacy

The naturalistic fallacy is to mistake what is for what ought to be. The price of genetic resources *is* low under the modality of bilateralism – an indisputable fact – but that does not mean the price *ought* to be low. The fallacy is committed whenever stakeholders deride the expectation of billions of dollars in royalty income as a "pipe dream"[91] or somehow "speculative"[92]. It is neither.

Extraction of rents is not confiscation, as Simpson suggests with "the supply seems 'unlimited'". Like the ocean around us and the sky above us, what species seem is not what species are. The argument for rents hinges on resources being limited over time. Indeed, were they unlimited, no need would exist for the CBD or the Nagoya Protocol. E.O. Wilson expresses frankly the psychology of economists: "They know that humanity is destroying biodiversity. They just don't like to spend a lot of time thinking about it."[93] That assessment, rendered in 2002, is thankfully dated in 2021 by *The Economics of Biodiversity: The Dasgupta Review*.[94] However, the 600-page distillation still does not include any probing discussion of ABS.

The Panoramic View

Summits allow sweeping vistas. Simpson claims eagle-eye vision. He and his colleagues at Resources for the Future have calculated the value for pharmaceutical bioprospecting at $2.29/hectare-year in the hottest biodiverse "hot spot" in the world, viz. the Chocó biome of Ecuador.[95] Advocates of the opposing economic framework deride such attempts as vaulting ambition.[96] They embrace the closing remarks of David Ehrenfeld in the landmark 1988 anthology *Biodiversity*,

> [I]t is not possible to figure out the true economic value of any piece of biological diversity, let alone the value of diversity in the aggregate. We do not know enough about any gene, species, or ecosystem to be able to calculate its ecological and economic worth in the larger scheme of things... I cannot help thinking that when we finish assigning values to biological

89 "Requests the Executive Secretary to invite, in consultation with the Co-Chairs of the Working Group, relevant experts to address the Working Group on Access and Benefit-sharing, at the appropriate time, on the following issues: Should economic rent be charged for access to genetic resources and what is the justification for such a rent or against such a rent? What should be the basis for the valuation of such rent?" CBD Secretariat COP9 Decision IX/12: Access and benefit sharing (2008). Available at https://www.cbd.int/decision/cop/default.shtml?id=11655

90 Ruiz Muller et al., Note 78, 65.

91 D.K. Prathapan and PD. Rajan, "An Open Access System for Genetic Resources to Facilitate Transboundary Exchange of Genetic Resources and Associated Knowledge to Promote Biodiversity Research, Conservation and International Collaboration. In response to NOTIFICATION for Submission of views and information further to decisions NP-3/13 on Article 10 of the Nagoya Protocol (SCBD/NPU/DC/VN/KG/RKi/87805)" (30 June 2019). Available at https://www.cbd.int/abs/submissions/Art10/2019/Prathapan-Priyadarsanan.pdf

92 J.H. Vogel, "Peer Review of The Emergence and Growth of Digital Sequence Information in Research and Development: Implications for the Conservation and Sustainable Use of Biodiversity, and Fair and Equitable Benefit-Sharing – A Fact-Finding and Scoping Study Undertaken for the Secretariat of the Convention on Biological Diversity" (2017): 2. Available at https://www.cbd.int/abs/DSI-peer/Vogel,%20UPR.pdf

93 E.O. Wilson, *The Future of Life* (New York, Vintage Books, 2002): 28

94 P. Dasgupta, *The Economics of Biodiversity: The Dasgupta Review* (London: HM Treasury, 2021).

95 D.R. Simpson, R.A. Sedjo and J.H. Reid,"Valuing Biodiversity for Use in Pharmaceutical Research", *Journal of Political Economy,* vol. 104, issue 1 (1996): 163-185.

96 Many estimations exist. The fact that they vary by orders of magnitude should give pause to economists and non-economists alike. See Table "Estimated Medicinal Value of Plants", R.K. Dronamranju, *Biological Wealth and Other Essays* (New Jersey: World Scientific Publishing Co., 2004): 145.

> diversity, we will find that we don't have very much biological diversity left.[97]

We acknowledge that dismissal of a question is bad form. But exceptions exist. Valuation is one of them. So, to the question of valuation of genetic resources for R&D,

> [T]he answer is beyond our lens of resolution and reflects a poor choice of questions. One should be asking: Does probable cause exist to justify public investment in the infrastructure needed to enable a market in genetic resources? Anecdotal evidence such as *Thermus aquaticus*, a microorganism that resulted in a billion-dollar industry worldwide, suggests that it does.[98]

T. Aquatics is not unique. Other blockbusters that derive from genetic resources include Vinblastine and Vincristine (Rosy Periwinkle), the peptide Ziconotide (Conus snails), and Taxol (*Taxus brevifolia*).

Rents from a "market in genetic resources" would be extracted to offset the opportunity costs of conservation and facilitate acceptance of limits on land use. The point was made early in the ABS debate and even vetted in The White Paper for the 1996 Summit of the Americas on Sustainable Development:

> People should pay, not because habitats must compete with timber, cattle, and dams, but because there is tremendous political pressure by the vested interests behind timber, cattle, and dams to encroach on protected habitats. The generation of revenues from the sustainable use of biological diversity can create countervailing pressures.[99]

Cases Morph into Thought Experiments

The OP-EDs of Simpson and Ruiz Muller et al., have one thing in common: both are deductive arguments. The commonality is not surprising. Economic analyses are seldom inductive. The task at hand demonstrates why: How can one assemble case studies on alternative modalities of fair and equitable ABS when no such case has ever happened? Open access, subscription fees and multilateral-benefit schemes have never been applied to genetic resources for the objectives of the CBD and Nagoya Protocol. The only way to square the circle is through thought experiments. What if a case eventuated under one or more of the alternative modalities? Indulgence is required. The cases are morphed by what could have occurred. Tweaked scenarios can be explored deductively.

The methodology has antecedents and enables deductive reasoning. The SPDA performed a thought experiment in its 2019 submission to the UN Secretariat of the CBD. The title was also its central message: "Even best case for bilateralism supports need for a Global Multilateral Benefit-Sharing Mechanism: Common ground in 'bounded openness over natural information' as the modality for ABS".[100] The submission drew on an earlier thought experiment about the poison dart frog *(Epipedobates anthonyi)* (Box 4).

Box 4.

Deadly brilliance and serendipity in discovery

The poison-dart frog (*Epipedobates anthonyi*) exhibits many chemical curiosities. The one which resulted in patent US11969793A has only been found in two populations over a brief timespan.[a] Had the discovery occurred after the 1993 CBD, one may think that jurisdiction shopping would not be an issue as there would have been nowhere else to shop but Ecuador, where the populations were located. However, one would be mistaken: the scientists involved have said that they always entertained the possibility of seeking access to alkaloids in other frog species, even from other continents. Over the years several hundred amphibian and insect alkaloids have been discovered.

Reasons other than jurisdiction shopping also support the need for a Global Multilateral Benefit-Sharing Mechanism. The reader may have deduced one from the information just provided. The period of time to conclude an MTA/ABS could outlast the ephemeral presence of a chemical curiosity. In the case of *E. anthonyi*, John W. Daly, the chemist who lead the research team, did not know exactly what to look for until the team was in the field. Another is serendipity. Response to contingency may be universal to creative minds. E.O. Wilson writes. "Creative minds do not always know from where they will be inspired. When it occurs, they also do not know exactly where that inspiration will lead."[b]

a Klaus Angerer, "*Epipedobates anthonyi* under 'bounded openness' " in M. Ruiz Muller, *Genetic Resources as Natural Information* (London: Routledge, 2015): 98-109

b E.O. Wilson "Chapter 26: The Origin of the Creative Arts": "Flannery O'Connor asked, correctly, for all of us, literary authors and scientists, "How can I know what I mean until I see what I say?", *The Social Conquest of Earth*, New York: W. W. Norton, 2012, p. 275.

97 D. Ehrenfeld,"Why Put a value on Biodiversity?" in E.O. Wilson, ed., *Biodiversity* (Washington D.C.: National Academy Press, 1988): 212.-216

98 J.H. Vogel, Note 33, 47-74.

99 Vogel, J.H. "White Paper: The Successful Use of Economic Instruments to Foster the Sustainable Use of Biodiversity: Six Cases from Latin America and the Caribbean", Biopolicy Journal vol. 2, Paper 5 (PY97005) (1997). Available at http://www.bioline.org.br/request?py97005

100 In response to Notification for Submission of views and information further to decisions NP-3/13 on Article 10 of the Nagoya Protocol (SCBD/NPU/DC/VN/KG/RKi/87805). Joseph Henry Vogel, Manuel Ruiz Muller, Klaus Angerer and Nicolas Pauchard (28 June 2019). Available at https://www.cbd.int/abs/art10/2019-2020/default.shtml; English: https://www.cbd.int/abs/submissions/Art10/2019/SPDA-EN.pdf

5. Cases as "Thought Experiments"

Detailed descriptions of four cases are included in Appendices I-IV of this Report. In this section, we analyze each case using theoretical constructs from economics and psychology to analyze what could have eventuated had circumstances been different. Economic concepts include excess burden, fungibility, The **Ramsey Rule** and The **Theory of Second Best**. Psychological concepts span cognitive dissonance, dominance hierarchies, perseverance and **taboos**. The fallacy of **sunk costs** straddles economics and psychology.

5.1 Naked mole-rat (*Heterocephalus glaber*)

Key messages

- R&D often requires access to physical samples despite dematerialization;
- Value in exchange is a fraction of value in use for life-saving drugs;
- Only Modality 3-II and Modality 4 afford rents;
- Royalties under Modality 3-II will be passed on because demand is inelastic, excess burden will be minimal and the fungibility problem not present;
- Any fee under Modality 4 will incur heavy excess burden and present the fungibility problem;
- Obligations for benefits *ex post* successful commercialization eliminates transaction costs for dead ends in R&D.

The naked mole-rat (*Heterocephalus glaber*) epitomizes several issues highlighted in Table 2, viz., "'Material' in Article 2 of the CBD", "*Ex Situ* Materials Collected Prior to CBD" and "Material collected in a "transboundary situation"", respectively Issues # 6, 10 and 11. The case illustrates how Users can avoid sharing benefits for any genetic resource dematerialized from an *ex situ* source, collected prior to the 1993 CBD or deposited in the non-Party (see Box 5). The unusual biology of the naked mole-rat makes its genome a cornucopia for research on human disease with huge commercial potential. In Appendix I, Anna Deplazes-Zemp organizes the information on the naked mole-rat according to the template of Appendix V.

Source: Roman Klementschitz, Wien, CC BYSA 3.0 via Wikimedia Commons

Box 5.

A Grand Bargain with *Ex Situ* Collections? †

What is transferred in a Material Transfer Agreement (MTA) depends on the agreement negotiated. MTAs are bailments, which means that possession of the "material" is transferred but not the title. "Material" is legally interpreted as tangible, where associated information falls under the licensing provisions.[a] Hybrid contracts concerning matter and information characterize most MTAs.

A synthesis of economics and chemistry invites a thought experiment: denature the material transferred in an MTA and then perform R&D. By the First Law of Thermodynamics, the sample will have retained all of its matter, but by the Second, much of the associated information will be lost. One deduces that the "material" in an MTA should not be interpreted as matter, though legally it is. The value lies in the information as the matter would still be there upon denaturation. A corollary exists: a sample returned in a pristine state to the property owner can also have lost all value in exchange, similar to denaturation, as the owner no longer has any leverage over granting access to the information therein.[b]

Ex situ collections with non-hybrid MTAs cannot engage in R&D without violating the safety of the valuable property, which is a criterion for the bailment: "the personal property of one person is acquired by another and held under circumstances in which principles of justice require the recipient to keep the property safely and return it to the owner".[c] However, legal uncertainty will most likely ensue for all MTAs negotiated before the ratification of the CBD in 1993. Few Users and Providers anticipated the meteoric rise of biotechnology. Ambiguity is expected in the provisions.

Evaluation of MTAs will be, above all, time consuming. In 1992, E.O. Wilson wrote that three species were being lost each hour.[d] Mass extinction has only worsened since. Modality 3-II can only align incentives if the object of conservation exists. Users and Providers must settle the status of *ex situ* collections while there is still time. A grand bargain emerges which could leave both Users and Providers agreeably unhappy: *Ex situ* collections prior to the ratification of the CBD would participate as a group in ABS, where the percentage participation would be equivalent to the geographic area to support a "minimum viable population".[e] The group would then split their share of royalty income among members with the same pre-1993 specimens.

a B.A. Garner, ed., BAILMENT, *Black's Law Dictionary.* 11th ed. (2019); A.B. Bennett, W.D. Streitz and R.A. Gacel, "Specific Issues with Material Transfer Agreements", in A. Krattiger, R.T. Mahoney, L. Nelsen, et al. (eds), *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices* (Oxford, UK: MIHR, 2007).
b Arrow's Information Paradox. Investopedia. Available at https://www.mbaskool.com/business-concepts/marketing-and-strategy-terms/12644-arrow-information-paradox.html
c 8A Am. Jur. 2d Bailment § 1 (1997).
d E.O. Wilson, *The Diversity of Life* (Washington D.C.: Island Press, 1992): 280.
e Carey L. Vath, "Minimum Viable Population: ecology" *Britannica*. Available at https://www.britannica.com/science/minimum-viable-population

†Special thanks to Professor Stanley P. Kowalski.

Even one facet of a case can offer a panoramic view. Consider the utilization of resources derived from the naked mole-rat in drug discovery. Patent application US 2014248371 is titled "Spalax fibroblast-derived anti-cancer agents".[101] The invention is a utilization for the treatment of breast cancer. Although the naked mole-rat is emblematic of dematerialization, the object of access in US 2014248371 was not dematerialized. The invention is comprised of the conditioned cell culture derived from a specimen, which illustrates the resilience of demand for the biological medium. As we will see in the case study of Ebola (Appendix IV), *digitalization will displace physical samples only when feasible*.

Economics can make sense of how the alternative modalities impact utilization. To measure impacts, one must first measure the value of the utilization. For the indirect utilization of the genetic resource as a tool in the R&D of a "breast cancer treatment", what is the value in exchange of the end product, i.e., "breast cancer treatment", had the genetic resource been *non-substitutable* in R&D? Although the value added in the actual case was just for a cell culture, one could easily imagine a scenario where the genetic resource was the principal agent in drug development.

The latest commercial statistics on breast cancer treatments are for the year 2017 when the global market was $17 billion.[102] However, that statistic does not capture the value in use. The paradox identified by Adam Smith almost two and a half centuries ago is still relevant. Just as water is essential for human survival, so too is medical treatment for cancer patients. Ask yourself: how much would you be willing to pay if you were diagnosed with breast cancer? If having difficulty with that question, then try this one: how would you aggregate willingness to pay for everyone who is so diagnosed?[103] Rather than grapple with consumer surplus, economists quantify a more tractable value, which is nonetheless challenging: the positive external effects of life extension. They call it social value.

A rigorous model was published for chronic myeloid leukemia (CML) that can serve as a proxy for any life-saving drug, including breast cancer treatment. The thought experiment for the naked mole-rat therefore requires a scaffolding of assumptions. What occurred with CML could conceivably have occurred with the naked mole-rat, though it did not. In the case of CML, a team of economists and scientists has shown that tyrosine kinase inhibitors (TKI) created "over $143 billion in present discounted social value. Approximately 90% of this value will be derived from survival gains to be retained by patients and society, while [approximately] 10% will be recouped by drug companies".[104]

With the expiry of a patent and entry of generics, the value in exchange drops. To continue with TKI as the proxy for any life-saving drug, including those for breast-cancer treatment:

> In the U.S., the second-generation TKI nilotinib has a base price of $152,814 and dasatinib has an annual cost of $230,000. By comparison, the average price of generic imatinib in the U.S. is $35,000 per year with a lowest cost of $4,400 annually. In Europe, generic imatinib costs $4,000 (U.S.) per year, and in developing countries, the price falls to $2,100 (U.S.) annually.[105]

Recapping: the cost *per* patient of TKI ranges from $230,000 to $2,100 per annum for near substitutes. The lowest price reflects the marginal costs of production as well as recovery of the fixed costs in local marketing and regulatory approval. Rents have been eliminated through competition. The highest price reflects the remarkable resilience of rents to market forces, perhaps due to the loyalty of the prescribing physicians to branding strategies. When genetic resources are utilized in a life-saving drug, the question for ABS becomes: can Providers of genetic resources also secure significant rents? Or would securement reduce *pari passu* the rents of Users? Perception of the answer depends on the persuasive power of economics versus psychology.

101 "Spalax fibroblast-derived anti-cancer agents", Carmel Haifa University Economic Development Ltd.. Available at https://patents.google.com/patent/US20140248371A1/en

102 Grand View Research. Breast Cancer Drugs Market Size, Share & Trends Analysis. Report by Type (Hormonal Receptors, Mitotic Inhibitors, HER2 Inhibitors, Anti-metabolites, CDK 4/6 Inhibitors), by Region, and Segment Forecasts, 2019 – 2025. Available at https://www.grandviewresearch.com/industry-analysis/breast-cancer-drugs-market

103 Economists phrase the question "How much are we willing to spend to reduce the odds of dying? The most recent estimate for the value of statistical life in the USA is $10 million." A. Thomson-Devaux, FiveThirtyEight "What Should the Government Spend To Save A Life?" Available at https://fivethirtyeight.com/features/what-should-the-government-spend-to-save-a-life/ For a user-friendly explanation of consumer surplus, see R. Muley, Consumers Surplus: Concept, Measurement and Limitations. Available at https://www.economicsdiscussion.net/consumers-surplus-2/consumers-surplus-concept-measurement-and-limitations/16728

104 Wesley Yin, John R. Penrod, J. Ross Maclean, Darius N. Lakdawalla and Tomas Philipson, "Value of Survival Gains in Chronic Myeloid Leukemia", *The American Journal of Managed Care* vol. 18, issue 11 (November 2012): S257

105 K. Jenkins, "Reducing the Cost of Frontline TKI Tx in CML" Medpage Today (28 August 2019). Available at https://www.medpagetoday.com/reading-room/asco/hematologic-malignancies/81836

Consider the economics.[106] The fact that only 10% of the social value of TKI was recouped by industry, means that prices are in the inelastic range of demand.[107] Inelasticity means that the quantity demanded adjusts little when prices rise. The incidence of a royalty would be borne mostly by the patient or the insurer, i.e., not by industry. Rents so obtained by Providers are not subtracted from Users. In the long run, one may also argue that Users benefit because rents incentivize Providers to conserve genetic resources. A bonus for the pharmaceutical industry would be favorable public relations.[108]

Now consider the psychology. Users and Providers perceive themselves in conflict. By COP14, the metaphors had become war-like.[109] The mental framing of Users *versus* Providers biases the perception of outcomes as if they were zero sum. In such scenarios, rents become **taboo** as is "natural information" to which they are closely associated. The bias is reinforced by **nested dominance hierarchies**, whereby arguable positions are not questioned within and among Parties or stakeholder groups.[110]

In the mindset of win or lose, numbers grab attention and fire neurons. Abstractions do not. The drop in the annual cost of TKI from $230,000 to $2,100 per patient-year is more impactful than the consumer surplus of a life saved. Would that not be so! Indeed, the value in exchange pales against the value in use, especially when the patent expires. With the expiry and subsequent mass production of generic substitutes, the aggregate value in use soars globally. People are no longer priced out of access. Hundreds of millions become beneficiaries. Seen in this light, the time-limited monopoly rents engender equity, albeit lagged by the duration of the patent. The system transfers wealth to poor people in poor countries. Charles R. McManis reminds critics of IPR that,

> a largely overlooked justification for both IPRs and ABS is that they not only create incentives to disclose innovation and sustainably use genetic resources for the benefit of the present generation, i.e. strategic reciprocity, but also function to make a gift of those innovations and conserved resources for the benefit of future generations.[111]

Just one facet of the thought experiment illustrates how much value is at stake should benefit sharing encumber access to genetic resources. What the thought experiment reveals, actual experience cannot. Recall that the patent application US2014248371 was abandoned. Does abandonment invalidate any lessons from the actual case? By reasoning strictly inductively, the answer would be "Yes – this is all hypothetical". Does abandonment invalidate the thought experiment? By deductive reasoning, "No". One imagines that the price trajectory of "Spalax fibroblast-derived anti-cancer agents" would have followed the same course as TKI had it been not just a cell culture but a principal agent in a blockbuster life-saving drug.

An irony emerges which points again to the merit of case studies. The abandonment of the patent allows the viewer to shift angles and expose another sweeping vista. In the abandonment, the applicants did not commit the fallacy of sunk costs, i.e., they accepted the loss. The expected benefit of pushing the compound through the R&D pipeline was deemed less than the costs expected from that moment forward. Abandonment is supremely rational – a lesson stressed in introductory economics – but no less painful. In both the reason and the pain, lie many lessons for Parties and stakeholders.

Whereas commission of the fallacy of sunk costs can ruin a commercial endeavor, nothing analogous happens in the COP. On the contrary, Parties and stakeholders can invoke *stare decisis* and kick the can down the road. And they do, COP after COP. Other homilies are apropos. Advocates of "bounded openness" have repeatedly deployed the Turkish proverb "no matter how long you have gone down the wrong road, turn back".[112]

106 The economics is exactly the same as if the royalty were a tax. T. Seth, Consumer's Surplus: Meaning, Criticism and Importance of Consumer's Surplus. Available at https://www.economicsdiscussion.net/articles/consumers-surplus-meaning-criticism-and-importance-of-consumers-surplus/1489

107 "Elasticity versus inelasticity: What's the difference?" Investopedia. Available at https://www.investopedia.com/ask/answers/012915/what-difference-between-inelasticity-and-elasticity-demand.asp

108 Jesse Drucker, David Gelles, Katie Thomas,"Covid-19 Vaccines Are Chance at Salvation, Financial and Beyond, for Drug Makers" *The New York Times* (14 October 2020): B1.

109 "But Rohden warned it would be a mistake for scientists to assume the *status quo* – a belief that open sharing of sequence data is the norm and the goal – will ultimately prevail in this process. Too many of the stakeholders in the discussions see the inclusion of sequence data 'as the hill they want to die on', he said. 'They are really making this the key issue.'" Branswell, H. "Science with borders: A debate over genetic sequences and national rights threatens to inhibit research." STAT (14 January 2019). Available at https://www.statnews.com/2019/01/14/science-with-borders-a-debate-over-genetic-sequences-and-national-rights-threatens-to-inhibit-research/

110 Indulgences for mistakes made at the top of the hierarchy result in what is known as "X-inefficiency". Investopedia. Available at https://www.investopedia.com/terms/x/x-efficiency.asp Correction is resisted as "the right answer must not come from the wrong person", "Primate Economics 101" Book Review of Stephen A. Marglin's *The Dismal Science: How Thinking Like an Economist Undermines Community*. J.H. Vogel, G. Lamboy and F. Tormos-Aponte, Evolutionary Psychology vol 8, issue 2 (3 May 2010): 189-193. Available at https://journals.sagepub.com/doi/full/10.1177/147470491000800204

111 C.R. McManis, "The Moral Foundations of Intellectual Property and Conservation Through Access and Benefit-Sharing" in J. H. Vogel, ed. *The Museum of Bioprospecting, Intellectual Property and the Public Domain* (London" Anthem Press, 2010): 82-83.

112 The proverb both opens and closes *Genetic Resources as Natural Information*, M. Ruiz Muller, Note 60, 5 and 97.

Box 6.

"Cooperation": Fraught and Elusive

"Cooperation" appears thirteen times in the CBD and is the one-word title of its Article 5. "Cooperation" appears twelve times in the Nagoya Protocol and is modified by "transboundary" in the title of its Article 11. Under the Vienna Convention, one may interpret "cooperation" as "working together toward a shared end".[a] The provisions of Article 5 of the CBD qualify "cooperation" with "as far as possible and as appropriate" or "where appropriate". More forcefully, Article 11 of the Nagoya Protocol reads "shall endeavor to cooperate". Although the qualifiers in both treaties render "cooperation" non-enforceable, the "shall" in the NP makes "endeavor[ing]" binding. From the context and purpose of the CBD and NP, one can infer that the "shared end" of "shall endeavor to cooperate" is "fairness and equity" in ABS, which in turn can be interpreted as equal treatment of rents in artificial and natural information.

Normal diplomatic relations are necessary for cooperation. One cannot work together if one cannot officially talk. In contrast to the recurrent tensions between many countries that share biomes, say, India and Pakistan, mega-diverse Brazil has enjoyed amicable relations with its neighbors in the Amazon basin. Yet there is no known MTA/ABS from Brazil that demonstrates any "endeavor to cooperate" since the CBD went into force as international law on 29 December 1993. Moreover, the 2015 Brazilian ABS legislation preempts cooperation by fixing the range of royalty percentages, which is the only commensurable benefit of any bilateral negotiation. Inasmuch as Brazil signed the NP on 2 February 2012, the aforementioned national legislation appears to have violated Article 18 of the Vienna Convention, which is titled "Obligation not to defeat the object and purpose of a treaty prior to its entry into force" (italics added).[b]

Brazil is not an outlier. Evidence of non-cooperation also comes from the non-compliance of members of the Andean Community. The 1996 Decision 391 is titled "Common Regime on Access to Genetic Resources". Title 2(e) exhorts "[s]trengthen[ing] the negotiating capacity of Member Countries" and the Final Provisions, "bear[ing] in mind the interests of other Member Countries".[c] As of this writing, no Member country has ever concluded a bilateral contract in cooperation with any other Member country.

a Cooperation, *Oxford Learner's Dictionary*, accessed on 12 September 2019, available at https://www.oxfordlearnersdictionaries.com/definition/english/cooperation?q=cooperation. In the context of ABS, the definition of cooperation from the Oxford Learner's Dictionary is clearer than the second entry for cooperation in *Merriam-Webster Dictionary*, accessed on 12 September 2019, available at https://www.merriam-webster.com/dictionary/cooperate

b Vienna Convention, Article 18. Available at https://www.oas.org/legal/english/docs/Vienna%20Convention%20Treaties.htm

c Andean Pact, 1996, available at http://www.wipo.int/wipolex/en/text.jsp?file_id=223610

The panoramic vista of drug discovery also exposes a hidden cost of bilateralism: Possible treatments may have forever been precluded by the high transaction costs of MTA/BSA. In light of the possible extinction of a principal agent in a life-saving drug (Box 4), *any of the alternative modalities is vastly superior to Modality 1, i.e., Nagoya – Bilateral Benefit-Sharing*.[113] The question of which is best reduces to how one weighs the issues of Table 2. Given the objectives of conservation and sustainable use, rent becomes the preponderant issue.

The absence of rents is almost tautologous in Modality 5 ("Free Access – Capacity Development"). Modality 2 ("Open Access – Bilateral Benefit Sharing") implicitly eliminates rents through competition. Modality 3-I (Open Access – Multilateral BS" Variant "Common Pools") also eliminates rents to the extent that common pools compete. Given that most species utilized in patents have been cosmopolitan and that countries have not cooperated on ABS, one may safely assume that common pools would compete (Box 6).[114] Only Modality 3-II ("Open Access – Multilateral BS") and Modality 4 "Open Access – Subscription fee / Levies" afford the possibility of capturing rents.

Imagination is required for analyzing what might have been the impact of Modality 3-II on "Spalax fibroblast-derived anti-cancer agents". Imagine that the treatment from US2014248371 were as commercially successful as TKI. Given the inelasticity of demand for life-saving drugs, the COP would probably have been able to negotiate a significant royalty percentage for that class of utilization.[115] Imagine that the royalty negotiated was 3% under Modality 3-II. On $16 billion of revenues, some $480 million of royalties would flow into the coffers of the Fund for the GMBSM.[116] How would ithey flow out?

Claimants would have to be determined scientifically; a budget to do so would not be lacking. Scientists would establish whether the cells used in the patented discovery were unique to the individual specimen of the naked mole-rat used by the patent applicants or to the population from which the specimen was drawn. If the latter were established, then scientists would have to establish whether the cells were common among randomly sampled individuals from diverse populations of the species. If common across all populations, then the steps would be repeated with related species and so on. In the case of the naked mole-rat, that would mean sampling the blesmols of South Africa.[117]

Let us also imagine that such cells are found from all populations of the naked mole-rat, but from none of the populations of blesmols. The taxonomic search outward can then stop. The science now turns to determination of the geographic distribution of the known populations of the naked mole-rat. Detailed maps exist but are not definitive, as the following excerpt from the IUCN indicates,

> This species is found throughout most of Somalia, central Ethiopia, and much of northern and eastern Kenya, extending as far south as the eastern border of Tsavo West National Park and the town of Voi (Jarvis and Sherman 2002). The species has also been recorded from Djibouti (e.g. Pearch et al. 2001) suggesting that the species has a wider range than is presently known. It has an altitudinal range of 400 to 1,500 meters above sea level.[118]

Once the geography is established, how would the money be divided among countries? Within countries? And how would it be spent? In answer to the first question: The share of the money for each country is proportional to the geographic size of the habitat in that country to the total habitat worldwide. Periodic monitoring would be required as changes in land use or climate will change those proportions. Similarly, the GMBSM would have to be receptive to new findings of diffusion beyond the taxon identified. Incentives are thus aligned for conservation. The third question entails **sovereignty**.[119] Under Modality 3-II, countries may spend the money however they see fit. One thinks economically: The State should always spend the money according to the highest social return, which for many countries are water projects and sewage systems. Incentives for conservation are thus aligned under Modality 3-II regardless of whether or not the Provider spends the money on conservation.

113 To avoid equivocation, we refrain from using the phrase "open access" to describe modalities other than the fifth in the First Global Dialogue on DSI.

114 See Note 63.

115 Feasibility depends on the elasticities of demand in commercial utilization. For example, the high elasticity for crop varieties would mean a low royalty and render uneconomic any disbursement through the GMBSM. However, a low elasticity for, say, horse breeds would mean a high royalty and render economic the disbursement. See, Joseph Henry Vogel (ed) *The Biodiversity Cartel, CARE Quito, Ecuador, 2000; and Haley McClory and Stanley P. Kowalski, "Horses as Sources of Proprietary Information: Commercialization, Conservation, and Compensation Pursuant to the Convention on Biological Diversity", AgBioForum*, vol. 17 issue 2 (2014): 141-155.

116 Because of the inelasticity of demand, the pharmaceutical industry would have been able to pass on the $480 billion to patients or insurers or governments, thereby raising their revenues from $14 billion to $14.5 billion..

117 Darren Naish, "African Mole-Rats: So Much More Than Just the Naked Mole-Rat", Scientific American (22 March 2016). Available at https://blogs.scientificamerican.com/tetrapod-zoology/african-mole-rats-so-much-more-than-just-the-naked-mole-rat/

118 Text Summary, Red List, IUCN. Accessed on 15 February 2021. Available at https://www.iucnredlist.org/species/9987/115095455

119 Critics of "bounded openness" often argue that any multilateral system would violate sovereignty. Ironically, Modality 3-II is an expression of Provider sovereignty while bilateralism is a violation whenever benefits are earmarked by the User.

The fungibility problem is a closely related issue (#19 in Table 2). Conservation in many countries is already financed to varying degrees or would be financed with economic growth. By not earmarking, Modality 3-II does not create the problem of fungibility, except perhaps for publicly funded taxonomic institutions. As argued in Section 2.3, the fungibility problem for those institutions, however, would ease the freeriding problem for what is essentially an international public good.[120]

Modality 4 ("Subscription fees / levies") deserves examination similar to 3-II. For other modalities, there is no fungibility problem simply because there are no rents. One suspects that were rents collected through Subscription fees / levies, Parties would expect earmarking for conservation. Modality 4 can secure rents but generates significant excess burden, as intuited by participants in the First Global Dialogue on DSI:

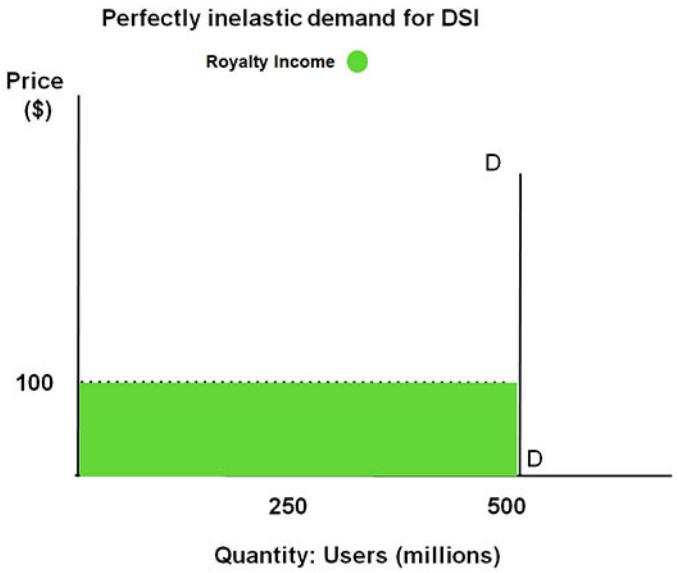
> It was suggested that subscription fees in general would put benefit-sharing burden on scientists and could potentially lead to a high level of dissatisfaction. A subscription option could potentially have unintended consequences for scientists in developing countries if they need to pay for access to sequences.[121]

Analysis of excess burden is warranted. Should the COP wish to obtain rents through subscription fees / levies, what would be the societal effect of raising such income? The answer can be depicted graphically. To achieve *ceteris paribus* in comparing Modality 4 with Modality 3-II, the annual income would have to be the same whether the income were generated from royalties or subscriptions fees / levies. The question remains, How high would the fees / levies have to be?

Any precision would be pretentious and even counterproductive. The numbers hypothesized are for illustrative purposes. Whether they are off by 5% or 50% would not undercut the validity of the argument. Imagine that annual sales in biotechnologies protected by intellectual property are globally $1 trillion per year. Robustness means that the logic holds whether the true figure is $500 billion or, say, $1.5 trillion. Imagine further that the average rent for utilizations is 5% of the value in exchange. One must analyze whether $50 billion in rent, i.e., 5% x $1 trillion, raised through "bounded openness" generates more, the same or less excess burden than would the same $50 billion raised through subscription fees (we will leave levies on equipment aside for now).

Graph 1a. Raising Rents through Subscription Fees

Rents are the green area which is the mathematical product of the price of subscription and quantity of subscribers



How many Users are there? The question is anything but simple. The authors of the commissioned "Combined Study on DSI in Private and Public Databases and DSI traceability" settled on a guesstimate. Inasmuch as the International Nucleotide Sequence Data Collaboration (INSDC) is levered through other platforms "perhaps more than 500 million users [exist] worldwide".[122] Dividing $50 billion by 500 million calculates to a per user annual subscription fee of $100. Assume, for the sake of simplifying the analysis, that demand is perfectly inelastic (the vertical line DD).

Perfect inelasticity is clearly false. Some Users will desist as soon as access is no longer free. We the authors know first-hand. We designed a prototype for the book cover *Genetic Resources as Natural Information* for its Spanish translation. The sequence of the naked mole-rat is embedded in the image of a keyboard (Figure 6). The sequence was

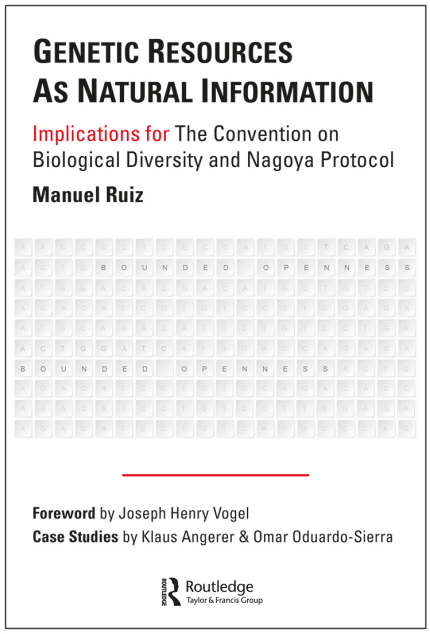
120 Fungibility also has a temporal dimension. "Empowered by a new position of access, ownership and benefit, such countries would, in turn, support CBOL's and iBOL's efforts to create a global library of biodiversity through barcoding techniques. This controversial reversal of roles recognizes the vulnerability of CBOL, iBOL and BOLI, which, as Vogel points out, cannot be sustainably funded by grants forever". C. Waterton, R. Ellis and B. Wynne, *Barcoding Nature: Shifting Cultures of Taxonomy in an Age of Biodiversity Loss* (London and New York: Routledge, London and NewYork, 2013): 96.

121 *Report of the First Global Dialogue*, Note 18, 19.

122 F. Rohden, S. Huang, G. Dröge, A. Hartman Scholz, "Combined Study on DSI in Private and Public Database of the Parties to the Convention on Biological Diversity", Secretariat to the UN CBD (2020): 25. Available at https://www.cbd.int/abs/DSI-peer/Study-Traceability-databases.pdf

down-loaded from The Naked-Mole Genome Resource (http://www.naked-mole-rat.org). Had the site charged a subscription of $100, we would have not used the image. That choice suggests a thought experiment. We would only have registered with the website had the subscription fee been $50. The economist deduces that our consumer surplus was $50 when we downloaded the sequence free of charge. At a subscription fee of $100, we would have desisted. The economist would further deduce that society would have incurred an excess burden of $50 through our non-consumption. How many users of databases are like us worldwide? We suspect that the answer would sweep in millions of students from the developing world.

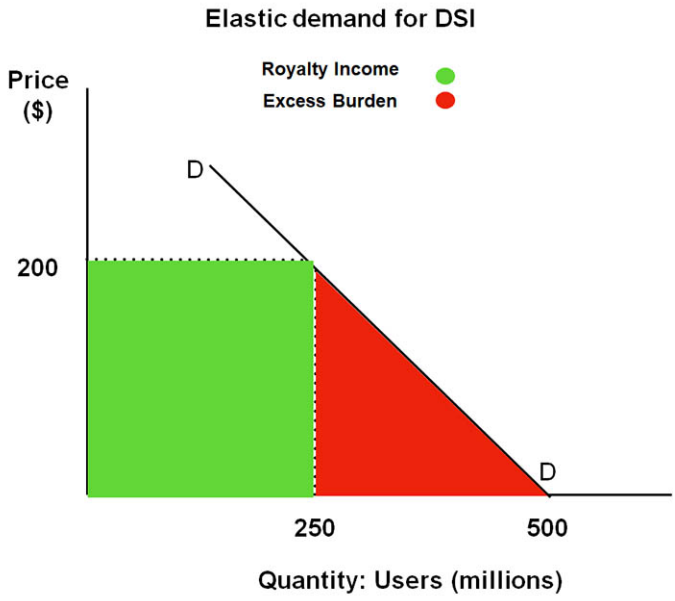
Figure 6. The prototype book cover design in English used in Spanish translation.



Elasticity means that with a lower number of users, the subscription fee must increase to keep the rents at $50 billion. Assume that demand has an elasticity typical of those drawn in the graphs of aforementioned textbook *ECONOMICS*. Graph 2 shows how $50 billion of rent can be secured through raising the subscription price to $200/user-year and forgoing half of the 500 million users. The inequity of subscriptions fees lies in the incidence of the $25 billion of excess burden. Should a student in an impoverished Provider country pay the same fee as would a transnational corporation which enjoys billions of dollars in value added through its limited-in-time monopoly patents? **Price-discrimination** seems like the obvious solution.

However, different prices for different Users open the doors to arbitrage and leakage, i.e., piracy. Users in exempted countries would be tempted to forward downloads to those in the non-exempted countries. Leakage would also shrink the number of paying users which would lead to even higher prices to maintain all things equal in the analysis, viz. the $50 billion of rent.

Graph 1b. Raising Rents through Subscription Fees



The logic of graphs can also be applied to the alternative suggestion of Modality 4: levies on equipment. Levies on new equipment are easier to impose than those on existing equipment. Inasmuch there are orders of magnitude fewer suppliers of equipment than there are of users of DSI, the levy would have to be orders of magnitude greater than the subscription fees. Demand for new equipment would be wiped out. No further analysis of levies is necessary.

Modality 5 ("Free Access – Capacity Development") suffers no excess burden as it generates no rents, similar to Modalities 1, 2 and 3-I. However, Modality 5 is superior to 1, 2, and 3-I because it does not incur transaction costs in negotiating agreements with individual Providers or common pools. Worth highlighting is that *Modality 5 is just as much an expression of sovereignty as are any of the other modalities*.

Economists of a conservative ilk often claim that the wealth created from economic development will bring forth demand for parks, nature reserves and laws to protect endangered and threatened species. No thought experiment

is necessary. We must avoid what E.O. Wilson calls "The Bottleneck".[123] On the road to development, industrialized countries so destroyed habitats that the original landscapes are now often unimaginable. Preventing a repetition of that history explains why the objectives of the CBD are interrelated.

5.2 Cone snails (genus Conus in Conidae)

Key messages

- Abundance of species and redundancy of chemical curiosities in the genus Conus can be extinguished within one century, despite appearances of being a free good;
- A User will shop for the jurisdiction in which the genetic resource can be accessed on the most favorable terms, where ease of access is of primary importance;
- Jurisdiction shopping extends to site location for R&D based on ABS;
- Modality 3-II augments the demand for scientists to work in home country and thereby diminishes brain drain;
- Modality 3-II obviates the concern that young scientists will evade regulations on ABS;
- Rents are justified as the means to offset the opportunity costs of conservation, i.e., relieve the political pressures for alternative land use. For terrestrial species, Parties are rewarded according to the geographic range of the species; for marine species, according to reduction of CO2 pollution beyond existing commitments.

The case of the genus Conus epitomizes some of the same issues examined with the naked mole-rat (e.g., #10 and #11 of Table 2). Given the taxonomic distance between the two species, the overlap is remarkable. What distinguishes the case is jurisdiction shopping (#3). The richness of the genus Conus means that if one of the 830 known species were not accessible, R&D could be re-directed to another species in the genus. In Appendix II, Nicolas Pauchard organizes the information on Conus according to the established template of Appendix V.

The salient lessons of the naked mole-rat also hold for the species of the genus Conus, viz., (1) bilateralism is inferior to any of the alternative modalities, (2) rents are only obtainable through Modality 3-II (bounded openness) or Modality 4 (Subscription fees/levies), however, (3) Modality 4 incurs an unacceptable level of excess burden. What other lessons do the sea snails offer ? Respect for the reader's patience requires that the lesson complement not only those of the naked mole-rat but also those of the sea sponge and the Ebola virus, which are the last cases to be examined. Jurisdiction shopping fits the bill. The issue has three dimensions which are elaborated in the next three sub-sections and then applied to the snail species.

5.2.1 First-Dimension Jurisdiction Shopping

The first dimension is intuitive. The scientist shops for the jurisdiction in which the genetic resource can be accessed on favorable terms. In the race to the bottom, Brazil seems to have already won. The 2015 Brazilian ABS Law permits royalty percentages as low as 0.1%.[124] However, no percentage is lower than zero percent, which is the *de facto* royalty of the non-Parties. As of this writing, the non-Parties are just two: The Holy See and the United States of America.

The USA is not just a marginally better Provider than the Holy See. The USA ranks tenth in the list of most mega-diverse countries.[125] *In situ* sampling in the USA can be complemented by *ex situ* collections within its borders. In legal terms, the medium of a genetic resource in the USA may be private property but the natural information is *res nullius*. This status was tested in Moore v. Regents of University of California.[126] In 1990, the Supreme Court of California ruled that genetic resources belong to no one, even when obtained without informed consent.

The landmark decision presaged what soon became the US position toward the CBD. At the Earth Summit Rio'92, the US delegation echoed the opinion of lobbyists who sent "a barrage of letters to President Bush".[127] G. Kirk Raab, then CEO of Genentech, said to *Nature*:

> I don't believe mixing in industrial property rights is the least bit appropriate. If you dig up a little piece of dirt in Naples... or pick a flower in Ecuador, I don't think there is necessarily a requirement that the country of origin has some predetermined economic rights.[128]

Twenty-seven years have lapsed since the CBD became international law. Not only does the USA appear resolute in non-ratification but aggrieved Parties also have no promising

123 E.O. Wilson, *Future of Life* (New York: Random House, 2002): 22.

124 Brazil: Law No. 13.123 of May 20, 2015, Article 20. Available at http://www.wipo.int/edocs/lexdocs/laws/pt/br/br161pt.pdf

125 R.A. Butler, "The top ten most mega diverse countries", Mongabay (21 May 2016). Available at https://news.mongabay.com/2016/05/top-10-biodiverse-countries/

126 Moore v. Regents of University of California (1990) 51 C3d 120. Available at http://online.ceb.com/CalCases/C3/51C3d120.htm

127 S.A. Greenhouse, "CLOSER LOOK; Ecology, the Economy and Bush", *The New York Times* (14 June 1992): Section 4, 1. Available at https://www.nytimes.com/1992/06/14/weekinreview/a-closer-look-ecology-the-economy-and-bush.html

128 S. Lehrman,"Genentech Stance on Biodiversity Riles Staff" *Nature* vol. 358, issue 97 (9 July 1992): 97.

strategy for recourse. Imagine Raab had legally scooped up some dirt in Italy or picked that flower in Ecuador. Imagine further that he did not utilize either until his return to California. Inasmuch as the genetic resource was not utilized in the country of origin, no crime would have been committed there. Once the samples were utilized in the USA, no crime would have been committed under US jurisdiction. Morten Walloe Tvedt and Tomme Young make this point abundantly clear. They also dash any hope for remedy through the US Lacey Act, which concerns illegally obtained biological material.[129] The skeptic may press: does non-disclosure of intent in Italy or Ecuador constitute fraud? Tvedt and Young note how the distinction between value in exchange and value in use would frustrate any such strategy:

> [E]nforcement may depend on the market value of the items taken, rather than their use value. Under The National Stolen Property Act], for example, the action can be taken only where the 'stolen' material's market value is at least US$ 5000.[130]

One sees just how much the interpretation of "material" is linchpin to first-dimension jurisdiction shopping. As long as the medium is conflated with the information therein, the information will flow rent-free through legal access to the medium.

Although all the alternative modalities may be interpreted such that "material" include information, only Modality 3-II and Modality 4 prevent the race-to-the-bottom among Parties, i.e., the elimination of rents. However, the success of either in capturing rents may encourage more flight to the non-Party. With dematerialization of genetic resources and encryption of data, access would move ever so more online.

Easy avoidance of ABS is so obvious that the other two dimensions of jurisdiction shopping are often eclipsed. Nevertheless, the second dimension is also an existential threat to the CBD. As we shall see, the third dimension, ties into a wider phenomenon and can be alleviated through ABS.

5.2.2 Second-Dimension Jurisdiction Shopping

Second-dimension jurisdiction shopping concerns site location of capital investment in R&D. Transnational operations perceive a safe haven in researching and developing genetic resources in the non-Party. Within a year of the ratification of the 1993 CBD, no words were minced. Manfred Schneider, the chairman of the pharmaceutical giant, Bayer A.G., told *The New York Time*s, "North America [US] has not replaced Germany as a location for business, but there are certain innovative activities which are best performed in the US".[131] Although Bayer A.G. did not re-locate to the USA, the threat was not an empty one. Fast forward some twenty years to the ratification of the NP. As reported in *Nature*,

> The new rules will also present challenges for synthetic biologists, who combine genetic code from many different organisms to create drugs or sensors. This could require dozens of ABS arrangements for a single product, says Tim Fell, chief executive of Synthace, a biotechnology company in London. Such bureaucracy could push European companies to countries – particularly the United States – that are not signatories, he adds.[132]

Ethology teaches that flight is triggered by fear.[133] In an alert titled "The Nagoya Protocol at Its 5th Anniversary: Legal Lessons Learned in the Pharmaceutical, Food and Cosmetics Sectors", Covington & Burling LLP cite three reasons to think twice before acting on such animal spirits,

- Companies must still comply with the ABS laws of provider countries (e.g. India or South Africa). Non-compliance could be sanctioned against subsidiaries or activities in those jurisdictions.
- U.S. headquartered companies often have multiple research sites across the world, including in Switzerland, Korea, or the European Union. Even if only a small part of the R&D is conducted in such a location, authorities may expect the entire product development process to be Nagoya-compliant.
- Carving out the U.S. from a global track-and-trace tool may undermine its effectiveness. For instance, even if all R&D on biological materials has been carried out in the United States, a company may still be asked to provide evidence to that effect.[134]

129 Lacey Act Amendments of 1981. Available at https://www.fws.gov/laws/lawsdigest/lacey.html

130 N.B. The "use value" in the quote should be interpreted as "value in use". "The Stolen Property Act was originally enacted in 1949 and has been amended at least seven times since its original adoption."M. Tvedt and T. Young, "User Country Compliance with the Bonn Guidelines" Pages 21-50 in *Beyond Access: Exploring Implementation of the Fair and Equitable Sharing Commitment in the CBD*, IUCN ABS Series No. 2 (Gland, Switzerland: IUCN, 2007): 25. Available at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.737.2551&rep=rep1&type=pdf

131 N.C. Nash, "Germany shuns biotechnology", *The New York Times* (21 December 1994): D1, D5.

132 See Note 69.

133 I. Eibl-Eibesfeldt, *Human Ethology* (New Brunswick, NJ: Transactions Publishers, 1989): 386.

134 Covington & Burling LLP, "The Nagoya Protocol at Its 5th Anniversary: Legal Lessons Learned in the Pharmaceutical, Food and Cosmetics Sectors", *Life Sciences*

The CEO may ask herself: Is that all there is?

Once in the non-Party, incentives are strong not to take for granted the cherished status of *res nullius*. The logic of collective action holds.[135] Industry will invest, perhaps heavily, in safeguarding the *status quo*. Ever since the 2010 US Supreme Court decision Citizens United versus Federal Election Commission, spending for lobbying elected representatives is limited only by the expectation of the return on investment.[136] Biotechnology lobbies will also enjoy a spill-over effect from sister lobbies in Big Business, which rail against any expansion of the State.[137]

Successful lobbying in the non-Party will be noted by the Parties. Resentment will build. How long will they tolerate losing competitiveness solely for being a Party?[138] For User governments sensitive to the multiplier effect of capital investment, second-dimension jurisdiction shopping may even justify withdrawal from the CBD. Any withdrawal lends to a positive feedback. Calls for a review of the CBD do not bode well.[139]

Modality 3-II is the only modality that addresses second-dimension jurisdiction shopping. To participate in deliberations over royalty percentages for classes of utilization, the USA must be a Party. Modality 3-II may nudge the USA toward ratification as US lobbies bemoan non-participation in the negotiations over royalties. Analogies inspire hope. One notes that US opposition to United Nations Convention on the Law of the Sea (UNCLOS) weakened as the advantages of treaty membership became clear to US industries.[140] The same could happen with the CBD and NP concerning negotiation of royalty rates for categories of utilization under Modality 3-II.

(18 September 2019): 7. Available at https://www.lexology.com/library/detail.aspx?g=2f0db598-a133-4df2-a67d-48366a0c2a88

135 M. Olson, *The Logic of Collective Action* (Cambridge, MA: Harvard University Press, 1965).

136 Duignan, B. Citizens United. v. Federal Election Commission, *Encyclopedia Britannica*. Available at https://www.britannica.com/event/Citizens-United-v-Federal-Election-Commission

137 D. Reuter and J Yoo, eds. *Liberty's Nemesis: The Unchecked Expansion of the State* (New York: Encounter Books, 2016): 139.

138 The International Federation of Pharmaceutical Manufacturers Association (IFMPA) minces no words. "Regulation of DSI amongst CBD countries would create incentives to move R&D to non-CBD countries. This would simply serve to benefit non-CBD signatory countries and undermine the CBD's benefit sharing objective", Submission to the Secretariat, "IFPMA views on the potential implications of the use of Digital Sequence Information (DSI) on the objectives of the Nagoya Protocol (NP) (8 September 2017). Available at https://www.cbd.int/abs/DSI-views/IFPMA-DSI.pdf

139 D.K. Prathapan and D. Rajan, Note 72.

140 G.A. Roncevert,"U.S. Ratification of the Law of the Sea Convention: Measuring the raison d"État in the Trump era", *The Diplomat* (24 May 2017). Available at https://thediplomat.com/2017/05/u-s-ratification-of-the-law-of-the-sea-convention/

5.2.3 Third-dimension jurisdiction shopping

Concurrent with the first and second dimension is a third: flight initiated from below. The scientist herself pulls up stakes. The third dimension interacts with the second in a dynamic of push and pull. To understand the impact, the COP must entertain the career paths of scientists in a globalized world.

Footloose scientists are nothing new. Novel is when migration is more push than pull. Consider, for example, the evangelical Christian agenda in the USA which helped elect George W. Bush to the presidency in 2000. Bush made good on his campaign promise to shutter embryonic stem cell research. A typical news story read "UK to open stem cell center: Director Roger Pedersen expects to lure top US researchers for embryonic stem cell work".[141] Unlike stem-cell research, migration of senior scientists due to ABS will probably be a minuscule fraction of the total brain drain, whether pushed or pulled. Most of the scientists who migrate will be those who are starting their careers.

The general public in the brain-drained countries may underestimate just how much they lose when junior scientists migrate.[142] Similarly, the general public in recipient countries may not appreciate how much they gain.[143] Without abstract reasoning, both publics mis-measure the losses and gains by the modest salaries of the scientists, thereby conflating the value in exchange with the marginal product of the labor and social value. To think economically about the impact of the modalities on migration, the COP must contemplate a series of economic questions. They are not peripheral to the analysis of alternative modalities.

What is the role of the scientist in patented inventions? What is the role of those inventions in capital? And lastly, what is the role of ownership of capital in economic development? Elaboration of the answers, ties into the choice of modalities. The chain of causation is most unexpected. The history of economic thought may help connect the dots. The following four paragraphs are not a digression from ABS modalities but a foundation for this third dimension of jurisdiction shopping. Each paragraph is a metaphorical dot.

What is the role of scientist? The notion that science adds astronomical value to an economy was expounded by

141 P. Hunter, "UK to open stem cell center", *The Scientist* (21 June 2004).

142 C.W. Dugger, "Study Finds Small Developing Lands Hit Hardest by 'Brain Drain'", *The New York Times* (25 October 2005): A9.

143 T.L. Friedman, "Start-ups. Not Bail-outs. " *The New York Times* (3 April 2010): WK9.

John Maynard Keynes in "Economic possibilities for our Grandchildren" (1930) and by Bertrand Russell, "In Praise of Idleness" (1932). Both Keynes and Russell addressed the false dichotomy of work and leisure. They advocated government finance of intellectual curiosity. Russell writes

> The method of a leisure class without duties was, however, extraordinarily wasteful. None of the members of the class had to be taught to be industrious, and the class as a whole was not exceptionally intelligent. The class might produce one Darwin, but against him had to be set tens of thousands of country gentlemen who never thought of anything more intelligent than fox-hunting and punishing poachers. At present, the universities are supposed to provide, in a more systematic way, what the leisure class provided accidentally and as a by-product.[144]

Science done as leisure can generate mind-boggling value. Darwin credits Malthus's *Essay on Population* which, according to his autobiography, he "happened to read for amusement".[145] Leisure for the young Darwin was financed by the only mechanism known in Victorian times, viz., family wealth.[146] One hundred years after Darwin, one infers from Russell that the joint probability of being gifted cerebrally and financially was still only 0.01%. The economic implication is strong: a miserly State forgoes realization of a huge value toward economic development. The deduction endures. The 20th-Century evolutionist Stephen Jay Gould was fond of saying "I am, somehow, less interested in the weight and convolutions of Einstein's brain than in the near certainty that people of equal talent have lived and died in cotton fields and sweatshops."[147]

The value of a government financing the amusement of a Darwin or an Einstein is incommensurable. So too is the value of tens of millions of capable students in the developing world, albeit to an admittedly lesser degree.[148] With limited financial resources, governments select precious few for doctoral education abroad. The UN compiles the statistics as percentages of tertiary enrollment according to geographic regions. The low is 0.9% from the Caribbean/Latin America to a high of 7.6% in Central Asia. Almost half of the students go to the non-Party.[149]

The statistics are clear. Developing countries do not finance public science to the extent that the social value warrants. An EMBO Report from the US National Library of Medicine and National Institutes relates how "[i]n most low-income countries, research is a luxury owing to economic constraints, and many scientists hold several other jobs"[150] Do-it-yourself relocation begins in graduate school and usually becomes irreversible after the initial job placement. For recent doctorates, the failure to perceive a career path in the home country dwarfs government regulations on access to genetic resources as the motive for migration.

The dots seem to dissipate. Where is the chain of causation from migration to ABS? One must consider the identity of Provider claimants under Modality 3-II. Should a blockbuster biotechnology originate in natural information that is diffused not only across species but also across genera, families and so on, billions of dollars of royalties will flow into the network of international taxonomy and related fields. The network depends on scientists in Provider countries. Modality 3-II would be a boom for graduates in biodiversity-related fields who wish to realize their professional careers in their home countries. From the previous economic discussion of social value and value in use, the boom for the scientists will be an even bigger boom for the economies of Provider countries. The three dimensions of jurisdiction shopping seem best addressed through Modality 3-II.

5.2.4 Conus through the Prism of Jurisdiction Shopping

The number of jurisdictions in which to shop will be determined by the geographic distribution of the chemical curiosity. That distribution may occur not just across populations of the species but also across species of the same genus or even genera of the same family and so on. For the species of the genus Conus, the class of chemical curiosities is immense. As Nicholas Pauchard points out in his introductory remarks to the case study (Appendix II),

144 B. Russell, *In praise of Idleness and Other Essays* (London: George Allen and Unwin, Ltd. 1935). Available at http://www.zpub.com/notes/idle.html

145 N Barlow, ed, *The Autobiography of Charles Darwin* 1809-1882 (London: Collins, 1958): 120. Available at http://darwin-online.org.uk/content/frameset?pageseq=1&itemID=F1497&viewtype=text

146 "Charles Darwin's personal finances revealed in new find", *The Telegraph* (22 March 2009). Available at https://web.archive.org/web/20171019230458/http://www.telegraph.co.uk/news/uknews/5032354/Charles-Darwins-personal-finances-revealed-in-new-find.html

147 S.J. Gould, *The Panda's Thumb*, New York: W.W. Norton & Co, 1980): 151.

148 Facts and figures from the UNESCO Science Report (2013). Available at https://en.unesco.org/unesco_science_report/figures

149 Of total tertiary enrollment, the outbound mobility ratio are 0.9% for the Caribbean and Latin America, 4.0% for Sub-Saharan Africa, 1.0% for South & West Asia, 1.9% for East Asia and Pacific, and 7.6% for Central Asia. For science and engineering almost half went to the USA. UNESCO Science Report: Towards 2030. UNESCO (2015). Available at https://en.unesco.org/sites/default/files/usr_2-12_prefered_destination_students.pdf

150 E. Harris,"Building scientific capacity in developing countries." *EMBO Reports* vol. 5, issue 1 (2004): 7-11. DOI:10.1038/sj.embor.7400058

> These toxins are called conotoxins or conopeptides. More than 10,000 different types are estimated to exist (Lobo-Ruiz and Tulla-Puche 2018) or even more than 700,000 if all variants and fragments are explored (Puillandre et al. 2014; Dutertre et al. 2013).

The abundance reminds us of Simpson's question: "How much would you pay for something whose supply seems, 'unlimited'? Probably not much. Things that are in short supply command high prices; things that aren't, don't". Pauchard notes that before the national ABS legislation in the Philippines, viz., Executive Order (EO) 247 of 1995, "it was pretty simple to obtain cone snails' venom in the Philippines: a researcher would buy specimens from fishermen that sell shells to tourists (Greer et al. 2004)" (Appendix II). In the spirit of Simpson's answer, so what if we lose one conopeptide? Ten? A hundred? A thousand? Or even ten thousand of the 700,000 chemical variants?[151] Left would still be, respectively, 699,999, 699,990, 699,900, 699,000, or 690,000. Ecology must be synthesized in the analysis. By Gauss's Law of Competitive Exclusion, each species is fitted to its niche.[152] The complex of its venom would probably not find perfect redundancy in the other 699,999 species. In other words, an opportunity for future R&D is lost even with the loss of just one of 830 species.

One need not quibble over losses of chemical variants of even four orders of magnitude, i.e., from one to ten thousand. The acidification of the ocean is threatening all 700,000. The causation is uptake of CO2 from greenhouse gas emissions. The US National Oceanic and Atmospheric Administration uses the example of sea snails to explain oceanic acidification,

> The pteropod, or "sea butterfly" is a tiny sea snail about the size of a small pea. Pteropods are an important part of many food webs and eaten by organisms ranging in size from tiny krill to whales. When pteropod shells were placed in sea water with pH and carbonate levels projected for the year 2100, the shells slowly dissolved after 45 days. Researchers have already discovered severe levels of pteropod shell dissolution in the Southern Ocean, which encircles Antarctica.[153]

Time can be measured in human life spans. The cornucopia of sea snails may go extinct within the expected lifespan of a baby now born in the developed world (approximately 80 years). Because humans perceive the species as "unlimited", humans misperceive the threat of extinction and are unwilling to pay an economic rent. Psychology must be synthesized in any analysis of ABS.

The skeptic may still be unconvinced. How would paying a rent do anything to conserve the species of the genus Conus?

One must return to the premises by which ABS will promote conservation and sustainable use. The economic rationale for rents is almost always expressed in the context of terrestrial biodiversity. Rents are justified to offset the opportunity costs of conservation, i.e., to relieve the political pressures for alternative land use. The popularized mnemonic HIPPO is in the context land-based organisms. The letters represent the order of extinction drivers: H (habitat loss), I (invasive species), P (pollution), P (human population growth) and O (over-harvesting).[154] The ocean scrambles the letters in a different order depending on the marine species considered. Only for some limited-range species will H still lead the mnemonic. For food chains perturbed through an explosion of exotic species, the first letter is I. For species which form shells in an alkaline aqueous environment, the first letter is P (pollution).

A change in the premise changes the deduction and hence the conclusion (see Table 1). For terrestrial species, the system should reward Parties according to the geographic range of the species; for marine shell species, Parties which reduce the pollution of CO2. Changes in emissions will lessen the acidification of the oceans.

A simple thought experiment is possible. Imagine that a conopeptide is common to all 830 species of Conus and results in a commercially successful drug. From the map in Figure 3 of the case study (see Appendix II), claimants would be countries with a coastline between latitudes 45N (Trieste, Italy) and 38S (Melbourne, Australia). Would compensation according to the Exclusive Economic Zone (EEZ) incentivize conservation? The answer is no because the driver is more P (pollution) than O (over-harvesting) or H (habitat loss). One deduces that the incentive must be centered on reducing P.

151 The assumption of continuity has been tacit in economics ever since Alfred Marshall's Principles of Economics (1890). He put the motto *"Natura non facit saltum"* on the frontispiece to his textbook. The latest example are the opening words of the Preface to *The Dasgupta Review*, "Economics, like I imagine other scientific disciplines, normally moves in incremental steps, and always without a central guide". See Note 94, 3.

152 "Competitive exclusion in ecology", *Science Daily*. Accessed on 15 February 2021. Available at https://www.sciencedaily.com/terms/competitive_exclusion_principle.htm

153 Ocean Acidification. NOAA. Accessed on 15 February 2021. Available at https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

154 National Resources Defense Council, "E.O. Wilson & E. Kolbert", Youtube (2008). Available at https://www.youtube.com/watch?v=GIlvstjsp8I

The problem of fungibility re-surfaces (Issue #19 in Table 2). If countries are already committed to reducing P through the UNFCCC, then incentives must be for reductions beyond the existing commitments. For example, under the 2016 Paris Agreement, claimants for royalties on conopeptides should be countries which go beyond National Determined Contributions (NDCs) to reduce CO2e emissions. Counterintuitive deductions emerge. Countries with protected marine areas which nevertheless fall short of the NDC would receive nothing. Landlocked countries which reduce emissions beyond the NDC should be rewarded. The deduction renders a policy which is efficient, fair and equitable.

How much money is at stake? The global market for marine bioprospecting was estimated at $3.5 billion in 2017 with an expected growth to $6.5 billion in 2024.[155] The estimates reflect the value in exchange. Given that much of the biotechnology will be in pharmaceuticals, the value in use may be several times higher, meaning that the excess burden of a significant royalty will be low.

5.2.5 Anecdotes as Bifurcation Points

Economists place little stock in case studies. Systematic empiricism rules, whether the reasoning be deductive or inductive. When presented with the findings of any particular case, the economist tends to be dismissive. Such statistical thinking breaks down when the anecdote is a bifurcation point with amplification effects.

Within the case of sea snails is one such bifurcation point. The remarkable trajectory of Professor Baldomir "Toto" Olivera touches on all three dimensions of jurisdiction shopping in ways that can inform policy. The biography of Olivera appears in Box 7.

Olivera is extraordinarily productive as can be evidenced by Google Scholar and Google Patents. As of this writing, he has authored or co-authored 844 scientific articles and holds 40 patents. One of the articles boasts 990 citations. Any comparison with a typical research-active professor is humbling; perhaps a few dozen articles, a hundred citations for the most cited article and one or two patents over an entire career.[156] To produce successfully and voluminously, the scientist must perform with precision and do so tirelessly. "Workaholic" seems an accurate description, notwithstanding our earlier quotation from Bertrand Russell's "In Praise of Idleness". The psychological aspect of joy in work has bearing on jurisdiction shopping.

After four years of paperwork and approvals, as required by EO 247, Olivera's team obtained permission in 2002 for access to *Conus geographus*. Advocates of the Modality 1 ("Nagoy-Bilateral") may claim that, lo and behold, the system works! Alas, exceptions are not the norm. No modality should require the level of perseverance typical

Box 7.

Scientist and Bifurcation Point

Baldomero "Toto" Olivera. University of Utah & Howard Hughes Medical Institute National Academy of Sciences

"Baldomero 'Toto' Olivera received a B.S. degree in Chemistry from the University of the Philippines, a Ph.D. in Biophysical Chemistry from Caltech and did his postdoctoral work at Stanford University. His early research contributions included the discovery and biochemical characterization of *E. coli* DNA ligase.

His laboratory initiated the identification and characterization of the biologically active peptides found in the venoms of predatory cone snails. This led to a broad involvement with molecular neuroscience, particularly the functional role of ion channels and receptor subtypes in nervous systems. The Conus peptide project has raised wide ranging biological questions, from mechanisms of protein folding and post-translational modification, to gene organization and mechanisms of speciation; several Conus peptides discovered in Olivera's laboratory are being developed as therapeutics and one is approved as a commercial drug.

Olivera is currently a Distinguished Professor of Biology at the University of Utah and a Howard Hughes Medical Institute Professor. He is also a member of the National Academy of Sciences and the Institute of Medicine."

Source: iBiology. Credit of Text and Image: https://www.ibiology.org/speakers/baldomero-toto-olivera/

155 CISTON PRnewswire, "Global Marine Biotechnology Markets Report 2019: Market is Expected to Grow from USD 3.5 Billion in 2017 to USD 6.5 Billion in 2024" (11 November 2019). Available at https://www.prnewswire.com/news-releases/global-marine-biotechnology-markets-report-2019-market-is-expected-to-grow-from-usd-3-5-billion-in-2017-to-usd-6-5-billion-in-2024--300955538.html

156 The average will vary from field to field as well as from country to country. For example, "Here [Italy], 10% of the professors [of organic chemistry] have produced on average less than one publication per year, and six were totally unproductive. On the opposite front, we find 20 professors with over 10 publications per year, and one absolute outlier with 25." Ciriaco Andrea D'Angelo and G. Abramo, G. "Publication Rates in 192 Research Fields of the Hard Sciences" *Proceedings ISSI Society* (2015): 912. Available at http://issi-society.org/proceedings/issi_2015/0909.pdf

of a top scientist.[157] Four years is a long time.[158] Many young scientists are discouraged by the hurdles of ABS and will simply desist.[159] Others will turn a blind eye to ABS legislation and do as they please. Like serendipitous discovery of the toxin in the poison dart frog (Box 4), doing as one pleases is an integral part of science-as-leisure. In the iBiology talk "Part I: Conus venom peptide" (see Appendix VIII), Olivera relates the phenomenal success of one undergraduate student who was barely out of high school. He tells the professor,

> "You should be injecting the toxin directly into the central nervous system, directly into the brain." I wasn't persuaded; I thought this wasn't such a good idea. What would we learn? I tried to dissuade him. But I really feel that the reason why the most creative research is done at the university is that the students do what they want. They don't follow what their professor advises. So fortunately for us…[160]

Youthful daring may extend to access to genetic resources. Solemn denunciations of biopiracy will carry little stigma among budding scientists bent on discovery. Analogies with file-sharing and the collapse of the music industry in the 1990s are germane.

As Olivera demonstrates, the transaction costs of access are high but not insurmountable. The conclusion is not just anecdotal. In a meticulous study of how Philippine EO 247 has impacted stakeholders, Klaus Leibig et al. write,

> Philippine legislation goes further in terms of community involvement in the access procedure than in most other countries. Is this provision in fact an obstacle to ABS agreements in the Philippines? Our interviews rather revealed that most users would be able to follow the PIC provisions if they were really willing to do so.[161]

> As long as international bioprospectors are able to find easy alternatives, they can circumvent ABS provisions. The country in question would need advantages like endemic resources, an efficient administration or highly skilled cooperation partners to effectively counter the internationally perceived "disadvantage" of having ABS legislation in place.[162]

Unencumbered access coheres with a professional reward structure that is winner take-all, whether it be to publish in a peer-reviewed article or to file a patent application. Like the multiple drivers of HIPPO, some variables are more significant than others in jurisdiction shopping. Leibig et al. write,

> Our interviews have shown, however, that stakeholders neither at the national nor at the community level, have specific expectations concerning benefits which might prove to be a burden for any research agreement.[163]

Recall from Section 5.1 that Users can pass on most of a royalty to the consumer whenever demand is inelastic, as often happens in the pharmaceutical industry. Users may be jurisdiction shopping more for ease of access than to secure low royalties. However, the two are self-reinforcing. Like HIPPO, they may also scramble over time. Supporting that inference is the 5% royalty agreed in the Philippines in 1995. It is 50 times more favorable to the Provider than the lower bound established in Brazil in 2015 and 333 times more favorable than the lower bound of ITPGRFA which inspired Option 2 of "Finding Compromise" in the WiLDSI Project of 2020.[164]

Openness is the *sine qua non* for the four alternative modalities. An unintended and ironic consequence of Modality 1 (Nagoya-Bilateral) is the decline of non-monetary benefits through the obligation of ABS. Leibig et al. report that interviewees complained of fewer collaborations with foreign scientific institutions due to EO 247.[165]

5.2.6 Conopeptides, Patents and Synthetic Biology

The definition of natural information would include any molecule that was produced biologically. The venom of the conus species are usually short chains of peptides, which in turn are short chains of amino acids. The venom would qualify as natural information, but would the peptides? Or the amino acids? Such questions vex the discussion of the scope of ABS as scientists synthesize biotechnologies from LEGO®-like building blocks. Before answering either question, "synthetic biology" comes to the fore, which is another highly disputed neologism.

157 K. Liebig *et al.*, *Governing Biodiversity: Access to Genetic Resources and Approaches to Obtaining Benefits from their Use: The Case of the Philippines.* Reports and Working Papers 5 (Bonn: German Development Institute, 2002): Box 9. Case Study I: The Application procedure, 42. Available at https://rmportal.net/library/content/frame/governing-biodiversity.pdf/view

158 Many examples of terminated bioprospecting projects exist. Perhaps the most (in)famous has been the Maya-ICBG. See Daniela Shebitz and Angela Oviedo "Learning from the Past: Reflecting on the Maya-ICBG Controversy in the Classroom", *Ethnobiology Letters* 2018 9(1):59–66 | DOI 10.14237/ebl.9.1.2018.1095

159 See, Revkin, A. "Biologists Sought a Treaty; Now They Fault It." *The New York Times* (7 May 2002).

160 B. Olivera. *Part I: Venom Complexity* (October 2014): 13:17-13:50. Available at https://www.ibiology.org/neuroscience/conus-venom/

161 K. Liebig *et al.*, Note 157, 43.

162 K. Liebig *et al.*, Note 157, 50. One should note that endemism may not be sufficient advantage for ABS as long as *ex situ* collections exist in the non-Party. Antibiotics developed in the USA from the Komodo dragon may prove to become a spectacular case. Available at https://www.bbc.com/news/health-39554531

163 K. Liebig *et al.*, Note 157, 45

164 K. Liebig *et al.*, Note 157, 45 and A. Scholz, Note 53, 21

165 K. Liebig et al., Note 157, 50.

This seeming detour is necessary to proceed with Conus. Definitions again beleaguer the discussion.

The neologism appeared as a new and emerging issue through a half-dozen submissions for COP11 in 2014.[166] Several stakeholders thought deeply about how to define the field. For example, from The Royal Academy of Engineering, we have

> Synthetic biology aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems.[167]

After rounds of formal online discussions organized by the UNCBD Secretariat, an official working definition emerged,

> Synthetic biology is a further development and new dimension of modern biotechnology that combines science, technology and engineering to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems.[168]

The working definition does not work for ABS. It does not imply clear inclusionary or exclusionary criteria and deploys modifiers which are time-sensitive (e.g., further, new, modern). Not one of its 38 words is "information". One can, however, infer information by interpreting "material" as inclusive of information. To do so, however, will put many Users in a pickle. As stressed in the Introduction to this Report, most have insisted that "material" not include information. The exclusion would mean that synthetic biology does not deal with the phenomenon which goes by the placeholder DSI.[169] To the extent that such contradictions do not really bother Parties, one must again insist that psychology be included in analysis of the ABS discussion.

Alternative definitions for synthetic biology exist which work for ABS. The SPDA offered the following,

Synthetic Biology: the extremely intensive use of artificial information in the manipulation of natural information.[170]

Inasmuch as the definitions of natural and artificial information can be applied, metrics would only be needed to measure the intensity of manipulation. Extreme may be interpreted as manipulations that fall in the right-end tail of a normal distribution in statistics. Should a class "synthetic biology" be thus delimited, fixed royalties can be negotiated for that class under Modality 3-II. The question for Conus is: Are peptides and amino acids natural information? Would they fall within the scope of ABS?

Classic experiments in the history of biochemistry show that eleven of the twenty-two common amino acids can be produced with ammonia, methane, hydrogen and water vapor, under an energy gradient that simulated primeval Earth.[171] Thus, amino acids would not qualify as biotic natural information. They are LEGO® building blocks. Would peptides qualify? They are chains of amino acids from two to fifty in length and joined by an amide bond; molecules longer than fifty are proteins.[172] Perhaps a very short chain could be drawn out of random chemical reactions through "Chance, Chaos and Old Time",[173] but the longer the chain, the less the likelihood. Conotoxins are between 10 – 40 amino acids in length, which is long enough to assume an origin only in biology. Proteins are sufficiently complex to assume that all arose through biology.

Should "material" in "genetic material" be interpreted as information (Issue #6 of Table 2), then the conopeptides of synthetic biology fall squarely within the scope of the ABS. A nuance arises which may quell the worries of Users. Type "peptide" and then "conopeptide" into Google Patent Search engine. The hits number 42,106 and 2,114 respectively (17 June 2020). Some of these patents will have expired more than a century ago.[174] Should the patent have expired, under

166 CBD Secretariat, New and Emerging Issues, UN Available at https://www.cbd.int/emerging/

167 Royal Academy of Engineering, Synthetic Biology: scope, applications and implications (2009): 6. Available at https://www.cbd.int/doc/emerging-issues/UK-submission-2011-013-Synthetic_biology-en.pdf

168 Portal on Synthetic Biology, Secretariat UN CBD. Accessed on 15 February 2021. Available at https://bch.cbd.int/synbio/

169 The neologism arose during discussions on synthetic biology. E. Karger, P du Plessis and H. Meyer, Digital Sequence Information on Genetic Resources (DSI) - An Introductory Guide for African Policymakers and Stakeholders Digital Sequence Information on Genetic Resources (DSI). Technical Report (November 2019): 9. Available at http://www.abs-initiative.info/fileadmin/media/Knowledge_Center/Pulications/DSI/Introductory_Guide_-_DSI_-_ABS_Initiative_-_201908.pdf

170 SPDA, "Submitted view for the Updated report and synthesis of views in response to paragraph 7(b) of Decision XII/24; and Report of the Meeting of the Ad Hoc Technical Expert Group on Synthetic Biology" (2016): 3. Available at http://bch.cbd.int/synbio/peer-review

171 S.L. Miller,"A production of amino acids under possible primitive earth conditions", *Science* vol. 117 issue 3946 (1953): 528–529. S.L. Miller,"A production of amino acids under possible primitive earth conditions", Science vol. 117 issue 3946 (1953): 528–529.

172 "What is the difference between a peptide and a protein?" Britannica. Accessed on 15 February 2021. Available at https://www.britannica.com/story/what-is-the-difference-between-a-peptide-and-a-protein

173 John Maynard Keynes' metaphor is apt description of causation. *The End of Laissez Faire*, (London: MacMillan, 1919): 20.

174 T. Kimmerlin and D. Seebach, "100 years of peptide synthesis: ligation methods for peptide and protein synthesis with applications to beta-peptide assemblies", *Journal of Peptide Research* vol. issue 2 (2005): 229-260. DOI:10.1111/j.1399-3011.2005.00214.x. Available at https://pubmed.ncbi.nlm.nih.gov/15705167/.

Modality 3-II, the natural information would have entered the public domain along with the value added, adhering to *quid pro quo* in the protection of natural and artificial information.

Other nuances surface which indicate that much of the natural information utilized in synthetic biology, would not be in the public domain, thereby quelling the worries of Providers. In the aforementioned iBiology talk, Olivera marvels at how evolution could not be improved through manipulation,

> It is interesting to note that the biotech company that originally developed this peptide did a lot of structure-function work. They essentially changed every amino acid in the peptide to try to make it better for therapeutic purposes. But in the end, they went with exactly with what the snails make. So, the commercial product is identical to the natural product except it is chemically synthesized. There is not a single functional unit that is different.[175]

The case of sea snails remind us why case studies are not only instructive but also insightful.

5.3 Sea Sponge (Tectitethya crypta)

Key messages

- Statistical analysis of views and information about DSI submitted to the UNCBD Secretariat, shows that Parties and stakeholders do not ground submissions in the published literature as would the published literature;
- Under Modality 3-II, the Global Fund must assume the character of an implementing agency for *marine species*;
- Potential royalty income depends on the elasticity of demand for genetic resources as inputs in production;
- Two tasks are primary for the COP: identification of the classes of utilization; estimation of the elasticities of demand for each of the most revenue-generating utilizations. The Ramsey Rule of Public Finance applies;
- Equity means that the same rent should be collected on each unit of pharmaceuticals sold across the OECD;
- Natural information falls into the public domain with the expiry of a patent, but the issuance of a new patent on an existing utilization should re-activate the obligation.

The sponge *Tectitethya crypta* invites reflection about the calculation of monetary benefits, *ex situ* material collected prior to CBD and Areas Beyond National Jurisdictions (Issues # 16, 10 and 23 of Table 2). Unlike the naked mole-rat, the supposition "what if the biotechnology product were a blockbuster" is not necessary. Blockbuster life-saving drugs have been inspired by the biochemistry of the sponge. Unlike the sea snails, the question "what if the habitat collapses?" is not necessary. The habitat of the sponge, reef ecosystems, are in collapse. Nevertheless, certain conditions do not obtain to make the sponge an ideal case. Notably, the first block-buster success occurred prior to ratification of the CBD and specimens were collected decades prior to that utilization.

One returns to the methodology of Section 1. A class of cases does not exist from which generalizations can be drawn about the optimal modality of ABS.[176] Thought experiments are necessary. Only by tweaking the cases can deductive reasoning proceed for the issues in Table 2. The implications can then be integrated together to form a whole. For *T. crypta*, the deductive approach to issues # 16, 10 and 23 integrate with # 3, 6 and 11 selected for the snail and naked mole-rat. In Appendix III, Nikita Kent elaborates the case and organizes the information according to the template.

5.3.1 Money, Economics and Psychology

"When somebody says it's not about the money, it's about the money."[177] Economics would seem to defy H.L. Mencken's insight. On the first day of class, professors will call upon students to define the discipline that they are about to study. The answers are invariably in terms of money. The professor then disabuses the students: economics is not about the money. Metaphors prove effective: money is only a lubricant to facilitate the division of labor and exchange of goods and services. From the viewpoint of psychology, however, the students' answer is not so wrong. Money commands resources. Economics is about resource allocation. Students equivocate because money lies in the same mental frame as resources in modern societies.

For the 30-year trajectory of ABS, Mencken's insight could not be more apropos. ABS is about the money, despite protestations to the contrary. The Annex to the 2010 NP "Monetary and Non-Monetary Benefits" embeds royalties as one of twenty-seven classes of benefits.[178] Yet royalties are the

175 B. Olivera, Note 160, minute 22:50-23:30.

176 SPDA, "Even best case for bilateralism supports need for a Global Multilateral Benefit-Sharing Mechanism: Common ground in 'bounded openness over natural information' as the modality for ABS" In response to NOTIFICATION for Submission of views and information further to decisions NP-3/13 on Article 10 of the Nagoya Protocol (SCBD/NPU/DC/VN/KG/RKi/ 87805) (28 June 2019). Available at https://www.cbd.int/abs/art10/2019-2020/default.shtml

177 H.L. Mencken. Best Quotations. Accessed on 26 August 2020. Available at https://best-quotations.com/authquotes.php?auth=123

178 Text of the Nagoya Protocol, UN CBD. Available at https://www.cbd.int/abs/text/articles/?sec=abs-37

only benefit for which *real money* could ever change hands. The Annex seems copied and pasted from the 2006 Bonn Guidelines.[179] Should a pesky economist press the issue of the percentage royalty, the User will intone "confidential information", for which MAT is code.[180] Transparency is the economist's stock rejoinder and the dialog stalls. The clock ticks. Inasmuch as the two lists of the Annex comprise twenty-six other benefits, the moderator will intervene with a chirpy "let's move on". Providers and stakeholders would be well advised to heed Mencken's advice. The absence of discussing the percentages is all about the money.

The above criticism is nothing new. It has been voiced for decades in ABS workshops and COP side events.[181] The argument is explicit in "Reflecting Financial and Other Incentives of the TMOIFGR", which is Chapter 3 in an ABS series from *IUCN Environmental Policy and Law Papers*. The volumes were published open-access in English in 2007 and in French and Spanish in 2008. [182] Regarding the percentage royalty,

> The Guidelines allow them to be negotiated on a case-by-case basis and are silent about whether the rate negotiated should be disclosed to the public. From the viewpoint of industry, such silence is very welcome. Novartis, for example, offered Brazil a rate which is insignificantly different from zero: 0.5% (Pena-Neira et al. 2002). Tellingly, the category "royalty" in the Guidelines [letter (d) of Category 1 of Appendix II] gets no more play than "Access fees/fee per sample collected" [letter (a)] and the list of monetary benefits [letters (a)-(j)] is followed by a much longer list of non-monetary benefits: capacity-building, technology transfer, and the like [letters (a) through (q) of Category 2]. The impression is unmistakable: little money will change hands in ABS and be happy with those non-monetary benefits![183]

Inferences can be drawn from the mere passage of time. The period between the publication of the IUCN series in 2007 and the tenth meeting of the COP in 2010 was sufficient for Parties to consider the issue of the percentage royalty. They did not. The verbatim reproduction of the Bonn Guidelines into the Annex of the NP suggests that Parties are not informed by the published literature

One swallow does not make a Spring. The opportunity to test statistically whether the perspectives of Parties are informed by the published literature arose years later, through the perspectives of delegations to DSI. Statistical analysis confirms the anecdotal evidence gleaned from the IUCN series. Delegates do not reference the published literature as do authors of the published literature (Box 8). The psychology of cognitive dissonance explains the absence of royalty percentages in the ABS discussions.

A caveat is in order. Economists are also not immune to cognitive dissonance. The TEEB Reports open "The TEEB study is underpinned by an assessment of state-of-the-art science and economics".[184] As elaborated in Section 4, the TEEB Reports "followed the definitions of the CBD", despite "material" not having been defined in the CBD or Decisions of the COP.[185] The Reports chose the *interpretation* that material is only tangible for ABS. Obeisance to that interpretation allowed TEEB authors to ignore the application of the economics of information, even as they cited that literature. Cognitive dissonance triumphed. One reads that cartels are "unstable with a strong incentive to undercut the agreed price".[186] The argument is a straw man as the goods are information. What would motivate TEEB authors to so misrepresent a literature that they cite? Cognitive dissonance goes hand in hand with nested dominance hierarchies. TEEB boldly repeats, both literally and typographically, the economic argument advanced by Users and well heeled stakeholders,

> Reasons for values being so low included the ***high costs of developing the final goods and bringing them to market, the long time lags involved and inefficiencies in the systems for exploiting genetic resource*** (bold in original).[187]

The rejoinder pre-existed in the relevant literature. The sociologist Jack R. Kloppenburg wrote in 1988 edition of *First the Seed*: "Curiously, this argument relies implicitly on a [Marxian] ***labor theory of value***. It is asserted that only the application of scientists' labor adds value to the natural gift of germplasm".[188] The authors of TEEB are not closeted Marxists. The explanation for neglecting opportunity costs

179 COP 6 Decision VI/24, UN CBD. Available at https://www.cbd.int/decision/cop/?id=7198

180 "Mutually agreed terms" appears twenty-five times in the NP while "transparency", twice, Note 178.

181 The second member of the SPDA team for this Report asked a party to an MTA about the royalty percentage at the Latin American Workshop on Access to Genetic Resources, sponsored by the World Resource Institute (Cancún, Mexico, 27 May 1999). The indignation of the queried User startled the Spanish-English interpreters at the event.

182 J.H. Vogel, Note 33.

183 J.H. Vogel, Note 33, 50.

184 Ecological and Economic Foundations, *The Economics of Ecosystems and Biodiversity* (2010). Available at http://www.teebweb.org/our-publications/teeb-study-reports/ecological-and-economic-foundations/

185 The notion of "material" as inclusive of information is not a conceptual revision. The TEEB authors chose an interpretation which they misrepresent as a definition, which leads to the conclusion generally desired by Users.

186 P. Ten Brink, Chapter 5: "Rewarding Benefits through Payments and Markets", *The Economics of Ecosystems and Biodiversity for National and International Policy Makers* (2009): 39. Available at www.cbd.int/doc/case-studies/inc/cs-inc-teeb.Chapter%205-en.pdf

187 Ibid, 3.

188 J. R. Kloppenburg Jr., Note 23, 185.

and invoking a labor-theory-of-value argument lies in psychology.[189]

The consequence of interpreting material as only tangible is now manifest in the 2020 "Quick Guide to Aichi Biodiversity Targets: Financial Resources from all Sources Increased."[190] Because so very little money has ever been captured through bilateralism, the Guide feels no need to mention ABS. The circle closes.

5.3.1 Differentiated Royalty Percentages

Management of the drivers of extinction is a question of resource allocation. Recall that the relative impacts of each letter in HIPPO scramble as one goes from terrestrial to marine environments. For the snails of the genus Conus, ocean acidification is the primary driver. But for the sponge, such prominence cannot be given to just the P of pollution. A metaphor for a scrambled HIPPO is the title of the bestseller by Agatha Christie: *Murder On the Orient Express*. The drivers of extinction act in concert (Box 8). One existential threat to millions of species in the reef ecosystem is the death of coral. Who are the assassins? The suspects act in concert: the lion fish devours fish herbivores and results in algal blooms (I of Invasive species); warm waters bleach the coral and farm runoff smothers it (the first P, again); fishing and recreational vessels damage the coral heads through anchors and chains (the second P is human Population) while snorkelers illegally collect (O of over-harvesting). Long before alkalinity falls below the threshold for calcification (P is Pollution), the reef will probably be teetering on death. Ocean acidification will deal the *coup-de-grâce*.

Payments of royalties must finance measures to reduce the IPPO for marine species. The payments would be in addition to whatever is already financed to reduce CO2 emissions, as dictated by the criterion of fungibility (Issue # 19, Table 2). An implication arises for the GMBSM: For terrestrial species, the Global Fund is a financial mechanism to distribute royalty income and thereby offset opportunity costs and align incentives. *For marine species, the Global Fund must assume the character of an implementing agency.*

One may assume that Users will not gleefully assume any cost. Providers should also put themselves in their

189 O. Oduardo-Sierra, B.A. Hocking, and J.H. Vogel, "Monitoring and Tracking the Economics of Information in the Convention on Biological Diversity: Studied Ignorance (2002-2011)." *Journal of Politics and Law* (11 May 2012). Available athttp://dx.doi.org/10.5539/jpl.v5n2p29

190 "Quick Guide to the Aichi Biodiversity Targets: Financial resources from all sources increased". Accessed on 15 February 2021. Available at https://www.cbd.int/doc/strategic-plan/targets/T20-quick-guide-en.pdf

Box 8.

Do Submission of Views and Information on "Digital Sequence Information" cite references as do authors in Published Literature?

By Gabriel J. Amador Cruz

A Google-Scholar search of the words "digital sequence information" generated 186 hits (articles) on 30 October 2019. From the population, a random sample of 30 articles was analyzed for the number of words per reference in either the notes or bibliography. *More words/reference means views and information proportionally less grounded in the published literature.* The average was 239.2 words/reference with variance of 41718.5, standard deviation of 204.3 and confidence interval at 95% of 166.1-312.3 words/reference.[a]

The descriptive statistics allow comparisons of how views and information on DSI are gathered by Parties, the non-Party and Organizations and Stakeholders.[b] *None* of statistics for the seventeen Parties and one non-Party demonstrates words/reference less than the upper limit of the CI for authors of the published literature. Only four of the eighteen submissions from Parties and the non-Party cite any reference whatsoever. Coincidentally, only four of twenty submissions from Organizations and Stakeholders demonstrate words/reference less than the upper bound of the CI. The inference is that the submissions on views and information do not ground those views and information in the published literature as would the published literature.

Context matters. Less well-grounded views and information have been discouraged by the Secretariat. For example, then Executive Secretary Braulio Ferreira de Souza Dias requested that submissions for new and emerging issues exhibit "[c] redible sources of information, preferably from peer-reviewed articles".[c] The Secretary's request suggests that views and information submitted will differ significantly should such grounding occur.

a See Appendix VII for the data from which the statistics were computed
b See, "Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity 14/20. Digital sequence information on genetic resources", CBD/COP/DEC/14/20 (30 November 2018). Available at https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-20-en.pdf
c Braulio Ferreira de Souza Dias, "Notification: Invitation to provide information on new and emerging issues relating to the conservation and sustainable use of biodiversity and the fair and equitable sharing of benefits arising from the use of genetic resources" (12 February2014). Available at https://www.cbd.int/doc/notifications/2015/ntf-2015-017-new-emerging-en.pdf

shoes. Users ultimately answer to shareholders and will explore alternative production methods or perhaps even different lines of production, whenever alternatives are more profitable than bearing the costs of royalty payments. The potential royalty income, therefore, depends on the elasticity of demand for the genetic resources as inputs for production. The royalty should never be so high as to substitute the genetic resource with other inputs. Excess burden is again relevant.

Price elasticity of the final product reflects market conditions as well as the quantity currently traded. For example, high-end apparel in a market awash with clothes will exhibit elastic demand. Not only do cheaper substitutes exist, but many customers can do without an expansion of their wardrobe. Hence, a significant percentage royalty for, say bionic fibers will create heavy excess burden.[191] In such cases, economics implies that the percentage royalty be low, perhaps only a fraction of one percent. Life-saving drugs, on the other hand, exhibit inelastic demand. Few who need a drug and have the financial means, will choose to do without. The royalty would create little excess burden. Economics implies that the royalty percentage be high. A counterintuitive deduction emerges: the imposition of the same royalty percentage regardless of the price elasticity is inefficient.

Two tasks are of primary importance: identification of the classes of utilization; estimation of the elasticities for each of the most revenue-generating utilizations for both marine and terrestrial species. Should the percentages implemented by the COP violate the Ramsey Rule (Box 9), knowledge of the elasticities will reveal how far Users and Providers deviate in their negotiations over percentages. Correction is always possible in a framework convention.

5.3.2 Valuation and Monetary Benefits: Scale Obviates Need for Precision

The differentiation in percentage royalties under Modality 3-II behooves Users whose goods exhibit elastic demand. One might think that differentiation would therefore go against goods which exhibit inelastic demand. The deduction does not hold for Big Pharma. Whatever is the incidence of a royalty, the cost borne by Big Pharma will

191 Ministry of Foreign Affairs, Taiwan, "From Fish Scales to Functional Fibers: Tainan's Textile Industry Goes Green". Accessed on 15 February 2021. Available at https://nspp.mofa.gov.tw/nsppe/news.php?post=139194&unit=410&unitname=Stories&postname=From-Fish-Scales-to-Functional-Fibers:-Tainan's-Textile-Industry-Goes-Green. See also, "A method of multi-functional recycled fiber with collagen peptide" Patent Application TW101127722A. Accessed on 15 February 2021. Available at https://patents.google.com/?q=umorfil&oq=umorfil

Box 9

Rainforests of the Oceans

The collapse of coral reefs reminds us how limited are resources that "seem unlimited" and why we should be willing to pay (see Section 4). *National Geographic* published a sobering article in 2017, titled "Coral Reefs could be Gone in Thirty Years". The subtitle alludes to the leading driver "World Heritage reefs will die of heat stress unless global warming is curbed, a new UN study finds".[a] Should Parties to the United Nations Framework Convention on Climate Change (UNFCCC) somehow curb global warming, coral reefs will still be threatened by the other drivers of HIPPO. Because conservation does not have a date of expiry, finance must address all the drivers of extinction, irrespective of whether the impact happens in one, ten or a hundred human generations.

One passenger on the Orient Express is the lionfish (genus Pterois), which hails from the Indo-Pacific Region. Through releases from home aquariums into backyard canals in southern Florida, the fish has found an open niche in the Caribbean. NOAA explains the threat posed "Adult lionfish are primarily fish-eaters and have very few predators outside of their home range. Researchers have discovered that a single lionfish residing on a coral reef can reduce recruitment of native reef fish by 79 percent".[b] A times-series map of the population expansion since introduction in 1985 looks like a high-school lesson in exponential growth.[c]

Royalties on utilization of any of the two million species in the reef ecosystem could help finance measures to reduce the populations of lionfish, as well as the other drivers of extinction. An example would be a massive expansion of a 2017 GEF-financed small grant project "Lionfish Containment Program incorporating structured culling practices, data collection, and promotion for consumption and jewelry production".[d] The budget for the original project was a stunningly modest USD 75K.

a Laura Parker and Greg Welch, "Coral Reefs Could be Gone in 30 Years", *National Geographic* (23 June 2017). Available at https://www.nationalgeographic.com/news/2017/06/coral-reef-bleaching-global-warming-unesco-sites/

b "Impacts of Invasive Lionfish" NOAA Fisheries (30 March 2020). Available at https://www.fisheries.noaa.gov/southeast/ecosystems/impacts-invasive-lionfishf

c BNAS- Non-indigenous aquatic species, USGS. Accessed on 15 February 2021. Available at https://nas.er.usgs.gov/queries/SpeciesAnimatedMap.aspx?speciesID=963

d The GEF Small Grants Program. "Lionfish Containment". Accessed on 15 February 2021. Available at https://sgp.undp.org/spacial-itemid-projects-landing-page/spacial-itemid-project-search-results/spacial-itemid-project-detailpage.html?view=projectdetail&id=22817

be offset by the political benefit of having paid a rent for biodiversity. The explanation is counterintuitive.

The profitability of Big Pharma is determined not in the "market" but in the political arena,[192] where compulsory licensing is a worst-case scenario, second only to a scrapping of the entire patent system.[193] Expenditures on pharmaceuticals per capita vary from country to country and nowhere are the differences greater than between the USA and the non-OECD countries. However, very significant differences also exist within the OECD countries. For the comparative statistics in 2017, the average per capita expenditure on pharmaceuticals was $553, with a low in Denmark of $282 and a high in the USA of $1162.[194] The span in prices is even greater when one focuses on life-saving drugs for which demand is most inelastic.

In such light, we examine the blockbuster drug developed from *T. crypta*. The nucleoside analogues of the sponge led to the invention of the antiviral drug Zidovudine (ZDV), also known as azidothymidine (AZT). The invention is only one example of the pharmacological properties of sponges, as captured in the title of a 2016 survey article "Marine Sponges as a Drug Treasure" (subsections elaborate antibacterial activity, antiviral activity, anti-fungal activity, anti-inflammatory activity, anti-tumor activity, immune suppressive activity and muscle relaxant). Overwhelmed by the scale of utilizations, we will confine ourselves here to a few brief words about the spectacular case of ZDV/AZT.

What is the value in exchange of ZDV/AZT? Over its patent life (1985 – 2005), Burroughs Wellcome Company reportedly earned $4 billion.[195] What is the social value of ZDV/AZT? That calculation would require a monetary estimate of the lives saved not only over the patent life of the drug but also beyond. One estimate for just the year 2010 is 700,000 lives saved.[196] What is the value in use of ZDV/AZT? The answer depends on each patient's willingness to pay to live. Safe is to say that the aggregate social value and value in use dwarf the value in exchange. One can affirm that the price of ZDV/AZT is in the inelastic region of

192 A case in point is evident in the very title of a front-page story "A Deal on Drug Prices Undone by White House Insistence on 'Trump Cards'", *New York Times* (18 September 2020): A1.

193 For a rigorous analysis, see Steven Shavell and Tanguy van Ypersele, "Reward versus Intellectual Property Rights", NBER Working Paper 6956 (1999). Available at https://www.nber.org/papers/w6956.pdf

194 OECD "Pharmaceutical expenditure", *Health at a Glance 2017: OECD Indicators* (Paris: OECD Publishing, 2017) Available at https://doi.org/10.1787/health_glance-2017-68-en

195 S. Vollmer,"AZT Patent Expires – Cheaper AZT on the way." *Raleigh News and Observer* (18 September 2005): A8. Available at http://www.natap.org/2005/HIV/092005_02.htm

196 A. S. Fauci and G.K. Folkers. "Toward an AIDS-free generation", *JAMA* vol. 308 issue 4 (2012): 343-344. DOI:10.1001/jama.2012.8142

Box 10

The Ramsey Rule for Negotiating Royalty Percentages

Public finance is a rigorous sub-discipline of economics. Percentage royalties occupy the same space as an *ad valorem tax* in the analysis. The mathematician Frank Plumpton Ramsey (1903-1930) worked out optimal taxation in what is now celebrated as the Ramsey Rule. The words "tax rate" can be swapped for "royalty percentage" and the Rule will stand for ABS:

To minimize total excess burden, [royalty percentages] should be set so that the percentage reduction in the quantity demanded of each commodity is the same.[a]

Occasionally an economic concept is easier to comprehend mathematically than verbally. Such may be the case with the Ramsey Rule,

$r_x \eta_x = r_y \eta_y$

Where,

r_x= royalty percentage on good x

r_y= royalty percentage on good y

η_x= demand elasticity of good x

η_y = demand elasticity of good y

The Rule can be illustrated with the previous example. Say X is bionic fiber from fish scales and Y, a life-saving drug. A low royalty percentage r_x multiplied by the high elasticity η_x should be equal to a high royalty percentage r_y multiplied by its low elasticity η_y. Once knowing the elasticities for each class and the incremental budget needed for the IPPO of marine species, analysis reveals the optimal percentages according to Ramsey Rule. Negotiators for Users and Providers for the royalty percentages should bear in mind the ideal.

a Harvey S. Rosen, *Public Finance* (Boston: Irwin, 1992): 334

demand. Little excess burden would have been generated had a significant royalty percentage been charged for the underlying genetic resource.

A thought experiment arises from the price discrimination of Big Pharma, as can be illustrated through ZDV/AZT.[197] Its price was steeply discounted in non-OECD countries.[198] In imagining "what if" ABS obligations had then existed, a high royalty percentage applied to low-priced sales results in low royalty income. The outcome seems equitable in non-OECD countries but not within the 31 OECD countries, where prices are also differentiated, albeit not so drastically. Should one interpret equity as meaning that the same rent should be collected on each unit of the same pharmaceutical sold across the OECD; equity means that the royalty percentage cannot not be the same. An OECD country which negotiates a price at, say, one-fourth the highest price, should pay a royalty percentage four times as high. Excess burden would still remain minimal as demand is highly inelastic.

5.3.3 Access, Retroactivity and Extinction *in situ*

ABS obligations for specimens collected prior to the 1993 ratification of the CBD violate the principle of non-retroactivity should genetic resources be interpreted as tangible. The issue has beleaguered the CBD since the Nairobi Final Act of 22 May 1992 (Resolution 3, para 4 (a))[199]. However, ABS does not violate the principle should genetic resources be interpreted as information. Biotechnology has only made the dematerialization of genetic resources ever more cost-effective post 1993. Most utilizations would be within the scope of ABS under Modality 3-II.

R&D of *T. crypta* for drug discovery illustrates the distinction. As Nikita Kent points out in Appendix IV, the foundational work on spongeonucleosides was done in the late 1950s, but new information about *T. crypta* has also been published as recently as 2015. Natural information disembodied from *T. crypta* before 1993 would only be within scope should the grand bargain eventuate (see Box 5), by which all collections of the accessed genetic resource enjoy the claim equivalent to one Provider.

Another wrinkle exists for Modality 3-II which is worthy of exploration. The development of ZDV/AZT occurred in 1964 but indication for HIV/AIDS received patent protection in 1985. Should new patents that owe to existing patented utilizations fall within the scope of ABS? *Quid pro quo* for Users and Providers in the protection of artificial and natural information suggests that they should. Novel use of an old drug can be interpreted as a new utilization. Natural information only falls into the public domain for a utilization for which protection has expired.

Fairness and equity lead to other thought experiments. Ocean acidification will threaten sponges everywhere by the end of the 21st century. Who should be the claimants should extinction reduce provision to only *ex situ* collections? The maintenance of collections requires resources. The criterion of efficiency implies that the collections themselves be claimants had the specimens been acquired before 1993. We return to the grand bargain of Box 5. Only if the Party granted access to collect specimens after 1993, should that Party be claimant to samples obtained from *ex situ* collections. Incentives would thus be aligned to collect, deposit and preserve natural information *ex situ* for the purposes of utilizations.

5.3.4 Jurisdiction Shopping Take-Two: Areas Beyond National Jurisdiction

Rents require that Users not be able to jurisdiction shop. The jurisdictions for *T. crypta* include various Caribbean nations, a non-Party, *ex situ* collections and areas beyond the 200 miles of the EEZ, also known as Areas Beyond National Jurisdiction (ABNJ).[200] The last potential Provider would be the UNCLOS, which has opened discussion on what will be ABS for marine genetic resources.[201] As previously mentioned in Section 2.3., one proposal goes by the latinized title "Mare Geneticum", which is also the title of the corresponding foundational article.[202] Mare Geneticum addresses monetary benefits from access but does not deploy economics in discussing "actual commercial value" of marine genetic resources.[203] As stressed throughout this Report, the value in exchange of information is negligible

197 B. Coriat, *The Political Economy of HIV/AIDS in Developing Countries: TRIPS, Public Health Systems and Free Access* (Edward Elgar, Cheltenham, UK: Edward Elgar, 2008).

198 "At the end of the 1990s, a patented tritherapy was put on the market at a price of about $12-14,000 dollars per person per year. They are now [2008] available (for the simple, most common formulations) at a price of about $100 per person per year", Ibid, 9.

199 "NAIROBI Final Act of the Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity" (22 May 1992): 408. Available at https://www.cbd.int/doc/handbook/cbd-hb-09-en.pdf

200 Inspection of the NOAA Deep-Sea Coral & Sponge Map Portal indicates sponges just beyond the EEZ. Accessed on 15 February 2021. Available at https://www.ncei.noaa.gov/maps/deep-sea-corals/mapSites.htm

201 Report of the Preparatory Committee established by General Assembly Resolution 69/292, Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (21 July 2017). Available at www.un.org/ga/search/view_doc.asp?symbol=A/ AC.287/2017/PC.4/2

202 A. Broggiato et al, Note 52

203 A. Broggiato et al, Note 52, 12.

without a mechanism to secure rents. Therefore, the "actual commercial value" cited is not meaningful.[204] The authors also do not mention the social value or value in use of goods derived from marine genetic resources, which would be necessary to evaluate the excess burden of any significant royalty percentage. In general, Mare Geneticum downplays monetary benefits.[205] Like the earlier critique of the TEEB Report, the Labor Theory of Value can be interpreted in the reasons that the authors list for why mostly developed countries utilize marine genetic resources.[206]

Despite the lacunae, Mare Geneticum overlaps with Modality 3-II. Similarities include advocacy of unencumbered access, the desirability of fixed royalty percentages and the role of a General Fund. Worth repeating is that Mare Geneticum distinguishes itself through the core issue of rents. It contemplates none:

> The percentage of revenue to be shared should be predetermined and fixed, possibly by consultation with representative organizations and stakeholders of several biotechnology sectors, in order to provide for legal certainty, predictability and equity amongst players. It should also be consistent with the market levels payable under ABS regimes already in place within national jurisdictions (e.g., Brazil) and under development at regional levels, to avoid creating any perverse incentives.[207]

Any deference to "market levels payable under ABS regimes already in place" eliminates rents. Inasmuch as the 2015 Brazilian ABS legislation permits royalties as low as 0.1%, one infers that 0.1% would also be the "realistic" assessment of "actual commercial value" under Mare Geneticum.[208] A back-of-the-envelope calculation provides sufficient precision: for a billion-dollar block buster drug like ZDV/AZT, only one million dollars would have been generated for the ABNJ. Block busters are preciously few and scale matters. A multilateral system which offers such low monetary benefit is simply uneconomic. Why even bother with ABS?

5.4 Ebola (Filoviridae)

Key messages

- For pathogens, the first objective of the CBD can be interpreted as preservation *ex situ* and the second, containment and development of diagnostics and vaccines. The third objective of ABS stands;
- Under bilateral ABS, the Provider holds leverage by withholding samples and linking access to the availability of diagnostics and vaccines;
- The public-good nature of the absence of communicable disease justifies that diagnostics and vaccines be free of charge to the populace, regardless of the economic status of the country;
- The best solution for access to samples is a flat-rate payment per sample. The recommendation is contingent on diagnostics and vaccines being free of charge universally;
- The second best solution may be modeled after the Data Access Agreements of GISAID or the standardized contracts of the PIP Framework.
- The facts of Ebola may be hung on the analytical skeleton of economics.

One may be tempted to describe Modalities 3-I and 3-II as a shift in paradigm for which bilateralism has given way to multilateralism. We resist that temptation. A paradigm shift as elaborated by Thomas S. Kuhn, is the acceptance of an alternative worldview in light of the success of a new theory.[209] One thinks of Darwinism in late 19th-Century Biology or Keynesianism in mid-20th-Century Economics. The interpretation of genetic material as information is just the correction of a category mistake. The implications for ABS policy, however, are so monumental that a paradigm *appears* to have shifted.

The economics of information is normal science, where anomalies are puzzles to be solved. The International Federation of Pharmaceutical Manufacturers Association (IFPMA) perceives an anomaly for the CBD in the case of pathogens, "Biodiversity is about conservation and sustainable use of genetic resources but when it comes to pathogens we are working to eradicate them, to annul them."[210] The anomaly is a solvable within economics as a normal science. One returns to ground zero in our methodology: validity in deductive reasoning (see Table 2).

204 A. Broggiato et al, Note 52.

205 "Non-monetary benefits are considered the most practical and immediately valuable aspect of ABS", A. Broggiato et al, Note 52. 23.

206 A. Broggiato et al, Note 52, 14 and 15.

207 A. Broggiato et al, Note 52, 29.

208 "Are the expectations of large financial gains from the utilization of MGR in ABNJ realistic?" A. Broggiato et al, Note 53. 12.

209 Thomas S Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago, 1962).

210 Quoted from Grega Kumer, IFPMA's head of government relations, in Mark Hillsdon, "Will the Convention on Biological Diversity Hinder the Sharing of Pathogens - like the Corona Virus", *The Guardian* (19 June 2020).

If the premise is true and logic applied, then the conclusion will also be true. False is the premise that the first objective of the CBD means conservation *in situ* for pathogens. "Conservation" is not defined in Article 2 of the CBD. By the Vienna Convention, a reasonable interpretation for pathogens is only preservation *ex situ*.[211] "Conservation" could thereby accommodate eradication for pathogens *in situ*. "Fair and equitable" no longer imply rents for the provision of samples in Modality 3-II.[212] Traceability becomes of paramount importance. Unlike "conservation", Article 2 does define "sustainable use".[213] Consistent with that definition are public health measures that contain the spread of pathogens and development of diagnostics and vaccines. As we shall argue, ABS can facilitate both the first and second objectives of the CBD for pathogens.

Despite the peculiar nature of pathogens for ABS, the case of Ebola exhibits some of the same issues analyzed in the cases of the naked mole-rat, the snails of the genus Conus and the water sponges (Issues #3, 6 and 7 of Table 2). Yet the pandemic potential of pathogens alters the reasonable interpretation of the providing country of origin and how benefits should be calculated and claimed (#1 and 2). Given the ease of disembodying the small genomes of pathogens, "Digital Sequence Information" (#7) takes on special significance.[214] Its treatment here is detailed as Ebola has become the poster-child for denunciations of high-tech biopiracy.[215] Institutional structures for ABS, outside the CBD and NP, exist for pathogens. The deductions from economics for the ideal structures can be compared to the existing structures. For that reason, "Human Pathogens" are their own issue in Table 2 (#24). Sections 5.4.1 – 5.4.3 analyze Issues #1 & 2, 7 and 24, respectively, for pathogens. Section 5.4.4 looks at Ebola in the light of that analysis.

Omar Oduardo-Sierra organizes the case about Ebola in Appendix IV. The narrative coheres with a 2013 article, co-authored by Oduardo-Sierra, titled "Human Pathogens as Capstone Application of the Economics of Information to Convention on Biological Diversity", sponsored by the Australian Research Council.[216]

5.4.1 "'Country of origin of genetic resources' means the country which possesses those genetic resources in *in situ* conditions" (Article 2 CBD)

The CBD definition does not restrict "country of origin" to where the genetic resource evolved. *A Guide to the Convention on Biological Diversity* makes plain the implication:

> [M]any species exist in ecosystems as apparently natural, self-maintaining populations outside their original ranges (that is ranges prior to the recent era of human translocation), and the country where these species are now living in situ conditions would be considered under the Convention as the country of origin.[217]

Countries of origin in a pandemic would be all countries with cases of infection. Under Article 15 (5) and (7) of the CBD, the Provider could be any afflicted country which grants PIC to a User on MAT. Time matters. An epidemic will not wait for MAT between Providers and Users. Massive death and even herd immunity could transpire before conclusion of an MTA/BSA. Recall from the case of Conus snails that the assiduous team of Prof. Baldomero Olivera spent four years in paperwork to access *Conus geographus*.

Timing is center stage for breaking the chain of transmission and beginning vaccine development.[218] What Thomas Cueni, director of the IMPFA, writes about COVID19 applies to all viruses,

> From the day of the outbreak's first report, it took little more than one week for the World Health Organization to confirm the existence of the new coronavirus and for Chinese scientists to publish its genetic sequence. Think back to 2003

211 M.F. Rourke, "Never Mind the Science, Here's the Convention on Biological Diversity: Viral Sovereignty in the Smallpox Destruction Debate." *J Law Med.* volume 25 issue 2 (2018): 429-447. Available at https://pubmed.ncbi.nlm.nih.gov/29978646/

212 One thus avoids the fallacy of accident or ignoring qualifications (*a dicto simpliciter ad dictum secundum quid)*, *Britannica*. Accessed on 15 February 2021. Available at https://www.britannica.com/topic/fallacy-of-accident

213 "'*Sustainable use*' means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." Text of the CBD. Article 2: Use of Terms. Available at https://www.cbd.int/convention/articles/?a=cbd-02

214 Viruses may have as few as three thousand pairs, compared to humans with some 3 billion pairs or the Japanese white flower, *Paris japonica*, with some 150 billion pairs. "Faster rates of evolution are linked to tiny genomes", Okinawa Institute of Science and Technology (OIST) Graduate University, Science Daily (6 August 2020). Available at https://www.sciencedaily.com/releases/2020/08/200806111850.htm

215 E. Hammond, "Ebola: Company Avoids Benefit-Sharing Obligation by Using Sequences", *TWN Briefing Paper*, 99 (May 2019). Available at https://twn.my/title2/briefing_papers/No99.pdf

216 J.H. Vogel, C. Fuentes-Rivera, B.A. Hocking, O. Oduardo-Sierra and A. Zubiaurre,"Human Pathogens as Capstone Application of the Economics of Information to Convention on Biological Diversity", *International Journal of Biology* vol 5, issue 2 (April 2013): 121-134. Available at http://www.ccsenet.org/journal/index.php/ijb/article/view/22760

217 Lyle Glowka, *et al.*, *A Guide to the Convention on Biological Diversity* (Gland, Switzerland: IUCN-The World Conservation Union, 1994): 18.

218 Although the analysis is for a case of human pathogens, the general principles also apply for non-human pathogens. For example, the first-to-submit principle and a flat-rate payment would align incentives for the Ash Dieback outbreak described in the submission by Ruth Bastow *et al.*, 2017-2018 Sessional Period, Submission "Open Access to Digital Sequence Information Benefits the Three Objectives of the Convention on Biological Diversity." Available at https://www.cbd.int/abs/DSI-views/DivSeek.pdf

> when it took more than two months for the sequence of the coronavirus that causes SARS to be shared with the world. The speed with which the sequence of 2019-nCoV has been shared is a potent reminder of how we should avoid tying up the research community in red tape when we are in a race to find a new vaccine or treatment for a new virus or other pathogen.[219]

The race begins with isolation and characterization, followed by sequencing and uploading the genome into online databases for medical research worldwide. Economics can address how incentives can be designed to submit samples rapidly.

> Because timely data is of essence in public health (Cole, 2012), an efficient ABS policy should expedite samples into the international stream of R&D. By the nature of information, be it natural or artificial, once the first sample is sequenced, exact copies subsequently submitted are redundant. But pathogens mutate and few subsequent submissions will be exact. Therefore, ABS policy should skew the reward heavily toward the first provider of a sample of natural information with pathogenic potential. Like the patent system itself, a first-to-submit principle would reign, albeit nuanced to also reward mutations. Countries, which suffer outbreaks late or simply procrastinate, would share fewer benefits.[220]

A paradox results should the benefits be royalties. Speedy submission facilitates epidemiology and containment, yet the future demand for the biotechnology products will be diminished because of such diligence.[221] The years which usually lapse from submission of a pathogen sample to the rollout of a vaccine will also undercut royalties as the monetary benefit.[222] Deductions emerge. The monetary benefit should be: (a) claimed by the first-to-submit the isolate and metadata,[223] (b) invariant as to whether an epidemic ensues, viz. a flat rate, (c) earmarked for work on future submissions of viruses and (d) contingent on the Provider not having reduced its budget after similar payments for past submissions (the fungibility problem of Issue #19, in Table 2).

Deductions (a) – (d) are themselves contingent on a recognition that the absence of communicable diseases is a global **public good** of the first order.[224] The social value and value in use of vaccination dwarf the total costs of vaccine development, which vary by disease.[225] Contrary to the popular adage, sometimes one can compare apples with oranges (both contain fiber, sugar and Vitamin C): for childhood immunization in the USA, the social value has been rigorously estimated at $68.8 billion USD;[226] the outlays for vaccine development of Ebola sum to $1.5 billion.[227] Due to the public-good nature of the absence of communicable diseases, all governments should undertake vaccination programs free of charge to the public.[228] Fairness suggests that developed countries of the OECD bear the fixed costs of the development of diagnostics and vaccines.[229] Developing countries should pay the **variable costs** of manufacture for national needs. And for the least developed countries, the OECD should sponsor the variable costs.[230] Such deductions cohere with the portmanteau of the WHO comments with respect to the first CBD fact-finding in 2017: "DSI from pathogens is a global public health good that should benefit all."[231] They also dovetail with the

219 T.B. Cueni, "Novel coronavirus 2019-nCoV exposes a flaw in the Nagoya Protocol" *Stat News* (5 February 2020). Available at https://www.statnews.com/2020/02/05/novel-coronavirus-exposes-nagoya-protocol-flaw/

220 J.H. Vogel, et al, Note 216. 123=.

221 Similar paradoxes are elaborated in D.N Fisman and K.B. Laupland, "The sounds of silence: Public goods, externalities, and the value of infectious disease control programs." *Can J Infect Dis Med Microbiol* vol. 20 issue 2 (2009): 39-41. DOI:10.1155/2009/946012

222 S.A. Thompson, "How Long will A Vaccine Really Take?", *The New York Times* (30 April 2020) Available at https://www.nytimes.com/interactive/2020/04/30/opinion/coronavirus-covid-vaccine.html

223 GISAID "collects associated metadata such as date of specimen, specimen source, date of virus harvest, antiviral susceptibility, and for human samples patient information such as age, gender, health status, treatment, and vaccination." C. Saez, "Virus Sharing Key Against Next Flu Pandemic: Global Database Hosts Genetic Data of Flu Viruses", *Intellectual Property Watch* (26 August 2016). Available at https://www.ip-watch.org/2016/08/26/virus-sharing-key-against-next-flu-pandemic-global-database-hosts-genetic-data-of-flu-viruses/

224 The vaccine itself is not the public good as the vial is excludable and rivalrous, which are the criteria for being a private good. The herd immunity from vaccination is non-excludable and non-rivalrous and thus is the public good. The case is so overwhelming that advocacy of government intervention for vaccination even comes from a fellow of the Adam Smith Society. See, T. Worstall, T. "Why Government Should Spend More On Public Goods", *FORBES* (5 May 2013). Available at https://www.forbes.com/sites/timworstall/2013/05/05/why-government-should-spend-more-on-public-goods/#7308251286fb

225 P. Hurford and M.A. Davis,"How much does it cost to research and develop a vaccine?", *Effective Altruism Forum* (23 February 2018). Available at https://forum.effectivealtruism.org/posts/BjBmcfwg2awqPJLin/how-much-does-it-cost-to-research-and-develop-a-vaccine#en7

226 F. Zhou, et al. "Economic Evaluation of the Routine Childhood Immunization Program in the United States, 2009." *Pediatrics* vol. 133, issue 4 (April 2014): 577-585; DOI: 10.1542/peds.2013-0698. Available at https://pediatrics.aappublications.org/content/133/4/577

227 Financial Tracking Services. "Ebola Virus Outbreak - Overview of Needs and Requirements" (Inter-agency plan for Guinea, Liberia, Sierra Leone, Region) - October 2014 - June 2015". Available at https://fts.unocha.org/appeals/453/flows?order=directional_property&sort=asc&page=5#search-results

228 The same message can be inferred from the subtitle to Arthur Allen's 500-page account Vaccines: The Controversial Story of Medicine's Greatest Lifesaver (New York: W.W. Norton, 2007).

229 For example, in the Fiscal Years 2004-2013, the USA has supported Ebola research with $333 million. C. Boddie,"Federal funding in support of Ebola medical countermeasures R&D", Health security vol. 13 issue 1 (2015): 3-8. DOI:10.1089/hs.2015.0001 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4389695/

230 The Minister of Health of Indonesia cited "unfair mechanism" of intellectual property law as the reason for the refusal of to share avian influenza in 2007. T.I.S. Gerhardsen, "Indonesian Avian Flu Stance Reveals Potential Weakness in Global System", *Intellectual Property Watch* (8 March 2007). Available at https://www.ip-watch.org/2007/03/08/indonesian-avian-flu-stance-reveals-potential-weakness-in-global-system/

231 "Comments by the World Health Organization on the draft Fact-Finding and Scoping Study 'The Emergence and Growth of Digital Sequence Information in Research and Development: Implications for the Conservation and Sustainable Use of Biodiversity, and Fair and Equitable Benefit Sharing'", WHO. (9 November 2017). Available at https://www.who.int/docs/default-source/documents/nagoya-protocol/whocommentscbddsi.pdf?sfvrsn=8e3c64f1_2

justification for COVAX Facility to address the Covid-19 global pandemic of 2020 and 2021.[232]

How much should be the monetary benefit for submission of sequences? An incentive would be a payment above whatever is the Provider's average cost for isolation, characterization, sequencing and uploading of a virus. The numerical answer would depend on relative prices in each country. Who should pay? Taxes raised within the OECD is one option. The other is drawing from the proposed global fund for the GMBSM, which we call the "International Fund of Sharing and Distribution of the Benefits Derived from the Utilization of Natural Information" in Article 23 of our proposed amendment to the Nagoya Protocol (see Appendix VI). The justification lies in the costs associated with the *ex situ* preservation of pathogens.

As we stress in Section 5.4.3, the theoretically optimal modality for pathogens is contingent on worldwide provision of vaccination and diagnostic kits free of charge.

5.4.2 Commissioned Studies and DSI: The cart in front of the horse

Because DSI is exemplified in the vaccine development of Ebola, we discuss the placeholder here and return to its application in subsequent sections.

Databases on genetic resources do not refer to DSI. The distinguished authors of a FAO fact-finding study write "The scientific community notably does not use the term DSI".[233] The terms most used for non-pathogens are Nucleotide Sequence Data (NSD), Genetic Sequence Data (GSD) and Gene Sequences (GS). [234] For pathogens, the World Health Organization uses GSD.

Despite the ordinariness of each word in DSI, the meaning of the three together is not self-explanatory. Examination of origins may elucidate the neologism. Under Article 32 of the Vienna Treaty, consideration of such circumstances is allowable when interpretation of a term "(a) Leaves the meaning ambiguous or obscure; or (b) Leads to a result which is manifestly absurd or unreasonable".[235] The SPDA unpacked each word in "DSI" in the context of ABS. The three words together become absurd and unreasonable:

> Digital: The adjective implies that anything not "digital" is not included in whatever policy emerges. So, a sequence which is first accessed through the print medium would not be within the scope of "digital sequence information on genetic resources";
>
> Sequence: The noun "sequence" as an adjective in "digital sequence information" does not cover expressions of natural information other than nucleic acids and amino acids. For example, molecular structures, biomimicry and animal behavior would not be within the scope of the neologism. "Sequence" would thereby require future duplicative approaches for the sharing of benefits when molecular structures, etc. are utilized;
>
> Information: By not modifying the noun "information" with either "natural" or "artificial", "digital sequence information on genetic resources" does not distinguish the provenance of the sequence. The noun "information", so unmodified, extends the scope of ABS to that which could be artificial in origin.[236]

The circumstances surrounding the emergence of the neologism are germane. Recall from Box 1 that denunciations of "digital biopiracy" roiled side-events at COP10 in 2010. The number of databases has exploded since 2010 and the concern has only intensified.[237] The tipping point occurred at COP 13 in 2016 when Parties commissioned a fact-finding and scoping study on DSI "to clarify terminology and concepts and to assess the extent and the terms and conditions of the use of digital sequence

232 "COVAX Explained". Gavi: The Vaccine Alliance. Accessed 5 October 2020. Available at https://www.gavi.org/vaccineswork/covax-explained

233 J.A. Heinemann and D.S. Coray, *Draft Exploratory Fact-Finding Scoping Study on 'Digital Sequence Information' on Genetic Resources for Food and Agriculture*, Commission on Genetic Resources for Food and Agriculture, CGRFA/WG-AqGR-2/18/Inf.10 (2018):11. Available at http://www.fao.org/fi/static-media/MeetingDocuments/AqGenRes/ITWG/2018/Inf10e.pdf

234 "Genetic sequence data appears to be the term most widely used within scientific research circles, but the large databases joined into the International Nucleotide Sequence Database Collection consortium (discussed below) employ slightly different variations of terms. The DNA Data Bank of Japan uses the term "nucleotide sequence data"; the European Molecular Biology Laboratory (EMBL) European Bioinformatics Institute (EMBL-EBI) uses "nucleotide sequence information" and GenBank in the US uses "genetic sequences". S. Laird and R. Wynberg, *Fact Finding and Scoping Study on Digital Sequence Information on Genetic Resources in the Context of the Convention on Biological Diversity and Nagoya Protocol*. Document, CBD/DSI/AHTEG/2018/1/3 (January 2018): 20. Available at https://www.cbd.int/doc/c/e95a/4ddd/4baea2ec772be28edcd10358/dsi-ahteg-2018-01-03-en.pdf

235 Article 32. Supplementary Means of Interpretation. "Recourse may be had to supplementary means of interpretation, including the preparatory work of the treaty and the circumstances of its conclusion, in order to confirm the meaning resulting from the application of article 31, or to determine the meaning when the interpretation according to article 31: (a) Leaves the meaning ambiguous or obscure; or(b) Leads to a result which is manifestly absurd or unreasonable." Vienna Convention on the Law of Treaties (with annex), Note 20, 340.

236 "Unpacking 'Digital Sequence Information on Genetic Resources': Scaffolding of Errors to Preserve a Category Mistake"" Simultaneous submission of English original and Spanish translation in response to Decision XIII/16 "Digital Sequence Information on Genetic Resources" according to its Paragraph 1 - Peruvian Society of Environmental Law / Sociedad Peruana de Derecho Ambiental NOTIFICATION, Digital Sequence Information on Genetic Resources, SCBD/SPS/DC/VN/KG/jh/86500 (30 July 2017) Available at https://www.cbd.int/abs/DSI-views/SPDA-DSI-EN.pdf]

237 "The results here show rapid adoption of online molecular biology databases, with accumulation of over 1,700 unique databases during the 25year period covered. Moreover, new databases published within NAR Database Issues are proliferating at a rate of over 100 per year and have been for well over a decade". H.J. Imker, "25 Years of Molecular Biology Databases: A Study of Proliferation, Impact, and Maintenance", *Front. Res. Metr. Anal.* (29 May 2018). Available at https://doi.org/10.3389/frma.2018.00018

information on genetic resources in the context of the Convention and the Nagoya Protocol."[238]

As with all such commissions, the COP imposed constraints. One was that the authors not consider the policy implications of DSI. However, the *raison d'être* for seeking a term was the standing allegation of digital biopiracy. In the Introduction to the commissioned study, the authors Sarah Laird and Rachel Wynberg write,

> This report focuses more narrowly on the terms of reference for the scoping study, as outlined in decision XIII/16, producing a resource for the consideration of the AHTEG, and does not explore the broader policy implications of digital sequence information, or make recommendations other than those that identify important information gaps and areas for future research.[239]

An Ad Hoc Technical Group was convened in 2018 to evaluate the fact-finding study as well as the submission of views on DSI. The consensus opinion was that DSI is "not the appropriate term". [240] One deduces that all other terms should be considered when choosing whichever is the most appropriate term.[241]

Concern over digital biopiracy did not abate during the intersessional period 2016 – 2018 leading up to COP14.[242] Four additional studies on DSI were commissioned, which would cover Concept and Scope (Study #1), Traceability of Databases (Combined Study #2&3) and Domestic Measures (Study #4).[243] The cart was positioned even though no horse had been chosen.

Inasmuch as science does not use the term DSI, the response to the commission of Combined Study #2&3 should have been a terse "No databases on DSI are found and nothing exists to trace".[244] Under Modality 3-II, such parsimony would have saved Parties from a needless distraction. The AHTEG on DSI in 2020 noted "[I]n the case of a multilateral approach to benefit-sharing, traceability of digital sequence information to the provider countries and monitoring its use along the value chain may not be required".[245]

Cart-in-front-of-horse objections have also been lodged against the methodology of Study #4. "One cannot examine domestic measures on national legislation that does not exist… Rather than explore how the Phenom originated in 'digital biopiracy' and go from there, the authors conformed to the *status quo* under the guise of inclusiveness".[246] Logic would be defied (the fallacy of affirming the consequent).

Unlike the Combined Study #2&3 and Study #4, successful execution of the commission for Study #1 on Concept was possible. Study #1 could have identified a string of horses, i.e., all the possible terms, to help future COPs pick the one most able to bear the load of ABS. Success, sadly, was forfeited. The authors of Study #1 state in the Introduction that "This study is scientific in scope and does not cover associated policy implications."[247] The separation of "concept and scope" from "associated policy implications" meant a separation from the circumstances of "digital biopiracy" that brought forth the placeholder, thus discarding the potential of Article 32 of the Vienna Treaty, which allows such recourse.[248] The self-imposed constraint did not escape peer reviewers. The opening comment of The Third World Network reads:

> [We] concur in general terms with the observation of Joseph Vogel (in his review of this study), that "Evaluation of a replacement term for 'digital sequence information' (DSI) cannot be divorced from its policy implications," and further

238 See "Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity XIII/16. Digital sequence information on genetic resources" (13 December 2016):1. Available at https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-16-en.pdf.

239 S. Laird and R. Wynberg, Note 234, 19.

240 Ad Hoc Technical Expert Group on Digital Sequence Information on Genetic Resources, "Report of the Ad Hoc Technical Expert Group on Digital Sequence Information on Genetic Resources", CBD/DSI/AHTEG/2018/1/4/ (20 February 2018): 5. Available at https://www.cbd.int/doc/c/4f53/a660/20273cadac313787b058a7b6/dsi-ahteg-2018-01-04-en.pdf

241 One of the authors of the Combined Study served on the 2018 AHTEG dissociated himself from the final report. M.E. Watanabe, "The Conundrum of Defining Digital Sequence Information", *BioScience* volume 69, issue 6 (June 2019): 480. Available at https://doi.org/10.1093/biosci/biz034

242 The controversy over the placeholder DSI spilled over to the FAO, WHO, WIPO and WTO, each of which had distinct interpretations. See Stuart J. Smyth, Diego M. Macall, Peter W.B. Phillips and Jeremy de Beer, "Implications of biological information digitization: Access and benefit sharing of plant genetic resources", *Journal of World Intellectual Property*, volume 23, issue 3-4 (July 2020): 267-287.

243 "Decision adopted by the Conference of the Parties to the Convention on Biological Diversity"14/20. Digital sequence information on genetic resources" (30 November 2018). Available at https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-20-en.pdf

244 "Peer Review by Joseph Henry Vogel of the 'Combined Study on Traceability and Databases' by Fabian Rohden et al. United Nations Secretariat of the Convention on Biological Diversity (19 November 2019). Available at https://www.cbd.int/abs/DSI-peer/2019/Study2-3/JosephHenryVogel.pdf

245 Report of the Ad Hoc Technical Expert Group on Digital Sequence Information on Genetic Resources (20 March 2020). Available at https://www.cbd.int/doc/c/ba60/7272/3260b5e396821d42bc21035a/dsi-ahteg-2020-01-07-en.pdf

246 "Peer Review by Joseph Henry Vogel of 'Study to Identify Specific Cases of Genetic Resources and Traditional Knowledge Associated with Genetic Resources that Occur in Transboundary Situations for Which it is Not Possible to Grant or Obtain Prior Informed Consent' by Margo Bagley and Frederic Perron-Welch". United Nations Secretariat of the Convention on Biological Diversity (23 March 2020): 10. Available at https://www.cbd.int/abs/art10/2019-2020/study.shtml

247 W. Houssen, R. Sara and M. Jaspars, "Digital Sequence Information on Genetic Resources: Concept, Scope and Current Use CBD/DSI/AHTEG/2020/1/3" (29 January 2020): 12. Available at https://www.cbd.int/doc/c/fef9/2f90/70f037ccc5da885dfb293e88/dsi-ahteg-2020-01-03-en.pdf

248 Ibid 237.

> that that study's assertion of being '"scientific in scope" and "not cover[ing] associated policy implications" is in fact a conceit and should be acknowledged as such.[249]

Inasmuch as the AHTEG had already reached consensus that DSI is not the appropriate term, the authors of Study #1 should have inspected every horse in the string. They did not. "*Glaringly absent is natural information*" (italics in original).[250] Tellingly, "natural information" had earlier appeared in the Brazilian submission of views on DSI[251] and was even the preferred term expressed by Ethiopia on behalf of The African Group:

> To avoid a situation in which emerging biodiversity governance policy is (again) overtaken by rapid technological innovation and change we favor the use of a neutral and wide term like "natural information", while remaining open to discussing the possibility that different types of natural information might eventually be subject to different governance regimes.[252]

Whereas dismissal of peer reviews is dispiriting, suppression of a term favored by mega-diverse Parties is inexcusable. How did the absence of "natural information" survive revision of the drafts and continue in the final text? Study #1 is exhaustive and otherwise meticulous. A plausible explanation lies in social psychology: natural information had long been taboo in the ABS discussion.

Recognition of taboos has belatedly begun. Movement forward on a replacement term for DSI can be gleaned from the 2019 Report to "First Global Dialogue", discussed in Section 3. In a list of a dozen expectations of participants, "taboos and restrictions in discussions" ranked second in "what should not happen at this dialog".[253] "Bounded openness" was therein cited twice albeit not followed by the words "natural information".[254] Nevertheless, "natural information" is elliptical in all such references. The full term for the modality is "bounded openness over natural information".

5.4.3 ABS Extant for Human Pathogens

Policy options must consider distortions related to each option. Richard G. Lipsey and Kelvin Lancaster published in 1957 "The General Theory of Second Best", which proved that non-consideration of distortions will prevent the optimal outcome.[255] Piecemeal reform may even amplify the related distortion and induce a loss. Therefore, concomitant with any reform must be interventions on related distortions.

Examples of second best abound. The favorite in the literature seems to be pollution. Free trade may enable efficiencies between trading partners but the gains from trade can be swamped by the losses from pollution. For efficiency, trade agreements must include environment-related provisions. An analogy for human pathogens lies in the globalization of economies and world-wide immunization.

The General Theory of Second Best is a reality check for armchair economists. However, the messiness of reality means that the interventions will also be messy. Abuse looms large.[256] In "Reflections for the General Theory of Second Best on its Golden Jubilee", Lipsey responds to the "allegation that second best theory provides justification for just about any crazy interventionist policy".[257] He writes,

> Highly elaborate theory is not necessary in these cases and many others like them. What is needed is a good appreciative understanding of how the price system works, as well as understanding the cautionary warning from second best theory that any policy may have unexpected and undesirable consequences in apparently unrelated parts of the economy that need to be watched for and mitigated where necessary. *Useful piecemeal policy advising is not impossible*; neither can it be determined purely scientifically. *Instead it is an art, assisted by good economics, both theoretical and empirical* (italics added).[258]

249 E. Hammond, Third World Network, "*Peer Review of Digital Sequence Information on Genetic Resources: Concept, Scope and Current Use*" (2019): 1. Accessed on 15 February 2021. Available at https://www.cbd.int/abs/DSI-peer/2019/Study1/TWN.pdf

250 "Peer Review by Joseph Henry Vogel of the 'Study on Concept and Scope' by Wael Houssen et al", United Nations Secretariat of the Convention on Biological Diversity (11 December 2019): 1. Available at https://www.cbd.int/dsi-gr/2019-2020/studies/#tab=0 Intralink: Joseph Henry Vogel

251 Peer Review by Ministry of Foreign Affairs of Brazil – Environment Division, Digital Sequence Information (8 September 2017): 1. Available at https://www.cbd.int/abs/DSI-views/Brazil-DSI.pdf

252 Ethiopia, "Potential implications of the use of "digital sequence information on genetic resources" (8 September 2017): 2. Available at https://www.cbd.int/abs/DSI-views/Ethiopia-AU-DSI.pdf

253 *Report of the First Global Dialogue on DSI*, Note 18, 4

254 Note 18, 22 and 24.

255 R.G. Lipsey and K. Lancaster,"The General Theory of Second Best", *Review of Economic Studies* vol. 24 issue 1 (1956): 11–32. For a non-technical explanation, see Legal Theory Lexicon (2003). Available at http:// legaltheorylexicon.blogspot.com/2003/11/legal-theory-lexicon-011-second.html

256 "Second-best arguments have a dubious reputation in economics, because the right policy is always to eliminate the primary distortion, if you can. But sometimes you can"t…" P. Krugman,"The Big Green Test", *The New York Times* (22 June 2014): A21.

257 R. Lipsey, "Reflections on the general theory of second best at its golden jubilee," *International Tax and Public Finance* vol. 14 issue 4 (2007): 349-364, 362. Available at https://www.researchgate.net/profile/Richard_Lipsey/publication/5148348_Reflections_on_the_General_Theory_of_Second_Best_at_Its_Golden_Jubilee/links/574ca68508ae061b3301d87f/Reflections-on-the-General-Theory-of-Second-Best-at-Its-Golden-Jubilee.pdf

258 Ibid.

Failure of the OECD to assure free vaccines and diagnostic kits worldwide is a distortion of basic economics. The COP must evaluate the interrelatedness of that distortion with a *sui generis* modality of ABS for pathogens. By the general theory of second best, payments for submission of samples, calculated as the average cost of a submission (deductions (a)-(d) in Section 5.4.1) could make access to pathogens considerably worse. The failure to assure free-of-charge vaccines will lead less developed countries to reject such payments as penurious.[259] Withholding samples is leverage for negotiating affordable diagnostic kits, anti-viral medicines and vaccines, all of which enjoy time-limited monopoly intellectual property rights.[260] One cannot sufficiently stress that the recommended policy of a flat-rate payment for submissions depends on diagnostic kits and vaccination being free-of-charge worldwide, regardless of whether or not samples were submitted. Only if they are universally free can the flat rates be optimal. Even then the goal of public health may prove elusive. Worrisomely, the WHO lists "vaccine hesitancy" (aka anti-vax) as a top-ten threat to global health.[261] Experts in other forums must simultaneously address misinformation campaigns and fear mongering.[262]

The best solution for the ABS of pathogens is untenable *as long as* the OECD does not assume the costs of vaccination and diagnostic kits for the least developed countries. What is second best? The answer may lie in experiences of Global Initiative on Sharing All Influenza Data (GISAID) and the WHO, which operate under a bilateral modality of ABS. The 2006 proposal for the establishment of GISAID exhibited the twin criteria for effective philanthropy, viz., public goodness and non-fungibility The broadcasting CEO Peter Bogner responded to the call with money and, perhaps even more importantly, expertise in licensing.[263] An indicator of the remarkable success of GISAID was assumption of the platform by the German government in 2009. In other words, a government was persuaded that GISAID was a worthwhile public good. Philanthropy could recede.

The possibility of GISAID as an ABS modality lies in the design of its Data Access Agreement (DAA). Six salient features of the DAA should be read through the lens of the general theory of second best:

> The core provisions… include that users: (1) will share their own data and allow other users to access it; (2) that they will not share or distribute data submitted directly to the GISAID sharing mechanism to other non-GISAID servers or to individuals/institutions who are not registered GISAID users; (3) that they will credit the use of others' data in publications; (4) that they will make best efforts to collaborate with the originating laboratory and involve them in analyses and further research involving the data; (5) that they will analyze findings jointly; and (6) that they will maintain common access to technology derived from the data so that it can be used not only for research but also for the development of medical interventions such as diagnostics, vaccines, or antivirals. According to the agreement, GISAID users thus have the right to develop a commercial product on the basis of data obtained through GISAID, but they may not impose any terms on the data itself (which remains the sole property of the contributor), and they must also seek to collaborate with the data contributors.[264]

The six benefits implicitly recognize DSI as within the scope of ABS.[265] The last provision, "mainten[ance] of common access", addresses the reason given by Indonesia to withhold avian-flu samples in 2003. However, number (6) lacks the clarity of the previous five provisions. Whereas the interests of the scientists who isolate, characterize and sequence samples are well addressed in (1)-(5),[266] those of the general public are not as equally well addressed in (6).[267] What we

259 "Los pobres venden barato" ["The poor sell cheap"] is also known as the Lawrence-Summers Principle, inspired by a 1991 memo from the then chief economist of the World Bank. Joan Martinez-Alier "Conflictos de distribución ecológica", *Revista Andina,* No. 1 (July 1997): 51. Available at http://www.revistaandinacbc.com/wp-content/uploads/2016/ra29/ra-29-1997-03.pdf

260 The theoretical distortion is the negative **externality** implied by the exercise of such leverage.

261 World Health Organization, "Ten Threats to Global Health in 2019." Available at https://www.who.int/news-room/feature-stories/ten-threats-to-global-health-in-2019

262 Salzburg, S. "How Anti-Vax Activists Use Conspiracy Theories To Spread Fear Of Vaccines", *FORBES* (3 February 2020). Available at https://www.forbes.com/sites/stevensalzberg/2020/02/03/how-the-anti-vaccine-cult-spreads-its-message/#4c4d9f022036

263 "GISAID may have had an unlikely birth as a new global health initiative – with an unusually strong role played by an energetic, influential, and dedicated philanthropist without a prior back- ground in global health". Ibid, 44.

264 Ibid, 39.

265 Nevertheless, explicit recognition is ticklish. "At the time of writing, GISAID is thus having to navigate a complex and sensitive set of diplomatic negotiations around the future role of genetic sequence data in the framework, with potentially considerable ramifications for the future of the initiative". Ibid, 45. However, other first-world stakeholders are explicit. See, K Sollberger, *Digital sequence information and the Nagoya Protocol. Legal expert brief on behalf of the Swiss Federal Office for the Environment* (FOEN) (7 April 2018). Available at https://www.bafu.admin.ch/dam/bafu/en/dokumente/biotechnologie/rechtsgutachten/digitale-sequenzinformationen-nagoya-protokoll-rechtliches-gutachten.pdf.download.pdf/20180407_kurzgutachten-digitale-sequenzinformationen_final.pdf

266 "It has since been highly successful, not only being adopted by GISRS and securing the confidence of MS, but has become increasing widely recognized (within and outside influenza) as an effective sharing mechanism, as evidenced by over 6,500 active users and influenza data from well over 800 institutions worldwide, a substantial amount of which is publicly accessible nowhere else." WHO PIP Framework Review Group 2016, GISAID's Comments on the Preliminary Findings of the PIP Framework Review (25 September 2016). Available at https://www.gisaid.org/references/statements-clarifications/gisaid-comments-on-the-preliminary-findings-of-the-pip-framework-review-group-2016-25-september-2016/

267 Elsewhere, GISAID has argued that "Access to medicines should not be linked to the provision of pathogen samples". "Notice and Request for Comments on the

see is the **principal-agent problem** of Economics. The interests of the agents, provisions (1)-(5), depart from those of the principal, provision (6), yet the former can greatly influence the decision made by the latter, which in this case is to decide whether or not to withhold samples.[268] Through the lens of the general theory of second best, the distortion of principal-agent counteracts the distortion of vaccines not being free of charge worldwide. To the extent that vaccines are not free of charge, DAA is a solution for ABS. But is it the second best?

Another solution arose from the distortion of vaccines not being free:

> The Pandemic Influenza Preparedness (PIP) Framework was adopted by the World Health Assembly in 2011, following the 2009 influenza pandemic caused by the A(H1N1) virus. During this pandemic, "[v]accines were in short supply, and there was slow distribution of donated vaccines to developing countries," which resulted in the deaths of "151,000 to 575,400 in the first year alone," and showed that the world was not prepared for a severe pandemic, the report said… The benefit-sharing component of the PIP Framework is the Partnership Contribution, which is an annual contribution of funds to the WHO from industry partners, such as influenza vaccine, diagnostic and pharmaceutical manufacturers, that utilize the WHO Global Influenza Surveillance and Response System (GISRS).[269]

Michelle Rourke elaborates the legal implications PIP Framework. Excerpts from her analysis are illuminating:

> The SMTA2 [Standard Material Transfer Agreement 2] transfers these materials from the GISRS to parties that sit outside of the WHO-recognized GISRS network and its governance reach, including academic laboratories and research institutes, as well as diagnostic and vaccine manufacturers (Article 5.4.2 and Annex 2). In exchange, these third-party, non-GISRS recipients elect to provide certain benefits to the WHO, according to their capacities (Article 5.4.2 and Annex 2, Article 4). For instance, an influenza vaccine manufacturer may elect to donate a percentage of its vaccine production to the WHO in the event of a pandemic or grant royalty-free licenses to vaccine manufacturers in developing countries (Annex 2, Article 4.1.1[A])…
>
> SMTAs do not create any direct or binding agreements between the originating Member States as the providers of PIP biological materials and the recipients of those materials, and that the SMTA2 may not be effective in securing the promised benefits from commercial third parties in the event of a pandemic…
>
> The article concludes that while the PIP Framework was broadly conceived to perform as an access and benefit-sharing framework, it might be better conceptualized simply as an access framework.[270]

Both GISAID and the PIP Framework are ambiguous about the affordability of diagnostic kits, antiviral medicines and vaccines. Unaffordable diagnostic kits, etc. will create future pressures on Providers to revisit the decision not to withhold samples. Crisis will return. Before such a foreseeable event, Parties and stakeholders would be well advised to channel energies on dismantling the distortion that prevented the best solution. Instead, the WHO announced plans in December 2020 to "shortcut" the benefit-sharing discussions of the Nagoya Protocol.[271]

5.4.4 Hanging facts about Ebola on the Analytical Skeleton of the Economics of Information

Scientists use various metaphors to describe their endeavors. Kuhn viewed theory as a way to solve puzzles. Hardin saw it as a compactor. In classroom lectures, E.O. Wilson would say that theory is a skeleton upon which the biologist will hang flesh, viz. facts. The economics of information compacts and solves puzzles about fairness, equity and efficiency in the ABS discussion. However, the flesh-skeleton metaphor seems the most appropriate to consider specific cases like Ebola.

Implications of Access and Benefit-Sharing (ABS) Regimes on Global Health and Biomedical Research US Department of State [Public Notice: 10789] - Submission by the GISAID Initiative", 13 May 2019, p. 5. Available at https://www.gisaid.org/fileadmin/gisaid/files/pdfs/GISAID_Comments_DOS-10789.pdf

268 The principal-agent problem is not confined to pathogens. The problem can also be gleaned in legislation from Panama which differentiates royalties fourfold according to whether or not a local organization is involved in the utilization. See, Capítulo 1, Artículo 42, "Por el cual se reglamenta el acceso y control del uso de los recursos biológicos y genéticos en la República de Panamá y se dictan otras medidas" No. 28741-A Gaceta Oficial Digital (27 March 2019): 13. Available at https://www.gacetaoficial.gob.pa/pdfTemp/28741_A/72121.pdf

269 D. Branigan, "WHO Report Shows Global Progress On Influenza Preparedness Response", *Intellectual Property Watch* (18 December 2018). Available at https://www.ip-watch.org/2018/12/18/report-shows-global-progress-influenza-preparedness-response/

270 M.F. Rourke, "Access by Design, Benefits if Convenient: A Closer Look at the Pandemic Influenza Preparedness Framework's Standard Material Transfer Agreements." Milbank Q. vol. 97, issue 1 (2019): 91-112. DOI:10.1111/1468-0009.12364. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6422609/

271 Edward Hammond, "Questions swirl about proposed WHO pathogen collection Effort to 'shortcut' the Nagoya Protocol raises fairness and equity and other issues", *TWN Briefing Paper* (January 2021). Available at https://twn.my/title2/briefing_papers/twn/Questions%20about%20proposed%20WHO%20pathogen%20collection%20Jan2021%20Hammond.pdf

Box 11

Facts as flesh to be Hung on a Theoretical Skeleton: Ebola and Economics

- Ebola was contained outside of Africa. The USA reported eleven cases and just two deaths. This fact demonstrates why royalties on a vaccine cannot be the benefit to be shared for submitting samples: success in containment would penalize submitters while failure to take such measures would reward them.
- Psychology cannot be ignored. Without behavioral reinforcement, people will grossly underestimate the value of avoiding infection. In a national survey conducted in the USA in 2015, 30% of the population sample would be willing to pay $100 or more to avoid infection.[b] With a population of 330 million, the value in use translates in excess of $33 billion for just the USA; one imagines similar value would emerge in other OECD countries.
- "Ebola virus disease is a rare but severe and often deadly disease that knows no borders. Vaccination is essential to help prevent outbreaks and to stop the Ebola virus from spreading when outbreaks do occur."[c] Ervebo, the first FDA-approved vaccine is based on strains from the species Zaire Ebola virus but was isolated in Guinea from what is believed to be "a single introduction of the virus into the human population".[d] Should only the country providing the sample be the beneficiary, then the afflicted country of biological origin, the Democratic Republic of the Congo (formerly Zaire), would not be a beneficiary. Given the absence of communicable disease is a public good, any such benefit would be not only inequitable but also inefficient.
- Resilient is the distortion that vaccines not be sponsored in low-income countries. "Merck says Ebola vaccine to be available at lowest access price for poor nations".[e] The absence of Ebola in the OECD is a public good which justifies OECD sponsorship of vaccination in the low-income countries.
- The gaping hole in sponsoring vaccination in low-income countries has been filled by philanthropy: "The plan is for poor and middle-income countries to access the $178 stockpile free of charge, GAVI said on Thursday, while other countries will need to refund the costs… GAVI is a public-private partnership backed by the Bill & Melinda Gates Foundation, the World Health Organization, the World Bank, UNICEF and others, which arranges bulk buys to reduce vaccine costs for poor countries".[f] Philanthropy is fickle. What if the priorities of a philanthropist change for any reason or for no reason? The Bill & Melinda Gates Foundation should be seen as a bridge to OECD financing, much like the example of Peter Bogner, GISAID and the German government.
- The analog to jurisdiction shopping for ABS is medium shopping. The Germany-based Nocht Institute uploaded the sequence of Ebola to GenBank which prides itself on open access; the USA-based Regeneron Pharmaceutical downloaded the sequence from GenBank "no strings attached".[g] ABS obligations were avoided or evaded, depending on one's perception of intent and interpretation of "material" in the definition of "genetic resources" in the CBD.

a B. Hounshell,"What Ebola Taught Susan Rice About the Next Pandemic", *Politico* (6 August 2020). Available at https://www.politico.com/news/magazine/2020/08/06/susan-rice-pandemic-ebola-391469

b J.E. Painter, J.E, M.E. von Fricken, S. Mesquita and R.J. DiClemente, "Willingness to pay for an Ebola vaccine during the 2014-2016 ebola outbreak in West Africa: Results from a U.S. National sample". *Hum Vaccin Immunother*. 2018; vol. 14, issue 7 (2018):1665-1671. DOI:10.1080/21645515.2018.1423928. Available at https://pubmed.ncbi.nlm.nih.gov/29333950/

c Peter Marks, "First FDA-approved vaccine for the prevention of Ebola virus disease, marking a critical milestone in public health preparedness and response", FDA News Release (19 December 2019). Available at https://www.fda.gov/news-events/press-announcements/first-fda-approved-vaccine-prevention-ebola-virus-disease-marking-critical-milestone-public-health.

d S. Baize, et al., "Emergence of Zaire Ebola Virus Disease in Guinea", *N Engl J Med* vol. 371 (9 October 2014)::1418-1425. DOI: 10.1056/NEJMoa1404505. Available at https://www.nejm.org/doi/full/10.1056/NEJMoa1404505

e "Merck says Ebola vaccine to be available at lowest access price for poor nations". Reuters (20 December 2019). Available athttps://www.reuters.com/article/us-merck-co-ebola/merck-says-ebola-vaccine-to-be-available-at-lowest-access-price-for-poor-nations-idUSKBN1YO29H

f Ibid.

g E. Hammond,"Ebola: Company Avoids Benefit-Sharing Obligation by Using Sequences." *TWN Briefing Paper*, 99 (May 2019): 1. Available at https://twn.my/title2/briefing_papers/No99.pdf

Conclusions

Analogical, inductive and deductive reasoning yield implications for the five modalities for ABS identified in the First Global Dialogue on DSI. Each modality can be evaluated by the criteria of fairness, equity and efficiency for achieving the objectives of the CBD. Four cases offer insights as to how each case would have eventuated under an alternative modality to bilateralism.

Twenty-four issues arise with the *status quo* modality, viz. the Nagoya – bilateral approach. Table 4 identifies the disadvantages of Nagoya – bilateral, and the advantages of the five alternatives. The rubric below each numbered issue explains the problem with the *status quo*. The requirements for the solution suggested by the alternative modalities are listed in the rows. Comparisons are thus facilitated not only between each of the six modalities for a specific issue but also among the twenty-four issues for ABS. Trade-offs are surprisingly few. Modality 3-II (bounded openness) dominates.

This startling and hopeful conclusion is embedded in considerations that merit discussion in the upcoming and future Conference of the Parties:

a. Many terms are not defined in the CBD and Nagoya Protocol. The Vienna Convention is clear as to how to interpret undefined terms. "Conservation" in the CBD and Nagoya Protocol cannot be interpreted with a date of expiry. *Conservation means* as if *forever.* Hence, the opportunity costs of habitat loss must be offset, even though extinction from business-as-usual will occur far beyond the time horizon of most political decisions.
b. Correct nomenclature is essential for policymaking, as painfully shown with the neologism "digital sequence information". Though supported by a trajectory of peer-reviewed literature, "natural information" has never been vetted and is not even cited in the five COP14 commissioned studies on DSI published in 2019-2020. The transdisciplinary approach of this Report includes the psychology that would explain the absence.
c. Is the object of access for R&D, a tangible or an intangible? Policy implications from economics are diametrically opposed between tangibles and intangibles. Classification must not conflate information with the medium even when the former cannot be extracted from the prior, as had been the case in biology prior to 1953.
d. The ABS discussion has been legalistic rather than economic. The argument of *stare decisis* preserves the category error of treating an intangible as if it were tangible for the purposes of policy. Correction is facilitated by the nature of the CBD and Nagoya Protocol being framework treaties.
e. Any modality chosen, including a return to "common heritage of mankind" is just as much an expression of sovereignty as are MAT and PIC in the bilateral approach.
f. Economic analysis of ABS provides powerful abstraction. Elementary concepts such as "rents", "social value", "value in exchange versus value in use" and "fixed costs versus marginal costs" allow Parties to entertain both efficiency and equity in the ABS discussion.
g. More advanced concepts such as "excess burden", "fungibility" and "The Ramsey Rule" provide clear policy implications.
h. The mega-diverse non-Party is the elephant in the room. With dematerialization, the room shrinks and the elephant grows. The current advantages of being a non-Party could set off a positive feedback of Party withdrawal from the CBD and NP or further solidify the non-Party status of the elephant. An ABS modality should be chosen to do just the opposite, i.e. incentivize the non-Party to become a Party. Modality 3-II provides such incentives, both directly and indirectly. The non-Party will want to have a voice in the negotiation of royalty percentages for classes of utilization. *Ex situ* collections in the non-Party will also want to participate in shared royalties for genetic resources which are ubiquitous. To the extent that the government in the non-Party finances those collections, fungibility becomes an incentive for the non-Party to ratify.
i. Significant monetary benefits for the commercial successes of R&D are only possible through Modality 3-II (bounded openness), thereby achieving the resource mobilization that has long alluded the COP and is central for the Post 2020 Biodiversity Agenda. Blockbusters are low-probability events of a high value for which the expected value is the probability of the event multiplied by the value of the event. Cognitive dissonance explains the impasse: Providers confuse the expected value with the value of the event; Users confuse the expected value with the probability of the event.
j. An amendment to the Nagoya Protocol is necessary for the realization of ABS.

Table 4. Advantages or Disadvantages of Modalities with Requirements & Solutions

1. Country of origin and fairness and equity	
Problem(s) rendering *status quo* disadvantageous: Inefficiency due to transaction costs. Competition among Providers eliminates rents (see Jurisdiction shopping by Users)	
Modality 1: "Nagoya – Bilateral"	Provider grants PIC to User for negotiation of ABS agreement
Modality 2: "Open Access – Bilateral"	Solution: Transaction costs of PIC and MAT (ABS agreements) are reduced but not eliminated Requirement: Country tag allows identification of country which provided genetic resource subsequently disembodied. Nevertheless, competition with other databases or media will eliminate rents
Modality 3-I: "Open Access – Multilateral" (Common pools)	Solution: Transaction costs of PIC and MAT (ABS agreements) are eliminated. Requirement: Determination of species and geographic range enabling identification of countries of origin. Fairness and equity obtain among Providers, but not between Provider and User. Benefit will be infinitesimal as rents are eliminated by competing pools. Coordination with institutions for classification of transboundary species
Modality 3-II: "Open Access – Multilateral" (Bounded openness)	Solution: Identification of species (plural) and geographic range enable identification of all possible *countries* of origin Requirement: Coordination with institutions for identification of diffusion of natural information across taxa and estimates of geographic ranges of corresponding species for terrestrial species
Modality 4: "Open Access – Subscription fee / Levies	Solution: Transaction costs reduced from elimination of PIC and MAT (ABS agreements) Requirement: Fairness and equity require that rents be incorporated in fee or levy, resulting in inefficiencies to the extent that payment would not vary with value added. The Global Fund can only be fair and equitable to the extent that the distribution reflects the country of origin
Modality 5: "Free Access – Capacity Development"	Solution: Transaction costs of PIC and MAT (ABS agreements) are eliminated Requirement: Openness defaults to unboundedness globally. The universality is assumed sufficient for the criteria of fairness and equity
2. Sovereignty and ownership	
Problem(s) rendering *status quo* disadvantageous: Cosmopolitan species mean competition among Providers and elimination of rents (see Jurisdiction shopping). To the extent legal title does not correspond to control over land use, incentives are not aligned between utilization and conservation	
Modality 1: "Nagoya – Bilateral"	States are sovereign over genetic resources and tend not to devolve title to benefits to landowners
Modality 2: "Open Access – Bilateral"	Same as Modality 1
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 1

Modality 3-II: "Open Access – Multilateral": (Bounded openness)	Solution: Cosmopolitan species claim a share of rents according to percentage of global geographic range. Inasmuch as alignment of incentives is overarching principle, State is more likely to continue aligning incentives to next lower level of control over habitat Requirement: Acknowledgement that a multilateral benefit-sharing mechanism is an expression of sovereignty
Modality 4: "Open Access – Subscription fee / Levies	Solution: Standardization of subscription fees or levies on equipment allows for the possible capture of rents Requirement: Acknowledgement that a multilateral benefit-sharing mechanism is an expression of sovereignty. Once "natural information" is uploaded into database, origin of sample is irrelevant
Modality 5: "Free Access – Capacity Development"	Requirement: Acknowledgement that even one one of complete unboundedness is an expression of sovereignty
3. Jurisdiction shopping for countries of origin by Users	
Problem(s) rendering *status quo* disadvantageous: The resultant elimination of rents violates fairness and equity as only Users enjoy rents on value added through time-limited monopoly IP. Legal uncertainty ensues even in simple ABS frameworks	
Modality 1: "Nagoya – Bilateral"	Users choose country of origin for cosmopolitan species based on lowest price and/or lightest regulatory burden
Modality 2: "Open Access – Bilateral"	Same as Modality 1
Modality 3-I: "Open Access – Multilateral": (Common pools)	Solution: Problem alleviated but nevertheless present, as Users compare regional common pools (RCPs) and other media to access natural information
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Royalty set according to utilization and type of IP. Rent is reflected in royalty Requirement: Among Parties, none as inherent to modality. With non-Party, greatly diminished due to openness
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Subscription fee or levy on equipment set across Providers and reflects a rent Requirement: None as inherent to modality.
Modality 5: "Free Access – Capacity Development"	Nonissue
4. Jurisdiction shopping for site selection of capital investments	
Problem(s) rendering *status quo* disadvantageous: Non-Party is reinforced not to accede as avoidance of ABS obligations is highly attractive to Users.	
Modality 1: "Nagoya – Bilateral"	Encouragement of non-Party not to accede to the CBD and the NP
Modality 2: "Open Access – Bilateral"	Same as Modality 1
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 1
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Royalty set according to industrial sector and type of IP. Rent is reflected in royalty. Requirement: None as inherent to modality

Modality 4: "Open Access – Subscription fee / Levies"	Solution: Irrelevant as "natural information" is transmitted electronically
Modality 5: "Free Access – Capacity Development"	Nonissue
5. Transparency	
Problem(s) rendering *status quo* disadvantageous: Conceals royalty concluded in contract, which is essential to evaluate fairness and equity	
Modality 1: "Nagoya – Bilateral"	Confidential business information cited in CBD and NP
Modality 2: "Open Access – Bilateral"	Same as Modality 1
Modality 3-I: "Open Access – Multilateral": (Common pools)	Solution: Same as Modality 1
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Royalties are public information Requirement: None, as inherent to modality
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Subscription fees and levies on equipment are public information Requirement: None as inherent to modality
Modality 5: "Free Access – Capacity Development"	Solution: Issue resolved as intrinsic to openness
6. "Material" in Article 2 of the CBD	
Problem(s) rendering *status quo* disadvantageous: Object of access for R&D is information. Evasion of ABS through disembodiment of genetic resource	
Modality 1: "Nagoya – Bilateral"	Interpreted as tangible or physical matter
Modality 2: "Open Access – Bilateral"	Solution: Interpretation of genetic resource as being information Requirement: "Tangible" interpretation is a foundational error. Precedent overturned by framework nature of CBD
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Interpretation of genetic resource as biotic "natural information" Requirement: Recognition that "tangible" interpretation is egregiously wrong. Precedent may be overturned
Modality 4: "Open Access – Subscription fee / Levies"	Same as modality 2
Modality 5: "Free Access – Capacity Development"	Nonissue
7. "Digital sequence information" (DSI)	
Problem(s) rendering *status quo* disadvantageous: Manifold shortcomings repeatedly identified by Users and Providers since debut of neologism in 2015	
Modality 1: "Nagoya – Bilateral"	Placeholder for phenomenon associated with the informational dimension of genetic resources
Modality 2: "Open Access – Bilateral"	Solution: Misnomer voided Requirement: Adoption of interpretation of "genetic material" as also having component in information

Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Misnomer voided Requirement: Adoption of interpretation of "genetic material" as biotic "natural information"
Modality 4: "Open Access – Subscription fee / Levies"	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Nonissue
8. Scope of ABS (collections)	
Problem(s) rendering *status quo* disadvantageous: Transaction costs exceed expected benefits, rendering ABS uneconomic for Provider. Nevertheless, taxonomy encumbered	
Modality 1: "Nagoya – Bilateral"	Expansion to include collecting activities irrespective of insignificant or non-existent benefits
Modality 2: "Open Access – Bilateral"	Solution: Expansion to access of database regardless of value adding activity
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: ABS obligations are *ex post* successful commercialization of associated IP thereby allowing collection. Access flows freely Requirement: None as inherent to modality
Modality 4: "Open Access – Subscription fee / Levies"	Solution: None as inherent to modality Requirement: ABS obligations are satisfied with institutionalization of subscription fee or levy on equipment
Modality 5: "Free Access – Capacity Development"	Nonissue
9. Scope of ABS (value added but not protected by IP)	
Problem(s) rendering *status quo* disadvantageous: Users may seek IP in order to pay for ABS obligation	
Modality 1: "Nagoya – Bilateral"	Non-pursuit of IP is not recognized as a benefit which is being shared
Modality 2: "Open Access – Bilateral"	Same as Modality 1
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 1
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Recognized as benefit and therefore User relieved of ABS obligation Requirement: None as inherent to modality
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Subscription fee or levy on equipment collected regardless of intellectual property granted over value added Requirement: None as inherent to system
Modality 5: "Free Access – Capacity Development"	Nonissue

10. *Ex situ* materials collected prior to the CBD	
Problem(s) rendering *status quo* disadvantageous: Scope depends on institutional policies of collection and national legislation	
Modality 1: "Nagoya – Bilateral"	Collected specimens pre-CBD are substitutes for *in situ* collections, thus avoiding ABS obligations
Modality 2: "Open Access – Bilateral"	Solution: Trigger for benefit sharing is access to database, regardless of where, when or how specimen was accessed Requirement: None as inherent to modality
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Trigger for benefit sharing is successful commerce of IP associated with "natural information", regardless of where, when or how accessed Requirement: Grand bargain whereby collections prior to 1993 ratification of the CBD count as if one Provider with a geographic area equivalent to the critical minimum habitat
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Trigger for benefit sharing can be (a) access to database, regardless of when specimen collected and disembodied or (b) exempted. Trigger through levy on equipment, invariant to date of collection Requirement: Institutions with collections prior to CBD must agree to (a) or (b)
Modality 5: "Free Access – Capacity Development"	Nonissue
11. Material collected in a "transboundary" situation	
Problem(s) rendering *status quo* disadvantageous: "Cooperation" according to Art 5 of CBD and Art 11 of NP has not eventuated. Unfeasible where relations scaled-back, impossible where suspended	
Modality 1: "Nagoya – Bilateral"	"Transboundary" can be reasonably interpreted as species whose ranges overlap
Modality 2: "Open Access – Bilateral"	Solution: Trigger for benefit sharing is access to database, regardless of where, when or how specimen was accessed Requirement: None as inherent to modality
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Trigger for benefit sharing is successful commerce of IP associated with "natural information", regardless of where, when or how accessed Requirement: Grand bargain whereby collections prior to 1993 ratification of the CBD count as if one Provider with a geographic area equivalent of the critical minimum habitat
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Trigger for benefit sharing through subscription fee can be (a) access to database, regardless of where specimen was collected and disembodied or (b) exempted Requirement: Trigger through levy on equipment, invariant to date of collection
Modality 5: "Free Access – Capacity Development"	Nonissue

12. Non-commercial research (including taxonomy)	
Problem(s) rendering *status quo* disadvantageous: Distinction cannot be made in practice as the two blur	
Modality 1: "Nagoya – Bilateral"	Regulation of commercialization with change of intent
Modality 2: "Open Access – Bilateral"	Solution: Lower benefit could be set for non-commercial research Requirement: Because the two blur, default must be commercial until shown otherwise (reversal of burden)
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: No distinction is made nor is any necessary. No benefit sharing obligations without successful commerce of IP associated with natural information Requirement: None as inherent to modality
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Lower subscription fee or levy on equipment could be made for non-commercial research. Requirement: Because the two blur, default must be commercial until shown otherwise
Modality 5: "Free Access – Capacity Development"	Nonissue
13. Changes in use of genetic resources and derivatives during R&D or change of intent	
Problem(s) rendering *status quo* disadvantageous: Not realistic to predict how and when changes will occur in R&D environments, which span jurisdictions, actors and time frames	
Modality 1: "Nagoya – Bilateral"	Contracts require conditions with verification for downstream utilization
Modality 2: "Open Access – Bilateral"	Solution: Terms and conditions must anticipate value for downstream utilization Requirement: Perfect foresight
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 1
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Irrelevant as trigger for benefit sharing is successful commerce of intellectual property associated with natural information Requirement: None as inherent to modality
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Irrelevant as subscription fee or levy on equipment charged with download from database Requirement: None as inherent to modality
Modality 5: "Free Access – Capacity Development"	Nonissue
14. Multiple sources of genetic resources and derivatives	
Problem(s) rendering *status quo* disadvantageous: Monitoring and tracking multiple contracts and R&D streams from multiple sources	
Modality 1: "Nagoya – Bilateral"	Complex and numerous contractual arrangements
Modality 2: "Open Access – Bilateral"	Solution: Benefits tied to downloads thereby allowing multiple sources, however anticipation of value from downstream utilization problematic Requirement: Perfect foresight

Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 1
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Rules for weighted shares of royalty to prevent "**stacking**" Requirement: None as inherent to modality
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Agreement among databases to share revenues and avoid subscription fee stacking Requirement: Cooperation
Modality 5: "Free Access – Capacity Development"	Nonissue
15. Materials under Annex I of ITPGRFA for uses other than those stated in the treaty	
Problem(s) rendering *status quo* disadvantageous: Monitoring and tracking complex contracts and R&D streams from multiple sources	
Modality 1: "Nagoya – Bilateral"	Predefined SMTA with low percentage for PGRFA carries over to CBD and NP
Modality 2: "Open Access – Bilateral"	Solution: No distinction is made for natural information in materials under Annex I for uses other than those stated in the ITPGRFA Requirement: None as inherent to modality
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Same as Modality 2
Modality 4: "Open Access – Subscription fee / Levies"	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Nonssue
16. Calculation of monetary benefits	
Problem(s) rendering *status quo* disadvantageous: Besides elimination of rents, asymmetries in expertise and negotiating power between Users and Providers. Potential values often impossible to calculate *ex ante* conclusion of agreement	
Modality 1: "Nagoya – Bilateral"	Case-by-case negotiations
Modality 2: "Open Access – Bilateral"	Solution: The transaction costs of such calculations are shifted from Parties concluding an MTA or benefit sharing agreement to the databases. Problems associated with Modality 1 remain
Modality 3-I: "Open Access – Multilateral": (Common pools)	Solution: Same as Modality 1 but asymmetry is of lesser degree Requirement: Willingness of Parties to incur transaction costs of organizing Regional Common Pools as royalties are meagre
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Royalty percentages set according to characteristics in utilization when intellectual property is commercially successful Requirement: COP authorizes Users and Providers to negotiate as stakeholder groups on determination of royalty percentages, according to industrial sector, type of IP and other characteristics

Modality 4: "Open Access – Subscription fee / Levies"	Solution: Subscription fees or levy on equipment implicitly reflect a calculation of rent Requirement: To the extent that potential values are impossible to foresee much less calculate, the benefit will tend to be underestimated
Modality 5: "Free Access – Capacity Development"	Nonissue. Assumed intractable as dependent on multiplier effect of investments in existing and future technologies
17. Calculation of non-monetary benefits	
Problem(s) rendering *status quo* disadvantageous: Because difficult to quantify, magnitude easily over- or understated by User or Provider, respectively	
Modality 1: "Nagoya – Bilateral"	Negotiation on a case by case basis
Modality 2: "Open Access – Bilateral"	The transaction costs of such calculations are shifted from Parties concluding an MTA or benefit sharing agreement to the databases. Problems associated with Modality 1 remain
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 1
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Categories of non-monetary benefits complement royalty percentage, which is the principal benefit and easily assessed Requirement: None as inherent to modality
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Resolved because irrelevant. Benefit is monetized in subscription fee or levy on equipment
Modality 5: "Free Access – Capacity Development"	Nonissue. Assumed intractable as dependent on multiplier effect of investments in existing and future technologies as well as consumer surplus form biotechnologies once IP expires
18. Trigger for benefit sharing	
Problem(s) rendering *status quo* disadvantageous: Monitoring R&D outside jurisdiction of Provider becomes impossible (or excessively costly) with successive transfers. Excessive reliance on good faith of Users despite well publicized cases of biopiracy	
Modality 1: "Nagoya – Bilateral"	Case by case negotiation
Modality 2: "Open Access – Bilateral"	Solution: Simplification Requirement: None as inherent to Modality
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Simplification Requirement: Modification of IP regimes to mandate disclosure of natural information (Y/N) and monitoring of commercial success
Modality 4: "Open Access – Subscription fee / Levies"	Solution: Simplification Requirement: Subscription fees charged regardless of outcome. Something similar applies to levies on equipment. **Excess burden**, aka. deadweight loss, must be ignored
Modality 5: "Free Access – Capacity Development"	Nonissue

19. Fungibility	
Problem(s) rendering *status quo* disadvantageous: To the extent that earmarked funds displace funds allocated or to be allocated, benefit sharing swaps the source of finance without increasing that finance. Art.21 CBD may be interpreted to address fungibility, but its language may also be reasonably interpreted to the contrary	
Modality 1: "Nagoya – Bilateral"	"Appropriate funding" Art. 1, Nagoya Protocol and Art 2, CBD are interpreted as dedicated to conservation. Explicit in Art 20 CBD and Annex, NP "Monetary and non-Monetary Benefits"
Modality 2: "Open Access – Bilateral"	Solution: Essentially impossible to solve Requirement: Each database has to evaluate government willingness to finance conservation projects in developing countries
Modality 3-I: "Open Access – Multilateral": (Common pools)	Same as Modality 2
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Conservation is achieved through alignment of incentives through relative share of geographic range that reflects conservation of terrestrial species or lack thereof. Benefits for marine species addresses drivers of extinction other than habitat loss. The problem of fungibility may arise for taxonomic institutions which benefit from royalties on ubiquitous natural information should their governments reduce financial support *pari passu*. However, to the extent that such reduction reduces freeriding among countries, efficiency and equity are enhanced Requirement: None for non-cosmopolitan species
Modality 4: "Open Access – Subscription fee / Levies"	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Nonissue
20. Checkpoints and monitoring	
Problem(s) rendering *status quo* disadvantageous: Reluctance of institutions (e.g. IP institutions, commercialization points, research institutions, funding agencies) to assume responsibility	
Modality 1: "Nagoya – Bilateral"	To be defined nationally, with ABS Clearing House Mechanism (CHM) playing a key role in tracking Certificates of Compliance
Modality 2: "Open Access – Bilateral"	High compliance expected as databases are easily observable and sanctionable
Modality 3-I: "Open Access – Multilateral": (Common pools)	Nonissue
Modality 3-II: "Open Access – Multilateral": (Bounded openess)	Solution: Simplification Requirement: Simple disclosure requirement of Yes/No in applications for IP. CHM monitors commercial success of IP disclosed
Modality 4: "Open Access – Subscription fee / Levies"	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Nonissue
21. Compliance	

Problem(s) rendering *status quo* disadvantageous: National legislation of Providers are slow to regulate as deemed of low economic importance, largely due to elimination of rents	
Modality 1: "Nagoya – Bilateral"	Certificate of Compliance
Modality 2: "Open Access – Bilateral"	Issue resolved because databases are easily observable
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Encouraged by penalties calculated as a multiple of rents due and facilitated through simple disclosure requirement Requirement: None as inherent to modality
Modality 4: **"Open Access – Subscription fee / Levies"**	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Nonissue
22. Institutional arrangements	
Problem(s) rendering *status quo* disadvantageous: Inadequate capacity of authority, especially in developing countries	
Modality 1: "Nagoya – Bilateral"	ABS competent authority
Modality 2: "Open Access – Bilateral"	Solution: Tremendous costs by Providers and databases to draft terms and conditions, whereby standardization could not extend to royalty percentages. Thus rents are still eliminated Requirement: Willingness to invest sufficiently in refining terms and conditions to avoid legal uncertainty
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Solution: Significant costs by Providers to coordinate RCPs and benefit sharing rules Requirement: Willingness to invest in infrastructure despite expectation of benefit -sharing will be uneconomic
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Authority coordinates with international organizations to support taxonomic identification of species and taxon and corresponding spatial distribution. Encouraged by capture of rents Requirement: Collaboration with taxonomic institutions to determine spatial dissemination of "natural information". Financed through benefits generated on cosmopolitan species, thereby ameliorating free riding of taxonomy, which is an international public good
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Authority coordinates with Clearing House Mechanism to justify petition for finance from Global Fund. Encouraged by capture of rents Requirement: Adequate capacity of Authority, especially in developing countries
Modality 5: "Free Access – Capacity Development"	Nonissue

23. Areas beyond national jurisdiction (Antarctica, deep seabed, etc.)	
Problem(s) rendering *status quo* disadvantageous: Cooperation or a GMBSM suggested	
Modality 1: "Nagoya – Bilateral"	To be defined by Nagoya Protocol under Articles 10 and 11
Modality 2: "Open Access – Bilateral"	Solution: Databases share royalties according to decisions of UNCLOS on ABS
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Commercial success of value added and protected through IP generates benefits for *in situ* conservation in areas beyond national jurisdiction Requirement: Coordination with ongoing processes in UNCLOS toward a multilateral approach to ABS
Modality 4: **"Open Access – Subscription fee / Levies"**	Solution: Because databases do not share benefits according to country of origin, the problem can only be resolved through the rules that recognize such areas in disbursement of the Global Fund
Modality 5: "Free Access – Capacity Development"	Nonissue
24. Human pathogens	
Problem(s) rendering *status quo* disadvantageous: Eradication of pathogens *in situ* runs counter to objectives of CBD	
Modality 1: "Nagoya – Bilateral"	Under Art 4, NP, other specialized instruments can substitute as long as not running counter to the objectives of CBD and NP
Modality 2: "Open Access – Bilateral"	Solution: Same as Modality 1 Requirement: Issue conceded to WHO
Modality 3-I: **"Open Access – Multilateral": (Common pools)**	Same as Modality 2
Modality 3-II: **"Open Access – Multilateral": (Bounded openess)**	Solution: Inversion of the premise of conservation *in situ* inverts policy deductions. Fairness, equity and efficiency mean benefits concentrated on Party first to submit samples into international medical research stream but requires that vaccines and diagnostic kits be free-of-charge to avoid Provider leverage through withholding samples Requirement: Coordination with ongoing processes in WHO to standardize a multilateral approach to ABS
Modality 4: **"Open Access – Subscription fee / Levies"**	Same as Modality 2
Modality 5: "Free Access – Capacity Development"	Issue conceded to WHO

Appendices

Appendix I

Naked Mole-Rat (*Heterocephalus glaber*)

Anna Deplazes-Zemp

Figure 1. Naked mole-rat

Credits: Josh More / flickr (CC BY-NC-ND 2.0)

Brief history

The naked mole-rat (*Heterocephalus glaber*) is a remarkable species of rodent that is endemic to East Africa (Kenya, Somalia, Ethiopia and Djibouti). The species owes its name to the lack of hair and resemblance to rats yet with a mode of life more like that of moles (Honeycutt, 1992). Naked mole-rats have a social structure more typical of the class Insecta rather than Mammallia. They live in extended underground tunnel systems in colonies, which number on average 75-80 individuals with one reproductive female and a few reproductive males. Other members of the colonies fulfill various worker functions (Honeycutt, 1992; J. Jarvis, U.M. & Sherman, 2002; J. U. M. Jarvis, 1981). Naked mole-rats are exceptional not only for their social organization but also for their physiology. They are the only known cold-blooded mammals. They exhibit longevity, resistance to cancer, hypoxia-tolerance and pain insensitivity (Lagunas-Rangel & Chávez-Valencia, 2017; Mulatu, 2018; Schuhmacher, Husson, & Smith, 2015; Ewan ST. J. Smith, 2019). The combination of outstanding features makes the species a promising object for pharmaceutical research.

Utilization of DSI

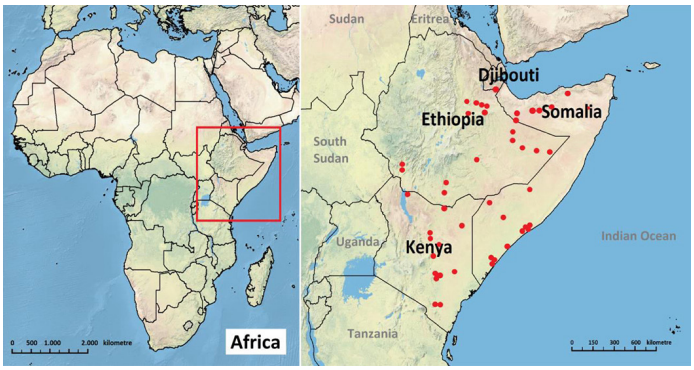
The order Rodentia is well studied. What makes *Heterocephalus glaber* so fascinating is the set of questions regarding the evolution of its exceptional traits. How did mammalian biology and biochemistry evolve such features? Comparison of the genetic sequences of the naked mole-rat – captured under the placeholder "digital sequence information" ("DSI") – with those of other species is a widely used vehicle to answer such questions. Research has been facilitated since publication of the whole genome (Fang et al., 2014; Keane et al., 2014; Kim et al., 2011) which is available on Genebank (https://www.ncbi.nlm.nih.gov/nuccore/AFSB00000000) as well as other databases.

Studies based on genetic sequences span fields from ecology to physiology (Da Silva, Tomasco, Hoffmann & Lessa 2009, Schuhmacher, Callejo, Srivats & Smith 2018). The comparisons of sequences of the whole genome (Kim et al., 2011; MacRae et al., 2015) allow exploration of differences in gene expression, i.e. activated in specific situations (e.g. Bens et al., 2018). The comparisons can also be interesting for the analysis of specific genes and associated proteins that fulfill core functions in mammalian biology. The identification of genetic differences provides crucial insight for understanding of biological processes, including variations that lead to human disease. For example, the introduction of the mole-rat version of a gene into a mouse may throw light on the impact of genetic variants. One analyzes whether the identified naked mole-rat sequence is sufficient to induce the altered biological processes in rat or human cells. Such an approach has enhanced understanding of acid-induced pain, for which naked mole-rats show exceptional insensitivity (Schuhmacher et al., 2018; E. S. J. Smith et al., 2011). The cancer resistance and longevity of the naked mole-rat have also been widely studied using genetic sequences for comparative genomic and gene expression analysis (e.g Hilton et al., 2019; Keane et al., 2014). The cancer resistance is often studied by expressing wild type or mutated versions of naked mole-rat genes in cultured naked mole-rat cells or those of other species (e.g. Seluanov et al., 2009; Tian et al., 2013).

Conservation status and distribution

The naked mole-rat is found in central Ethiopia, northern and eastern Kenya, throughout most of Somalia and in southern Djibouti (Maree & Faulkes, 2016)). They live in arid and hot areas with low or irregular rainfall (Maree & Faulkes, 2016). The Red List of Threatened Species of the International Union for Conservation of Nature (IUCN Red List) classifies the naked mole-rat as a species of "least concern" (Maree & Faulkes, 2016). The species is common and currently not threatened. However, where naked mole-rat territory overlaps with agricultural areas, conflicts arise: the animals eat root vegetables such as cassava and sweet potatoes. In view of the population growth and concomitant agricultural expansion into the habitat of naked mole-rat, pest control measures could threaten the species in the future (Wale, Kassie, & Fekensa, 2016).

Figure 1. Naked mole-rat concentration and general geographic distribution



Distribution of Heterocephalus glaber in the horn of Africa, presence of NMR represent by red dots. https://d3i71xaburhd42.cloudfront.net/460625628d0b1411512f50d25027df31bd8435bb/18-Figure5-1.png

Credits: Maree & Faulkes, 2016.

Ex situ status of species

Zoologists became aware of the naked mole-rat in the 1970s; the social organization arose great interest. Jarvis (1981) collected a colony in Mtito Andei, Kenya in 1977 (Jarvis, 1981), which presumably led to the first laboratory lineage of naked mole-rats at the University of Cape Town. Other animals were collected in Kenya in the 1970s and early 1980s. Some collections were to establish laboratory samples at Michigan University and Cornell University (R.D. Alexander, P.W. Sherman), and at the University College London (R.A. Brett) and Harvard University (R.L. Honeycott) (Sherman, Jarvis, & Alexander, 1991). Today *ex situ* naked mole-rat populations are popular in in zoological gardens. Research with naked mole-rats is usually conducted with the laboratory strains established in the 1970s to 90s rather than capturing new animals from the wild (e.g. Keane et al., 2014; Kim et al., 2011; Hilton et al., 2019; Seluanov et al., 2009, Tian et al., 2013). Research on the molecular biology and biochemistry is performed with immortalized cell cultures in lieu of the live animal. However, some exceptional projects still research animals from the wild, as evidenced by studies on the gut microbiome (Debebe et al., 2017; Debebe et al., 2016). While the authors highlight that the study was authorized by the Ethiopian Wildlife Conservation Authority, ABS was not explicitly mentioned in the associated publications.

Uses

The main user of naked mole-rats remains academia. While the original interest were the social and ecological features, current interest lies more in physiological and genetic traits. Other users are zoos around the world. As discussed below, most patents involving naked mole-rats concern methods of working with the animals rather than with their genetic information. The genome is freely available online at http://www.naked-mole-rat.org (Keane et al., 2014) and accessible on GenBank under accession number AFSB01000000 https://www.ncbi.nlm.nih.gov/nuccore/AFSB00000000 (Kim et al., 2011).

Type of R&D undertaken and actors involved

Several of the extraordinary properties of the naked mole-rat may hold promise for understanding and treating human diseases. Among the properties of interest are longevity, cancer resistance, insensitivity to agonizing stimuli such as acid and capsaicin, and tolerance for low oxygen (Ewan ST. J. Smith, 2019). A patent search indicates that research is usually conducted at academic institutions for a general understanding of the species rather than for specific components or gene sequences for a potential medical utility. A few exceptions are described in the section on patents below.

The majority of patent documents concerns the "research support sector" dealing with cultivation methods for naked mole-rat cell cultures. There are also two patents on methods for mating, breeding and pairing naked mole-rats (CN106857386 A, CN106857387 A) or for identifying female mole-rat queens (CN106614276B). Two patents exist on short DNA sequences for biological detection (CN105671040 A, CN105695455 B).

Application of ABS

As of this writing, no monetary benefits obtained from research on naked mole-rat genetic resources are apparent in the literature. Nevertheless, research on this exceptional species generates a non-monetary benefit in the advance of the science of biology. Insights may contribute to a general understanding of biological and biochemical processes, which include deviations that lead to human disease. Nevertheless, discussion on ABS is absent in the context of the use of naked mole-rats in research. As mentioned above, most research is performed with *ex situ* colonies as laboratory strains, which were established in the 1970s and 1980s. For example, Keana et al. state that the sequenced individual was *"obtained from the colony established by Vera Gorbunova at the University of Rochester, USA. The founder animals originated from the colony of J.U. Jarvis, at the University of Cape Town, South Africa."* (Keane et al., 2014: p3558). Likewise, Kim et al. highlight that *"[t]he sequenced individual male NMR was from a captive breeding colony located at the University of Illinois, Chicago"* (Kim et al., 2011: p226). In the non-systematic literature search performed for this report, no indications for ABS were found in any research paper nor were ABS agreements mentioned in any of the listed patent documents.

Market information

We are not aware of any naked mole-rat products that are commercially available.

Relevant IP involved

A search for patent documents claiming products or processes involving naked mole-rats resulted in 34 hits[1] of which 27 patents[2] were specific for naked mole-rats and 7 patents[3] concerned a range of animals which includes the naked mole-rat. Most of the patents are registered only in China. Of the 27 naked mole-rat-specific patent documents, only two were applied for jurisdictions outside China, one US patent and one worldwide patent application originating from South Korea. The USPTO reports the status of patent application US20140248371A1 by Carmel-Haifa University of Israel as abandoned as of 23 January 2018. A worldwide application of 2017 has so far only been granted in South Korea. Overall, applicants are mostly academic institutions, indicating that, most applications of naked mole-rats in R&D are concentrated in academia rather than industry. Most of the identified naked mole-rat patent documents concern methods and tools for research with naked mole-rats such as cultivation methods for different types of naked mole-rat cell cultures. A few patent documents exist on short DNA sequences (SNP sequences or primer sequences) for technical detection in molecular biology, for instance, to detect genetic polymorphism in mole-rat colonies (CN105671040 A, CN105695455 B).

Four patent documents relate to potential medical applications. The patent CN107384699A, held by a Hainan Baicaoli Yaotang CO LTD, a Chinese drugstore company, concerns a "naked mole-rat nourishing longevity health wine" to be used in Traditional Chinese medicine, in combination with other ingredients, to inhibit tumors and enhance immunity. The wine contains "naked mole-rat macromolecular hyaluronic acid mixed solution". A second Chinese patent, CN107050045A, held by the Harbin Institute of Technology, covers the use of naked mole-rat hyaluronic acid in "preparation of drugs for treating breast cancer". The patent description mentions that naked mole-rat hyaluronic acid can be gained by over-expression of the naked more rat gene HAS2 in breast cancer cell lines, however, the production of hyaluronic acid or the genetic sequence is not covered by the patent. The third medically relevant patent document is US2014248371 A1, applied for by Carmel-Haifa University in Israel. This patent application concerns a conditioned cell culture medium derived from naked mole-rat cells. The use of this medium was to identify anti-cancer agents as well as active agents selected in this medium and anti-cancer treatments involving these agents. The fourth naked mole-rat patent document with direct pharmaceutical relevance is WO2019039826 A1, held by the Korean Konkuk University Industrial Cooperation Corp. The patent concerns the digital amino acid sequence of a naked mole-rat polypeptide with antimicrobial activity, which could be used for the development of new antibiotics. None of the discussed patent descriptions mentions ABS.

ABS issues

Countries of origin have taken note of the potential value of the naked mole-rat as a genetic resource and ongoing use in

1 We would like to thank Prof. Heinz Mueller from the Swiss Federal Institute of Intellectual Property for performing this search. This search covered more than 110 million patent documents (published applications and granted patents) from more than 90 countries. In addition to practically all national patent documents around the world, applications with regional and international organizations (PCT, ARIPO and OAPI patents) are included, as well.

2 WO2019039826 A1, US2014248371, CN107384699 A, CN107142242 A, CN107050045 A, CN107058492 A, CN107034185 A, CN107022520 A, CN106906177 A, CN106834208 A, CN106857386 A, CN106857387 A, CN106754716 A, CN106614276 B, CN106577470 B, CN106520697 A, CN106333761 A, CN105754943 B, CN105671040 A, CN105695410 B, CN105695408 B, CN105695409 B, CN105695455 B, CN105695411 B, CN105505863 B, CN105256038 A, CN105200132 A

3 WO2016054032 A1, CN109529054 A, WO2017124086 A1, CN109432129 A, WO2016161973 A1, WO2013149259 A1, US2014023628 A1

R&D without ABS-agreements. On the website describing the CBD Clearing House Mechanism of Ethiopia, the naked mole-rat has been identified as a potential object for an ABS agreement if access to the organisms occurs in the scope of the national ABS framework (Taye, 2017). Mulatu (2018) discussed the potential for bioprospecting of the rodent but did not explain how benefit sharing would unfold for Ethiopia. Open access to the genome of the naked mole-rat is seen as emblematic of how the object of R&D must be recognized as natural information for any sharing of benefits to be fair and equitable (Peruvian Society of Environmental Law, 2017; Vogel, Ruiz Muller, Angerer and Oduardo-Sierra, 2018). Criticism of ABS lies in the unbounded openness of the genetic resources, despite the potential for medical applications and need for habitat conservation in the countries of origin.

Summary

The naked mole-rat is a treasure trove for academic research. Medically interesting features such as longevity, cancer resistance and insensitivity to pain are being studied at the molecular and biochemical level. The dematerialization of the species, endemic to East Africa, into digital sequences plays an essential role. To date, use of the naked mole-rat

as a genetic resource has mainly taken place in academia with the non-monetary benefit being a deeper understanding of biological processes. One may easily imagine R&D on naked mole-rats will result in future medicines and be of monetary benefit to the pharmaceutical industry. Most of the research which utilizes genetic resources from the naked mole-rat, including the open-access genome sequence, used *ex situ* strains that were established in the 1970s and 1980s. So, the countries *providing* the genetic resources are now those of databases, university laboratories and zoos. Naked mole-rats are generally being used without ABS-agreements with the countries of origin.

Table 1. Details of references to geographic origin of naked mole-rat strains (NMR) mentioned in the literature and discussed for the NMR-case study

References	Materials & Methods section referring to the NMR strain
Honeycutt, 1992	Review article, no country of origin mentioned
J. Jarvis, U.M. & Sherman, 2002	Review article, no country of origin mentioned
J. U. M. Jarvis, 1981	"Mixed colonies or mole-rats have been under laboratory observation for 6 years. In October 1977 an almost complete colony of 40 individuals was collected at Mtito Andei, Kenya" (p. 571)
Lagunas-Rangel & Chávez-Valencia, 2017	Review article
Mulatu, 2018	Review article
Schuhmacher, Husson, & Smith, 2015	Review article
E.S.J. Smith, 2019	Review article
Fang et al., 2014	"A breeding colony of DMRs (Damaraland Mole-rat) (Fukomys damarensis) was housed at the University of Illinois at Chicago. The DMR was known as *Cryptomys damarensis* prior to a recent subclassification into a new genus, Fukomys"(p. 1361; no origin mentioned) For NMR they used databases

References	Materials & Methods section referring to the NMR strain
Keane et al., 2014	"Briefly, high molecular weight DNA was extracted from tissues of a single partially inbred female adult NMR obtained from the colony established by Vera Gorbunova at the University of Rochester, USA. The founder animals originated from the colony of J. U. Jarvis, at the University of Cape Town, South Africa" (p. 3558)
Kim et al., 2011	"The NMR genome was sequenced on the Illumina HiSeq 2000 platform. The sequenced individual male NMR was from a captive breeding colony located at the University of Illinois, Chicago" (p. 226)
Da Silva, Tomasco, Hoffmann, & Lessa, 2009	They analyse Cytochrome b gene sequences in databases
MacRae et al., 2015	Genome analysis (refer to Kim et al. 2011)tochrome b gene sequences in databases
Bens et al., 2018	"NMR colonies were kept inside a climatized box (2×1×1 m) in artificial burrow systems, consisting of eight cylindrical acrylic glass containers (diameter 240 mm, height 285 or 205 mm)..." (p. 9; no origin of NMR is mentioned)
Hilton et al., 2019	"The NM-Rs in this study came from 10 different captive colonies, while the mice were purchased from the Jackson Laboratories (Bar Harbor, ME) and maintained in the vivarium for at least 2 weeks prior to use."(p. 9; no origin or specification of the founder strain mentioned)
Seluanov et al., 2009	"Naked mole-rats were from the colony of K.C.C. at Vanderbilt University. Mice used for isolation of cell lines were C57BL6"(supplementary material p. 1; no origin mentioned)
Tian et al., 2013	"Naked mole-rats were from the University of Rochester colonies. C57BL/6 mice and NIH III nude mice were purchased from Charles River Labs. Non-albino guinea-pigs were obtained from Elm Hill Labs"(p. 349; no origin mentioned)
Maree & Faulkes, 2016	This is the source of the IUCN red list → no empirical data
Wale, Kassie, & Fekensa, 2016	Local research (assessment of naked mole-rat distribution) → no export. Study areas in Ethiopia
Sherman, Jarvis, & Alexander, 1991	A book on NMR that mentions some founder strains (as summarized in the case study)
Debebe et al., 2016	The two studies by Debebe et al. are the only studies found in which research was performed with wild animals, without any mention of ABS issues: "Eleven wild naked mole-rats from the Rift Valley of Ethiopia were captured and detained. Intestinal and fecal samples of the animals were obtained from individuals captured in Ethiopia. Permission comprising both, field permit and ethics approval was granted by the Ethiopian Wildlife Conservation Authority (EWCA; ref. No. 31/394/07 dated 27 November 2014)" (p. 2; some of the authors are from the University of Addis Ababa)
Debebe et al., 2017	"Study subjects were captured and detained from the Rift Valley ecosystem in the eastern part of Ethiopia. Briefly, the fecal samples from each animal were collected and immediately frozen in a liquid nitrogen tank and transported to Leipzig, Germany, and stored at −80 °C prior to further analysis. The study was approved and permitted by Ethiopian Wildlife and Agricultural Authorities (reference number 31/25/08 dated 19 November, 2015). Subject collection and sampling were performed in accordance with the Ethiopian Wildlife Law guideline and regulation" (p. 6, some of the authors are from the University of Addis Ababa, but they mention export (as quoted)

Patent applications

CN107384699A	Describes a procedure of producing NMR extracts, but says nothing about the origin or strain of the used animals

CN107050045A	About generating NMR Hyaluronic acid in cell culture with cells that overexpress the NMR gene Has2 → no NMR animals are involved
US2014/0248371	Mentions "Spalax [NMR] and Acomys [spiny mouse?] were captured in the field and housed under ambient conditions in individual cages in the Animal Facility of the Institute of Evolution, University of Haifa" (Supplementary Information 0075) Does not mention the country of origin
WO2019039826A1	Work with sequence data from a protein database UniProtKB/Swiss-Prot → in silico analysis (on the computer) → chemical synthesis of the protein → different tests with bacteria and cultured cells, → no NMR material

References

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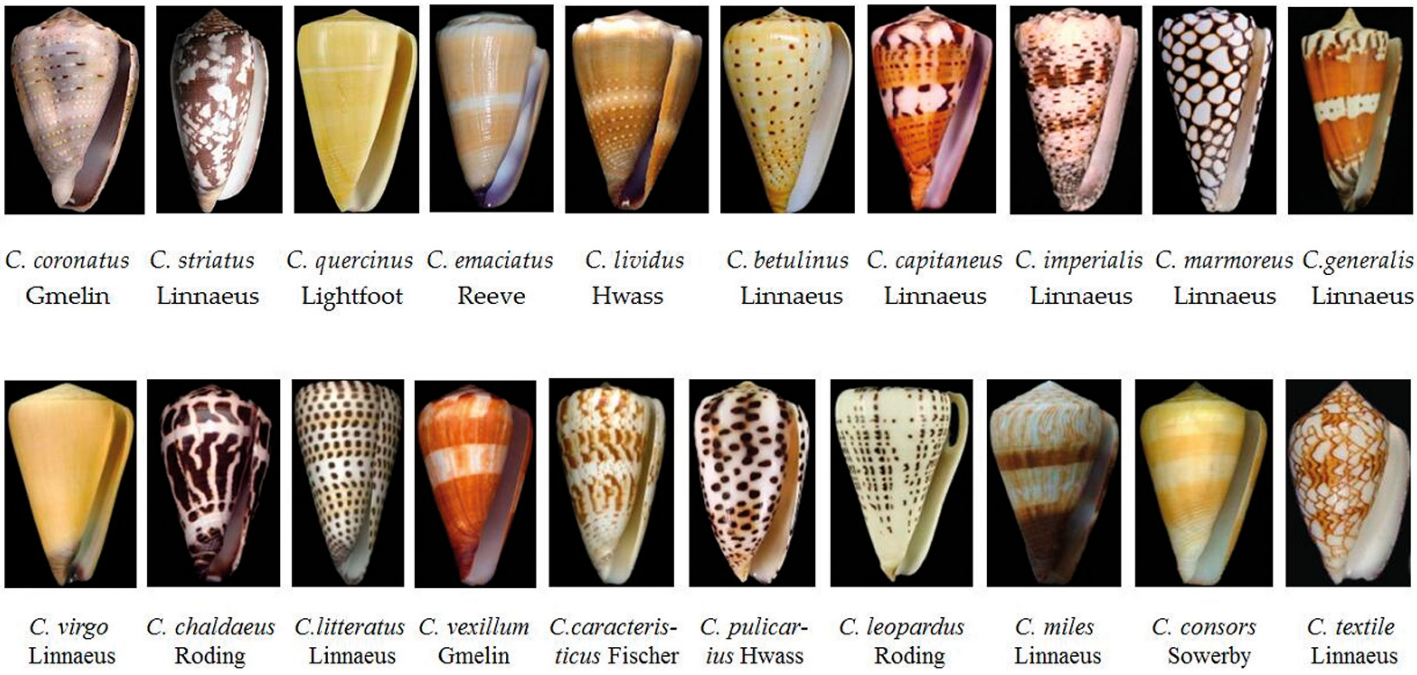
Appendix II

Cone snails (family *Conidae* and *genus Conus*)

Nicolas Pauchard

Figure 1. Twenty most abundant Conus species in the South China Sea



Credits: Gao et al. 2017 (CC BY 4.0)

Brief history

Cone snails in the genus Conus from the family Conidae are marine gastropods that take their name from the conic shape of their shells (Figure 1). They are predatory and paralyze their prey through venom injected through a harpoon-like tooth (Baybayon et al. 2017). Cone snails exhibit an extraordinary taxonomic diversity, with more than 830 described species (Uribe, Puillandre and Zardoya 2017), thus making them one of the most diverse genera in the marine environment (Puillandre et al. 2014). The venoms of cone snails, called *conotoxins* or *conopeptides*, are highly diverse neurotoxic peptides. More than 100,000 types are estimated to exist (Lobo-Ruiz et Tulla-Puche 2018). If all variants and fragments are included, the estimate surpasses 700,000 (Puillandre et al. 2014; Dutertre et al. 2013). Numerous post-translational modifications enable chemical diversity (Mansbach et al. 2019). Conotoxins have inspired R&D for over a half century (Olivera and Teichert 2007). Baldomero Olivera and colleagues Lourdes Cruz and Michael McIntosh were among the pioneers.[1] In the early 1980s, they isolated and characterized a conopeptide (ω-MVIIA) which exhibited powerful analgesic properties (McIntosh et al. 1982). The research would later be developed into analgesic Ziconotide, which goes by the trade name Prialt from Elan Pharmaceuticals. The drug was approved by the FDA in 2004 and is 1,000 times more powerful as morphine. Commercialization of the species lies in the R&D of the medical potential of conopeptides.

Cone snails cause the following ABS issues:

- some species are widely distributed while others endemic to limited areas;
- specimens can be found within or beyond the Exclusive Economic Zone of coastal countries;

Intellectual Property Watch. https://www.ip-watch.org/2018/04/06/ending-unauthorised-access-genetic-resources-ala-biological-diversity-convention/ Accessed 25 March 2020.

Wale, M., Kassie, A., & Fekensa, T. (2016). Assessment of naked mole-rat distribution and threats in Eastern Ethiopia. *Journal of Coastal Life Medicine*, *4*(8), 655-658. doi: 10.12980/jclm.4.2016J6-95

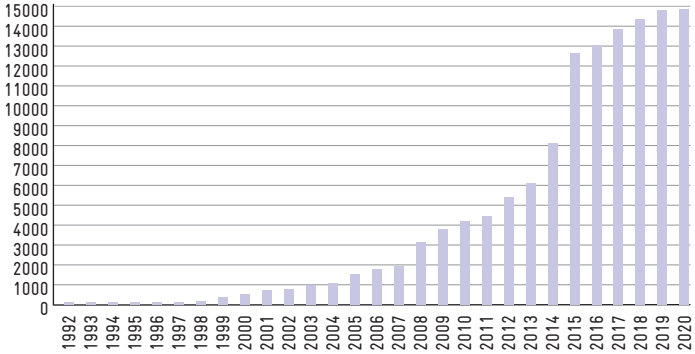
1 Baldomero Olivera is a Filipino chemist and Distinguished Professor of biological sciences at the University of Utah where he has spent most of his academic career. He is perhaps the leading expert have worked on the cone snail's venom since the late 1960s, .

- a high number of genetic sequences, known by the placeholder "digital sequence information" (DSI) by Parties to the CBD, lie in open access through online databases;
- intense R&D of conotoxins is conducted mainly in university laboratories; one product developed has become a commercially successful drug.

Utilization of "DSI"

The dematerialization of Conidae has been ongoing for almost three decades. Searches on GenBank, as of this writing, generated 25,203 sequences with Conus as the research item and 14,875 results with the family name Conidae. The first entry from 1992 corresponds to a sequence coding for the expression of a conotoxin (Hillyard et al. 1992). To date, the number of conotoxin sequences is 1800 and rapidly rising, with 67 transcriptome data sets available from the NCBI (Gao et al. 2017). Many whole genomes are available. Figure 2 illustrates the upsurge since the beginning of the millennia. As noted by Durek and Craik (2015), the exponential growth in conotoxin sequences and related knowledge from 2010 onward reflect advances in the '-omics' disciplines, viz., improvements in DNA sequencing, bioinformatics, mass spectrometry and high-throughput assays. The authors determined that more than 50% of the conopeptide sequences described in Uniprot have been publicly released in the last four years preceding their analysis of 2015.

Figure 2. Evolution of the number of sequences from Conidae on GenBank



Source: Generated from search engine on NCBI GenBank using the keyword Conidae, performed on 27.03.2020.

In 2007, David Craik's research team at the Institute for Molecular Bioscience, The University of Queensland, Australia created ConoServer, a database dedicated explicitly to conopeptides.[2] Protein and nucleic acid sequences as well as structural information on conopeptides are available through the platform. Whether they may be classified as DSI depends on how the placeholder is officially defined and then how the definition is interpreted. The sources of the data for ConoServer are peer-reviewed literature and public databases which include UniProt, NCBI GenBank and the World Wide Protein Data Bank. ConoServer enables users, for example, to search a peptide and find the corresponding sequences, pharmacological family and corresponding region and diet of the organism. Some 7,638 conotoxin sequences are now available from the platform.[3]

Regarding the production and utilization of DSI, different fields of research can be distinguished. For example, the remarkable taxonomic diversity of the *Conidae* family is addressed in molecular taxonomy through the identification of molecular markers (Puillandre et al. 2014; Uribe, Puillandre, et Zardoya 2017). Research in genomic, transcriptomic and/or proteomic analysis identifies and explains the molecular processes leading to diverse peptides, i.e., their genes and transcripts (Hu et al. 2011; Lavergne et al. 2013; Gao et al. 2017). Other studies deploy computational techniques to explain conopeptide structures, binding affinity or molecular mechanisms and predict potential molecular targets and applications (Mansbach et al. 2019). Synthetic biology on conopeptides illustrates utilization of DSI. The Chinese patent application for an invention described as a "Method For Biosynthesis Of Conotoxin From Yeast" (CN 110358770 A) describes how the corresponding inventors artificially synthesized an optimized peptide gene from DSI. Bruce et al. (2011) explain how they constructed a recombinant conopeptide coding sequence based on the original sequence P18511 obtained from UniProtKB/Swiss-Prot. The conotoxin of interest is then obtained by transfer of those sequences into engineered yeast strains that ultimately produce the compound.

Conservation status – distribution

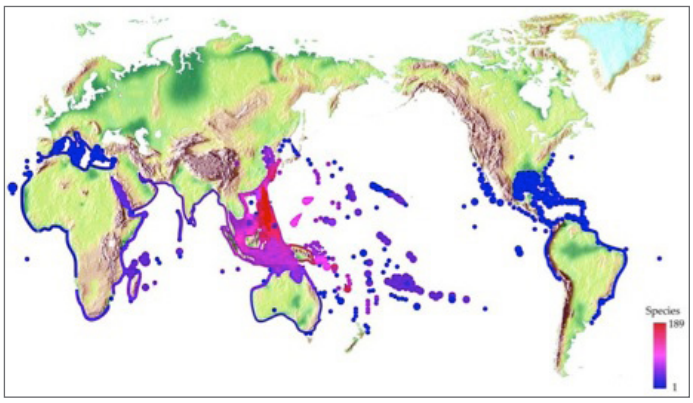
Cone snails are found in the warm waters of tropical and subtropical seas and oceans, with the highest species diversity in the Indo-West Pacific region (Puillandre et al. 2014; Uribe, Puillandre, et Zardoya 2017). The Indo-Pacific region is thought to be the center of evolutionary origin of the family (Puillandre et al. 2014). Some species have radiated and adapted to cooler environments, such as the North American Pacific coast that hosts *C. californicus*

2 Accessible through the following URL: http://www.conoserver.org/?page=about_conoserver.

3 Using the "search a peptide" tool search and selecting "all" on every proposed research criterion. Search performed through http://www.conoserver.org on 28.03.2020.

(Gao et al. 2017) and the Mediterranean Sea. Some species are cosmopolitan while others have a habitat restricted to a single island or even a bay (Uribe, Puillandre, et Zardoya 2017) (see figure 3).

Figure 3. Worldwide distribution of cone snails.



Credits: Gao et al. 2017 (CC BY 4.0)

Ex situ status of species

The IUCN lists three species as critically endangered (*C. mordeira, C. lugubris* and *C. salreiensis*), eleven as endangered, 27 vulnerable and 26 near threatened. The majority (478) are considered as requiring least concern.[4] Despite the IUCN list and classification of conservation status, no cone snail species is listed the appendix of CITES (Convention on International Trade in Endangered Species). The most serious short-term threat to cone snail diversity is the destruction of habitat, which in most cases are fragile reef ecosystems (Dutertre and Lewis 2013). Hundreds of tons of shells (millions of individuals) are also imported each year into the United States and Europe for ornamental purposes (Chivian, Roberts, et Bernstein 2003). The most serious long-term threat is acidification of the ocean (Daniel Karp, 2018, https://medium.com/student-conservation-corner/ocean-acidification-becomes-a-big-threat-to-marine-predators-c57905c2722a, Watson, *et al*, 2017, https://royalsocietypublishing.org/doi/pdf/10.1098/rsbl.2016.0797, Peters, https://www.york.ac.uk/research/themes/cone-snails/)

Cone snails have been the subject of international transfers through MTAs and ABS agreements. Liebig et al. (2002) identified an agreement for commercial research that was concluded in 2002 between the Bureau for Fisheries and Aquatic Resources (Department of Agriculture of The Phillipines), the Marine Science Institute of University of the Philippines (UP-MSI), which was the affiliation of the collector and collaborating researcher, Lourdes Cruz, and the University of Utah, which was the affiliation of the principal investigator Baldomero Oliveira. Until 2005, the agreement allowed access to and the transfer of cone snails for research on neurologically and other biologically active compounds. Specimens were sent to the U.S.A under MTAs. The U.S. National Institutes of Health (NIH) funded the research. Information of the number and content of provisions in the MTAs are not publicly available.

Uses

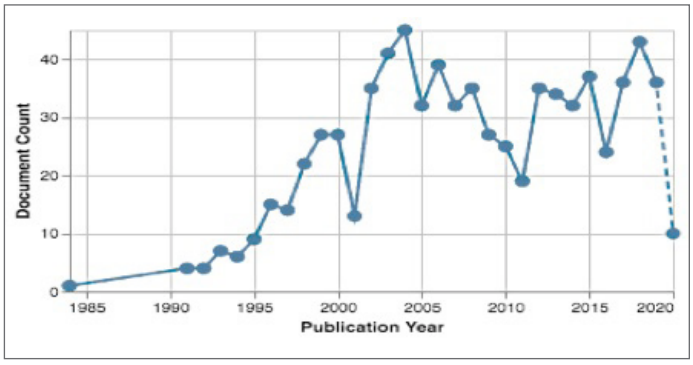
Cone snails are commercialized for their ornamental value in jewelry and, to a lesser degree, for R&D. The lethality of *C. geographus* envenomation attracted the attention of the toxicology community (Olivera 2002). In 1960, Kohn et al. (1960) conducted the first comprehensive study of the effects of Conus venoms which were followed in the 1970s by Endean et al. who suggested the potential of pharmacological properties (Olivera 2002). By 1990, the complexity of the venom of all cone snails had become clear. One individual species could express some 100-200 different venom peptides (Olivera 2002). Conotoxins have a high specificity and affinity to voltage and ligands-gated channels, which are receptors and neurotransmitter transporters in the central and peripheral nervous systems. The properties render them promising compounds for drug leads (Peng et al. 2016; Sharpe et al. 2001; B. M. Olivera et Cruz 2001). Furthermore, the diversity among and within species makes the diversity of the peptides produced the largest library of natural drug-lead compounds obtained from the marine environment (Gao et al. 2017). Puillandre et al. (2014) argue that the pharmacological diversity of conotoxins has been underestimated. Similarly, Gao et al. (2017) stress that the diverse and selective conopeptides are valuable as research tools, drug leads and drugs. Chivian, Roberts and Bernstein (2003) also remark on the wide-ranging research interest as evidenced by 2600 studies on the subject published since 1980. A quick search on Google Scholar using "conus snail" generated approximately 11,900 results (26.03.2020).

Regarding IP, Gao et al. (2017) conducted an analysis using the largest patent databases (Chinese, US and European patent offices and the World Intellectual Property Organization database). They searched the following keywords: conotoxin, conopeptide, conantokin, contryphan and contulakin. The last three terms belong to families of peptides. The period search ranged from 1998 to 2017.

4 These numbers were found by searching for the keyword *Conidae* on the IUCN red list search engine on 28.03.2020 : https://www.iucnredlist.org/search?taxonomies=100892&searchType=species

The results comprised 811 patent documents of which 243 were granted. In most cases, property rights were claimed or granted for inventions corresponding to composition of matter (conotoxins) while 360 documents referred to application processes and methods. Some 58% of the patents were claimed or granted in the U.S., 13% in China and 11% in Australia. A similar search using Patent Lens database identified 766 patent documents (251 granted patents and 515 patent applications).[5] The two largest applicants are Utah University, which is home of the laboratory of Baldomero Olivera, and the biotech company Cognetix, for which some 152 and 86 patents have been granted.[6] The next largest are followed the University of Queensland (Australia), Neuraxon (biotech) and the University of California. Regarding inventors, Baldomero Olivera is the most prolific first inventor with 174 inventions, followed by Michael McIntosh at 107. Lourdes Cruz, the collaborator of Olivera holds 56 patents.

Figure 4. Evolution of the number of patent documents published per year.



Credits: Patent Lens database using "conotoxin", "conopeptide", "conantokin"," contryphan" or "contulakin" in section "claims" of the patent document, performed on 29.03.2020

5 Using the same keywords (conotoxin, conopeptide, conantokin, contryphan and contulakin) in section *claims* but without any specific time frame (search performed on 29.03.2020). The platform is accessible through the following URL: https://www.lens.org/lens/new-search.

6 Cognetix is a private biotech company located in Salt Lake City (Utah). It was founded by Olivera and the University of Utah, precisely to obtain patents on conopeptides related inventions more efficiently than through the University of Utah technology transfer service (Wells 1998).

Type of R&D undertaken and actors involved

R&D activities on conus snails are concentrated mainly in "red biotechnology", i.e., medical and pharmaceutical fields. Conotoxins are thus used as drug lead compounds for pain,[7] cancer[8], renal function disorder[9], gastrointestinal disorder[10], epilepsy[11], depression[12]. They are also analytical tools to identify and characterize several ion channels and receptors (Grau et al. 2019)[13]. A close look at the patent documents confirms that a majority of the patent documents are classified, according to the Cooperative Patent Classification, into sections, classes and groups corresponding to medical or pharmaceutical fields. For example: group A61K38/00 contains medicinal preparations containing peptides; group 61P29/00, non-central analgesic, antipyretic or anti-inflammatory agents, e.g. anti-rheumatic agents and non-steroidal anti-inflammatory drugs; group A61P25/04, centrally acting analgesics, e.g. opioids. The remaining patent documents are classified into groups corresponding to peptides only (without application domain). For example, group C07K14/435 contains inventions corresponding to peptides having more than 20 amino acids from animals or humans. Group C12N15/12 are genes encoding animal proteins or group C07K7/08, inventions corresponding to peptides having 12 to 20 amino acids. An example of the inventions classified into C07K7/08 is the U.S. application US 2020/0071544 A1 which claims an invention described as *Conotoxin Peptides For Use In Biofouling Deterrence*. In short, the claimed invention is a coating composition, in essence a marine paint, containing conopeptides, which prevents the undesirable accumulation of marine organisms and their remnants on submerged structures. The invention falls within the field of "white biotechnology", also called *industrial biotechnology,* referring to the utilization of microorganisms and, in particular, enzymes of microorganisms to manufacture industrial goods like chemicals, plastics, detergents or energy carriers. The specific geographical origin of the specimens used in R&D is mostly missing, at least in the sources used in this case study.

Application of ABS & ABS issues

Schematically, there are four possible scenarios regarding the application of ABS rules on access and/or utilization of GR from cone snails, where access is

- *in* or *ex situ*, within a national jurisdiction where a legal framework for ABS is in force (for example, in the Philippines, after 1995);
- *in* or *ex situ* within a national jurisdiction where no legal framework for ABS is in force (for example in Japan,

where no ABS measures for providers are in force).
- *in situ* in areas beyond national jurisdiction (64% of the oceans).[14]
- via a different medium than a tangible specimen (for esample, DSI from cone snails accessed through GenBank or UniProt).

As mentioned above, an ABS agreement was concluded in 2002 between the authorities of The Philippines, a local institution (UP-MSI) and a foreign one (the University of Utah) for commercial research on conopeptides. The cumbersome process took almost four years. The Philippines has had a regulatory framework for bioprospecting of GR in force since 1995 and was the first such framework in the history of ABS (Smagdi 2005). The legal basis under which the agreement was concluded is *Executive Order 247 (EO 247)*, *Prescribing Guidelines and Establishing a Regulatory Framework for the Prospecting of Biological and Genetic Resources, their Byproducts and Derivatives, for Scientific and Commercial Purposes* (entered in force on May 18 1995).[15] Before Executive Order 247, access was as simple as buying specimens from fishermen who sell the colorful shells to tourists (Greer et al. 2004).

Market information

Despite intense R&D and numerous patent applications, submitted and granted, the commercial success of inventions based on cone snails remains limited. To date, only Prialt has reached the market. According to Durek and Craik, "Conotoxins have been, overall, exceptionally valuable as molecular probes in academic research but their transition into the clinical phases has proven to be extremely difficult" (2015, 1169). Several conotoxin drug candidates indeed failed clinical trials (Harvey 2014). The result is not surprising: approximately 90% of drug candidates entering phase 1 clinical trials fail before their eventual approval. Gao et al. (2017) identified 3 conopeptides that have entered the preclinical development phase[16], four are in the clinical phase (I or II)[17] and one (Ziconitide/Prialt) is in the market. Seven of the eight target ion channels or receptors and act as pain medications; the eighth is for treatment of myocardial infarction and under R&D. In sum, conotoxins present much promise for drug development because of their potent activity, specificity and selectivity as pep-tides toward numerous targets. Natural conotoxins require more medicinal chemistry efforts aimed at optimization to gain acceptable delivery, stability, cost and pharmacokinetic properties to attract investment (Durek et Craik 2015). Durek and Craik also highlight that most large pharmaceutical companies have resumed working on peptide chemistry. This trend is noted by experts who speak about a rediscovery of nature as an efficient provider of drug candidates, in comparison with combinatorial chemistry that ultimately proved to be disappointing (Grabowski, Schneider, 2007; Harvey, 2008 ; Newmann, Cragg, 2012).

Ziconotide is an analgesic for the treatment of chronic pain, which is potent, long-lasting and non-addictive. Nevertheless, the neurological and psychiatric side-effects and the necessary intrathecal administration mode lower its therapeutic value (Durek et Craik 2015). The conotoxin Prialt is based on a peptide (ω-MVIIA) which was first identified and isolated by Olivera and McIntosh in the 1980s. They did not patent the peptide at that time. George Miljanich, working for a biotech start up called Neurex, pursued the research on the peptide and eventually patented the compound as an analgesic (Wells, 1998). Neurex was acquired by Elan Pharmaceuticals in 1998, which brought the product to market in 2004. Ziconotide was then the first new intrathecal analgesic approved in the USA in more than 20 years (Wallace 2006). Regarding its commercial value, in 2006 Elan sold its European-only rights on Prialt to the Japanese Pharma company Eisai for approximately 100 million USD. In 2006, drug sales generated 6.3 million USD in revenues worldwide.[18]

Focusing on the regulation of ABS, the cone snail specimens used by Olivera were accessed in The Philippines well before any ABS regulation was in force.[19] The case typifies the long timeline from R&D to commercial product: three decades lapsed before the FDA approved Prialt (Wynberg 2015). Inasmuch as access to physical samples occurred prior to the CBD, no agreement was necessary. The case also typifies the undefined scope of ABS for dematerialized genetic resources – the controversial issue of DSI – considering

14 To date, marine GR situated beyond national jurisdiction are not covered by any ABS rule (legal gap). The ABS regime established by the CBD and the Nagoya Protocol only apply to (marine) GR accessed within national jurisdiction. The global legal framework supposed to regulate the marine area beyond national jurisdictions - the United Nations Convention on the Law of the Sea – is currently negotiating ABS rules (Broggiato et al. 2014).

15 EO 247 was further clarified by the Implementing Rules and Regulations on the Prospecting of Biological and Genetic Resources in 1996. The Wildlife Resources Conservation and Protection Act of 2001 (together with its 2004 Implementing Rules and Regulations) and the 2004 Draft Guidelines for Bioprospecting Activities in the Philippines compose the current ABS legal framework of the country (Smagdi 2005).

16 κ-PVIIA (CGX-1051) for Myocardial infarction, μO-MrVIB (CGX-1002) for Neuropathic pain and Conantokin-G (CGX-1007) for Pain/Neuro protection.

17 α-Vc1.1 (ACV1), Contulakin-G (CGX-1160), ω-CVID (AM336) and χ-MrIA (Xen2174), all for pain treatment.

18 https://www.thepharmaletter.com/article/elan-to-sell-european-prialt-rights-to-eisai (accessed on 30.03.2020).

19 The link between the R&D conducted by foreigners on cone snails from the Philippines and the pressures from Filipino scientists in the early 90s (Greer et al. 2004; Smagdi 2005) for a regulation of bioprospecting activities is not clear.

the ConoServer and other open-access databases. Almost no provider or user country has any ABS measures that cite DSI. The Philippines is not an exception, although plans exist to introduce measures (Bagley et al. 2020). Additionally, the processes of chemical optimization of GR highlighted by conopeptides complicate the situation. In optimization, the original molecular structure of GR tends to be modified, thereby diminishing the appearance of a 'natural basis' and making monitoring of ABS more difficult. Utilization of the natural information of Conidae through, for example, synthetic biology techniques illustrates just such modification of sequences from cone snail specimens.

Summary

Cone snails are widely used in both basic and applied research. To date, only one product from the R&D of the GR of the cone snail has reached the market. This may change as peptide chemistry once again attracts the interest of pharmaceutical companies. Meanwhile, the ABS regime suffers multiple legal gaps such as the status of DSI, absence of national rules, areas beyond national jurisdiction and cumbersome rules, which enable R&D activities on cone snails to avoid regulation.

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Appendix III

Marine Sponge (*Tectitethya crypta*)

Nikita Kent

Figure 1. Tectitethya crypta in Bahamas, San Salvador (2004)

Credits: Sven Zea (2014)

Brief history

Tectitethya crypta is a species of sea sponge found in the shallow waters of the Caribbean Sea.[1] The species is notable for having triggered the discovery of unique nucleic compounds that were developed into several life-prolonging medicines.

Max Walker de Laubenfels named the species *Crypotethya crypta* (1949). He discovered the sponge near the island of Bimini in the Bahamas. Laubenfels noted that this particular species of sponge was amorphous of about 4-7cm per slab, with a color in a spectrum of green, black and a dull, light-brown. Pores on the sponge are small. The visible surface is smooth. The small pores prevent clogging and appear to be an adaptation to burying in the sand. *Cryptotethya crypta* was later officially reclassified as *Tectitethya crypta* by Michele (2002) as belonging to the family *Tethyidae*.

Utilization of (compounds rather than) "DSI"

Compounds isolated from *T. crypta's* nucleic acids have been developed into three highly popular drugs for antiviral and ant-cancer treatment: Aciclovir (Ara-A), Cytarabine (Ara-C),and Zidovudine (AZT).[2] The drugs appear on the List of Essential Medicines by the World Health Organization (2019). As detailed in Table I, Aciclovir is used for herpes simplex via topical cream applied to cold sores or by tablets taken orally. Cytarabine is used globally for severe cases of leukemia and non-Hodgkin's Lymphoma. Zidovudine has also been used to treat HIV and AIDS. Other compounds synthesized from the species have been identified as useful in the treatment of pain and anti-viral treatment (Boué-Grabot, et al. 2020).

The sponge is too complex for a commercial market as a natural product. However, the mechanism of action can be imitated to produce more simple, synthetic analogues which are later useful to chemists, biologists, and pharmacologists alike, as observed in *T. crypta* (Denny, 2010, p.83).

The process of incorporating the nucleoside analogues of *T. Crypta* into modern medicine owes largely to synthetic chemistry. In a paper by Newman and Cragg (2016), a new source category for drug development, labelled "**S***", was inspired by the nucleoside analogues found within *T. crypta*. Newmann & Cragg defined the "**S***" **category** as "[drugs] made by total synthesis, but the pharmacophore is/was from a natural product". The respective category is set apart from the '**S**' category (i.e., without "*") which applies to "totally synthetic drug[s], often found by random screening/ modification of an existing agent" (p.633; Bergmann & Stempien, 1957; Mayer, 2010).[3]

Historically, specimens or compounds isolated from the sponge, have not been frequently used for research or drug development. The chemical structure obtained at the initial specimen collections or observations, can be used in the laboratory as a starting point for synthetic manufacture and improvement of the compounds or structurally analogue derivatives (Bergmann & Stempien, 1957; Newman & Cragg, 2016). Usually no need exists for specimens as synthetically producing compounds are more cost and time-effective for laboratory work. Only in the new millennium have scientists recognized the value in collecting and studying additional specimens, which have led to the discovery of valuable compounds using modern isolation techniques. Discoveries from the group are described in the subsection *Types of R&D being undertaken and actors involved*.

1 A comprehensive photo guide to Caribbean sponges is available at www.spongeguide.org

2 N.B. The compounds have had many names over the years. Other drugs developed from *T. crypta* compounds, such as Vidarabine, are no longer in the US market due to displacement by the more effective drug (Trifluridine). For the purposes here, I will be using the nomenclature most common in the literature.

3 Other classifications from this paper include 'B' (Biological source), 'N' (Natural product, unmodified), 'NB (Natural Botanical), 'ND' (Naturally derived, semi synthesized).

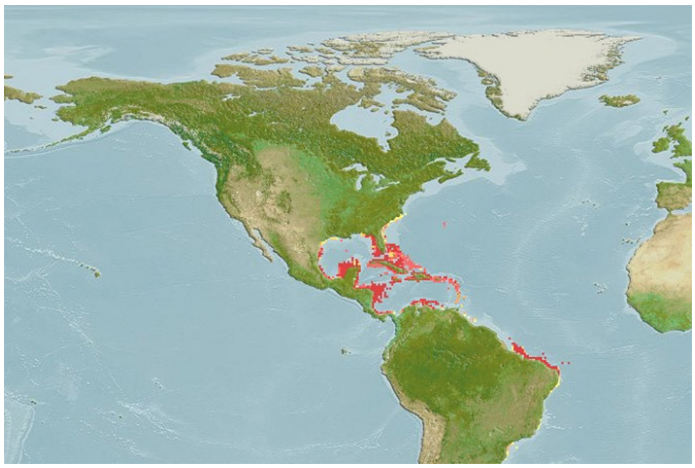
Table 1. Constituents developed from natural information derived from *Tectitethya crypta* (Wishart et al., 2017, unless otherwise stated)

Compound Name:	Structural Formula:	Type of compound	Applied treatments:	Known trademark names:	Marketed by:
Aciclovir (US) Acyclovir (UK)	$C_8H_{11}N_5O_3$	Nucleotide Analogue: *Adenosine Ribose*	Herpes simplex Varicella-zoster Herpes zoster Herpes labialis Acute herpetic keratitis	Ara-A Zovir Aciclovir (ES) Zovirax ® Penciclovir	GlaxoSmithKline (primary). Multiple others, after the patent had expired in the 1990s.
Zidovudine 'Ara-T'	$C_{10}H_{13}N_5O_4$	Pyrimidine Nucleoside Analogue: *Dideoxynucleoside*	HIV/AIDS Anti-Retrovirus	Azidothymidine AZT ZDV Retrovir ®	9 Manufacturers; 38 Labellers GSK/ Wellcome (Gupta *et al.*, 2010)
Cytarabine	$C_9H_{13}N_3O_5$	Anti-metabolite (also known as an anti-pyrimidine) (Mathe, et al., 2017)	Non-lymphocytic leukemia Lymphocytic leukemia Blast phase of chronic myelocytic leukemia.	Cytosine Arabinoside Ara-C Cytosar-U® Depocyt® Udicil® Alexan®	Pfizer (main) 5 manufacturers 8 packagers, including Enzon Inc., marketers of Depocyt® Cytarabine was initially marketed by Upjohn in 1969. Upjohn's product was then acquired by Pfizer in 2003 (Pfizer, 2020).

Conservation status and distribution

T. crypta is associated with the island of Bimini in the Bahamas of the Caribbean, located 80km east of Miami, Florida. Projections based on the IPCC 8.5 protocol, generate predictions that by 2020, the coasts of eastern Brazil, the Caribbean, and northern Australia will also be suitable habitat for *T. crypta* ($p > 0.80$). To date, the overwhelming majority of observations[4] pertains to the Western Central Atlantic Ocean, of the United States of America, the Dominican Republic, West Indies, Bahamas and of Cuba (Sara, 2002; Sea Life Base, last edit: 2017, accessed March 2020).

Figure 2. Native Range of *T. Crypta* distribution in the Caribbean, Kaschner et al. (2019). Map: Computer generated from SeaLifeBase (2021)



4 "The country list of *Tectitethya crypta* is available at Sea Life Base (online, 2017). Access date March 2020. Information available at: https://www.sealifebase.ca/country/CountryList.php?ID=51717&GenusName=Tectitethya&SpeciesName=crypta

Given appropriate benefit-sharing mechanisms, the discovery of life-prolonging compounds within marine species could promote protection of coral reefs of tropical and neotropical regions. Kaschner et al., have modeled future distribution patterns of marine species. In Figure II, the native range of *T.crypta* is mapped. Additionally, the University of California researchers Searle and Molinski (1994) successfully isolated 2'- deoxyspongosine from a specimen of *T. crypta* from Western Australia (Bertin, *et al.*, 2015). De Laubenfels (1949) had noted that the *T. crypta* grew "quite buried" under the sand, indicating that the species may also exist in other neo-tropical ecoregions, other than the Caribbean and await discovery.

Ex situ status of species

Records or specimens of *T. crypta* are held by predominantly United States institutions, including the United States Smithsonian Museum and the Yale Peabody University of Natural History. Other collections around the world may also hold specimens, without having yet updated their records on Porifera (sponge) information websites such as spongebarcoding.org, marinespecies.org (World Proferia Database). We have confirmed that the Museum of Western Australia, which hosts an extensive Porifera collection, does not have any specimens of this genus or species in their collections, despite Searle and Molinski having reported a specimen obtained from Western Australia in 1994. Specific specimen prototypes examined by marine taxonomist Michele Sarà (2002) are available online in the paper *Family Tehyidae Gray*, 1848.

Uses

Spongonucleosides from *T. crypta* were first isolated by Bergmann and Feeney (1951) at Yale University. The specimen was obtained from the shallow waters of Elliot Key, which is the northernmost of the Florida Keys (p. 981). The two chemists isolated spongothymidine ($C_{10}H_{14}N_2O_6$) from this specimen using a Soxhlet extractor and acetone solution. They discovered spongothymidine bore similarities to thymine deoxyribose, which is one of three pyrimidines that constitute DNA and RNA. Upon identifying a fragment of thymine, spongothymidine was assumed to be a pyrimidine nucleoside, called pentofuranosylthymine, whose composition had not been previously observed (Bergmann & Feeney, 1951, p. 982). Spongothymidine (Ara-T) later became the informational basis for HIV drug Zidovudine via 1-β-D-arabinofuranosyl thymine (Ara-T).

Procedures to isolate a pentose fragment in a nucleoside compound discovered in 1951 from the spongothymidine were unsuccessful. Both scientists found the evidence convincing that the purine nucleoside discovered had not been "encountered in nature... the sponges should prove to be an abundant source of new nucleosides the knowledge of which would be important to the understanding of biochemical evolution." (Bergmann & Feeney, 1951, p. 984-985). Later, in 1955, Bergmann and Burke would later isolate spongouridine which lead to the synthesis of 3-β-D-arabinosyluracil (ARA-U).

The effective activity of these spongonucleosides from the 1950s onward, triggered a worldwide inquiry into the use of nucleoside analogues. The information became the basis for many anti-viral and anti-cancer medicines worldwide[5] (De Clercq & Li, 2016, p. 12-13). Although not the first pyrimidine analogue to be synthesized, the compounds based on information obtained from *T. crypta* were different: the spongonucleosides were the informational keystone for the synthesis of 3-β-D-arabinofuranosylcytosine in 1959 (Walwick, Roberts & Dekker) at the University of California, Berkeley. 3-β-D-arabinofuranosylcytosine has been used as the informational basis for drugs cytarabine, vidarabine, and aciclovir, among others (see: Table I). The compound 3-β-D-arabinofuranosylcytosine acts as an antiviral agent by inhibiting reverse transcriptase, which is the genetic information replication process attributed to viruses. However, in anti-cancer cases (non-viral), these nucleoside analogues are similar enough to DNA to be incorporated into the DNA chain but inhibit further DNA chain replication via DNA polymerase. Thus, when cancer patients are treated with pyrimidine nucleoside analogues such as Cytarabine through chemotherapy (cell disruption treatment), the cancerous cells are unable to replicate further. The cytotoxicity of this process often causes adverse symptoms in patients, such as baldness and bone marrow depletion.

Types of R&D undertaken and actors involved

Tectitethya crypta continues to fascinate chemists, microbiologists and the pharmaceutical industry Scientific journals frequently publish new compounds related to the spongonucleosides as well as processes of isolation and synthesis. Although sponge compound R&D is found mostly at academic research institutions, many laboratories

5 Vidarabine is another medicine used for special cases of herpes simplex and HSV Keratoconjunctivitis (herpes of the eye). Vidaraibine has been discontinued in many countries since another nucleoside analogue, Trifluridine, is more effective and less toxic in HSV cases. However, patients sensitive to the active chemical idoxuridine in trifluridine, are administered vidarabine (Aoki, 2015). In the same manner, patients who are resistant to Ara-A nucleoside analogues (also referred to as pyrimidine nucleosides) are administered alternatives that work in similar ways to Ara A.

also have strong affiliations with anti-cancer or anti-viral institutions and corporations, such as the National Institute for Cancer Research or GSK Corporation in the United States.

Only recently has the Gerwick group (Bertin et al., 2015) reported isolation from a fresh collection of *T. crypta*, which lends support to the hypothesis that a microbe, such as bacterial strain *Vibrio harveyi*, produced spongosine compounds. An earlier paper published in the journal *Molecular Cancer Therapies* suggested that microorganisms, living in conjunction with sponges, are the true sources of many bioactive and useful constituents (Simmons et al., 2005, p. 335). Spongosine compounds are currently being used for novel drug development to treat inflammation and pain (Newman, 2018; Bertin et al. 2015).

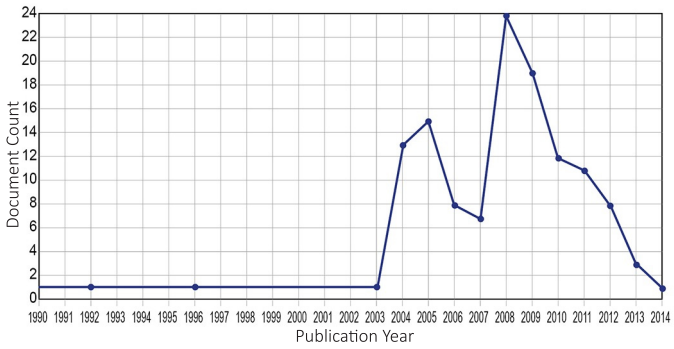
This discovery may have been delayed since many compounds found in *T. crypta* from the 1950s have been developed synthetically. For this reason, their presence in the habitat of the sponge has not been studied in depth. These new findings conclude that either *T. crypta* contains microbes which produce compounds of interest, or sequesters such compounds (Newman, 2018) The answers are as of yet unclear and require further investigation, perhaps utilizing not only samples of the species but also a detailed observation of the habitat.

Application of ABS

ABS rules have been largely ignored in the field of nature-inspired structural formulas based on *T. crypta*. Many scientists and pharmaceutical companies have relied upon the synthetic and biochemical understandings produced by the Bergmann group. They have never worked directly with sponge samples or compounds isolated from sponges but instead rely on information gained by previous investigations into such tangible resources. One exception involves researchers from the Gerwick group,[6] who have recently been involved with the production of a Global Natural Products Social Molecular Networking (GNPS), after having successfully isolated the spongosine compound in 2015 (Wang, et al., 2016).

An example of ABS *unawareness* involves Peter Richardson, who handles the intellectual property of spongosine and adenosine receptors through the company Cambridge Biotechnologies (CBT), whose affiliated subsidiaries are assigned or granted patents related to the spongosine compound, including in China [CN101479268B], South Korea [KR101122495B1] and Japan [JP4836454B2][7]. A majority of the thirty some patents relates to the synthesis of spongosine or its optimisation. The most commercially viable is the "Use of Spongosine for the Treatment of Pain" assigned under CBT Development London [US008252766B2]. CBT raised 6.3 million pounds in 2001 as venture capital and thereafter 18.3 million pounds after three rounds of capital raising (S&P Capital IQ [a], 2021). After numerous restructurings, CBT has finally merged into a private company named BenvolentAI, an artificial intelligence (AI) enhanced, drug-discovery entity valued at one billion USD (S&P Capital IQ [b], 2021). At the time of this writing, Peter Richardson serves as Vice President (Pharmacology) at BenevolentAI (Benevolent AI, 2020; Powell, 2019; CN1910194B).

Figure 3. ***A Patent Lens*** **Search of keywords spongosine, spongothymidine, spongouridine, spongonucleosides**



The sponge *Cryptotethya crypta* is mentioned in Richardson's patent filings regarding spongosine, but little exists regarding the material transfer agreement. In patent publications, Richardson addresses the discovery of Bartlett et al. (J. Med. Chem. (1981) 24, 947-954) who discovered the first biological activity of spongosine. Academic credit appears to be the only transaction between the two groups. There are no patents listed under "Robert T. Bartlett", nor any relevant spongosine patents before 1990, which suggests that Richardson was among the first researchers to pursue IP rights aimed at protecting investments based upon biological discoveries performed by academics before him.

The research on spongonucleosides has largely been based in the developed countries of Europe and North America. *T. crypta's* spongonucleosides were first isolated by affiliates of the United States, namely in the US established

6 Spongonucleoside MS/MS spectra have been published and annotated at gpns.uscd.edu (Bertin, et al., 2015)

7 Using the keywords ('spongosine') under granted patents. No specific time frame used. The platform is accessible through the following URL: https://www.lens.org/lens/new-search.

Lerner Marine Laboratory in the island of Bimini before independence of the Bahamas from Britain in 1973. The chronology and patent searches have pointed to the conclusion that US scientists have led taxonomical and anti-viral/cancer compounds from *T. crypta* compounds, with strong support from the National Cancer Institute (NCI) and affiliated universities. A patent search conducted using keywords of *T. crypta's* compounds (see: Figure III) has reiterated that 28% of patents filed belong to the jurisdiction of the US, 21% to Australia, and 16% to the World Intellectual Property Organization.[8] The remaining 35% of patents pertains to the EU, New Zealand, Japan, China, South Korea, and Germany.

Based on this search, there has been no evidence of any institution or person originating from the Bimini Islands, nor the Bahamas, engaging in the chemical, pharmaceutical, or microbiological research of the compounds within *T. crypta* or of benefit-sharing agreements between local institutions and users.

Market Information & Relevant IP Involved

Many chemists and biomedical scientists studying sponge nucleosides either work for large pharmaceutical companies or cooperate with multinational pharmaceutical corporations for more effective R&D of life-prolonging compounds. The chemist Howard J. Schaeffer is one such example, having played a key role in the development of Aciclovir in 1974 while working with Wellcome Research Laboratories in North Carolina and authoring patents of Aciclovir to subsidiaries of GlaxoSmithKline (GSK) [GB2130204A; CA1305138C; US4199574A, among others] (Bouton, 1989). Inasmuch as patents expire after 20 years, a variety of 1990s Aciclovir-containing drugs are now public domain and on the world market as generics (Gupta, et al. 2010; The Pharma Letter, 1997). Nevertheless, the most common is Zorivax®, which is still owned and marketed by GSK[9].

In 2000, SmithKline Beecham GlaxoWellcome merged to become GlaxoSmithKline, which co-owns the global specialist HIV company, ViiV Healthcare (2019), along with Pfizer (Moore, Waldholz, Raghavan, 2000). ViiV Healthcare is assigned a majority share of patents for Zidovudine [US9580431B2], and market Retrovir/AZT® (zidovudine), Combivir® (zidovudine and lamivudine), and Trizivir® (zidovudine, abacavir, lamivudine) globally (Wishart, et al. 2017). As a result of numerous mergers and acquisitions, the pharmaceutical giant GlaxoSmithKline controls a large market share of the anti-viral and anti-cancer drugs with compounds which have been inspired by *T. Crypta*.

Cytarabine, the third drug in Table I, has also been marketed by another chemist, John Evans, who discovered anticancer activity in 1961 while working for Upjohn & Co. [Patent US33201321[10]]. In the 1990s, Upjohn was merged with the giant Pharmacia, which later merged with a division of Monsanto in 1999. By 2002, Pharmacia Corp. was acquired by Pfizer (Sorkin, 2002) which now holds title to the widely used Cytarabine Injection product[11] (Pfizer, 2020). However, as the patent for the active ingredient has expired, other companies have also patented their technologies using the active ingredient cytarabine. Examples include: Pharmascience Inc. (Canada) with 'Cytosar®', Pacira Limited (EU), 'Deocyte®', and Novopharm Ltd. (Canada),'Cytarabine-Pws 1gn/vial 'and 'Cytarabine -Pws 2gm/vial', 'Cytarabine - Pws 500mg vial', etc. (Wishart et al. 2017).

Inventors or companies who discover and patent natural products may only enjoy commercial success in the short term, which supports the findings from Gupta et al. (2010). [M]arket exclusivity over the initial patent protection period of 20 years has allowed pharmaceutical entities, in particular GlaxoSmithKline and Pfizer, to enjoy a time-limited monopoly over their invention and thereby recover the costs associated with R&D. Significant benefits have been gained by generics companies upon patent expiry.

ABS issues

Although *T. crypta* is considered a marine "genetic resource", none of the genomes of the sponge is utilized. Rather, research and development based on the unique biochemical compounds found in marine sponges have led to successful results (Vierros et al., 2016). To this end, most researchers and companies do not require access to tangible samples of marine sponges, neither *in situ* nor *ex situ*. In many cases, published knowledge on structure and bioactivity of the compounds was all that researchers and drug-makers required.

8 Patent Lens. Conducted May, 2020. Using key words spongosine, spongouridine, spongonucleosides, sponothymidine. Lens Patent search is available at: https://www.lens.org/

9 GlaxoSmithKline, Consumer Healthcare Products (https://www.gsk.com/en-gb/products/our-consumer-healthcare-products/skin-health/zovirax/)

10 John S. Evans (1963) *Composition containing 1-beta-d-arabinofuranosylcytosine useful in treating mice tumors*. Patent granted: 1967. Expired: 1984.

11 Pfizer's cytarabine (2020). Available from: https://www.pfizer.com/sites/default/files/products/uspi_cytarabine_1000mg.pdf)

T. crypta has truly produced global benefits. As outlined by Deplazes-Zemp (2018), various benefits are associated with R&D based on genetic resources, including academic credibility and financial gain. Researchers such as Bergmann, Laubenfels and Schaeffer have propelled their careers with findings of nucleosides from the sponge. An example is Gertrude Elion, who spearheaded AZT medication development at Burroughs Wellcome and won a Nobel Prize in 1988 (Bouton, 1989). In addition, pharmaceutical companies have benefited financially. Many patients have prolonged their lives by taking synthetic marine compounds.

Though many people have benefited from *T. crypta*, the natural habitat of the sponge has not. Anthropogenic damage is greatly diminishing biodiversity in the Caribbean (Jennings, et al., 2016). In 2016, former Environment Minister of the Bahamas, Mr. Kenred Dorsett, was quoted as saying: "For decades, pharmaceutical companies and cosmetic companies have exploited our waters for genetic resources. These resources are used to make medicine and cosmetics and are a part of billion-dollar industries. The Bahamas receives no royalties and no benefit. So, my ministry and this government seeks to change that" (Nassau Guardian, 2016). That same year, Nassau set aside 1.9 million dollars to prepare itself to sign the Nagoya ABS framework but is still not a Party or Signatory as of 2020 (UNSCBD, 2020).

Experience exists where benefits gathered by R&D on sea sponges can be shared with Providers. The University of British Columbia (UBC) shares royalties with the University of Papua New Guinea (UNPG) for the utilization of a sponge akin to *T. crypta* in anti-cancer compounds. Royalties have helped to finance infrastructure and a start-up at the UNPG, thus incentivizing the conservation of the coast of Papua New Guinea as well as enhancing education. As both the UNPG and the UBC own equity in the R&D, both will not be excluded from the mid to long-term benefits arising from the arrangement (Vierros, et al., 2016).

Similar species of marine sponges have been found in highly biodiverse habitats in different parts of the world. Because most countries in the neotropics lack authoritative governing institutions to negotiate and monitor material transfer agreements, patents are usually filed in developed countries. Benefits have not been equally distributed with countries of origin, who are ultimately responsible for conserving coastlines from anthropogenic damage. Furthermore, *T. crypta* lies within the EEZ of countries of the USA, a non-Party to the CBD, thus allowing jurisdiction shopping and an apparent "safe haven for biopiracy" (Vogel, 2007). If the compounds of interest are produced by microorganisms symbiotic with the sponges, the distribution of natural information may be extremely wide. One positive advancement has been the development of the GNPS software for natural product data, which will support the traceability and accountability of compound usage and development of naturally derived compounds.

Summary:

Discovery of spongosine compounds and drug development based on information about the properties of those compounds constitute a challenge for ABS. Direct links usually do not exist between access to tangible specimens from which the products were inspired by or derived. Any direct connection is further complicated by the fact that spongosine may not be produced by *T. crypta* on its own, but rather by a metabolite of a microbe living in symbiosis with the sponge.

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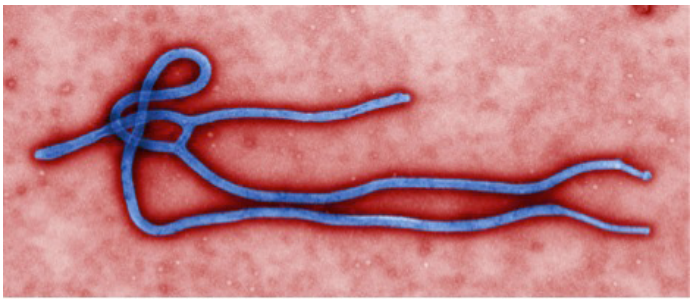
Appendix IV

Ebola

Omar Oduardo-Sierra

Figure 1. Ebola virus virion.

Credits: Health Image Library, #10816 (accessed 2021)



Brief history

Strains from the genus Ebolavirus in the family Filoviridae cause the hemorrhagic fever known as the Ebola Virus Disease (EVD) (WHO, 2020). Only *Zaire ebolavirus, Sudan ebolavirus, Tai Forest ebolavirus* and *Bundibugyo ebolavirus* are infectious to humans (CDC, 2019). Over the last fifty years, 46 confirmed outbreaks have been reported (CDC, 2019). As of this writing, the confirmed outbreaks occurred in February 2021 (WHO, 2021) and June 2020 (WHO, 2020). As of 19 December 2019, the US Food and Drug Administration (FDA) approved the Ebola vaccine rVSV-ZEBOV, trademarked Ervebo. The vaccine is safe and effective against only the Zaire ebolavirus species (CDC, 2019), which is the deadliest strain (Chowell & Nishiura, 2014).

Ebola originated in Africa. Certain species, such as Reston ebolavirus, have also been observed in non-human mammals in Asia. Various fruit bat species of the Pteropodidae family are natural hosts. Other non-human primates, such as chimpanzees and gorillas, also transmit the virus. Transmission can be transmitted via contact with blood and bodily fluids and in direct contact of contaminated environments (Laupland & Valiquette, 2014). The virus inhibits interferon molecules to hinder the immunological response to the virus. Ebola proteins trigger coagulation by forming blood clots that travel throughout the body, leading to hemorrhaging (Servick, 2014).

Distinguishing features for ABS

Categorized as a Biosafety Level 4 organism by the CDC along with the reconstructed 1918 influenza virus, Smallpox, and SARS CoV, Ebola variants are highly restricted for usage and distribution. Specific guidelines and cold-chain processes must be followed for safety of personnel involved in transportation and care of samples. Research labs collect and sell samples for vaccine development. Several observations are worthy of consideration from what would be the fair and equitable sharing of benefits:

- Samples are collected from individuals with little or no compensation even though re-sold at a significant price;
- The virus originates in regions where populations have been economically disadvantaged;
- Specimens can be found beyond national and even continental boundaries;
- Impact of research can benefit local populations and potentially prevent future outbreaks;
- Although studied since 1976, the first vaccine was only approved in 2019 and for only one of the known strains affecting humans. R&D continues on other potential vaccines.

Utilization of "DSI"

GenBank uploaded the complete genomes for all Ebolavirus strains (NCBI, 2018) in accord with its policy of open access.[1] The ineligibility of patentability of isolated genetic information was established in the landmark 2013 ruling in Association for Molecular Pathology (AMP) v. Myriad Genetics Inc. by the US Supreme Court.[2] The information extracted from samples taken from victims of EVD is an essential element in epidemiological research and vaccine development. The question is how to prevent User accessibility from becoming leverage for Provider accessibility to diagnostics, antivirals and vaccines?

In mid-2019, New York-based pharmaceutical Regeneron successfully trialed a treatment for EVD, REGN-EBR, developed using sequence data from the C15 strain of the virus. The strain was sequenced and published on GenBank by the German Nocht Institute, which concluded an MTA over the physical sample. The results of the research were historic as was the method of access to the genetic resource. By citing sequence data rather than physical samples, the issue arose whether sequence data and other interpretations of DSI are under the scope of the NP. Under the current international framework, neither the Guinean woman who supplied the sample or Guinea are entitled to benefits from the estimated $10,000 per dose that Regeneron is posed to collect (Hammond, 2019). It should also be noted that Guinea did not have an ABS regulatory framework at the time of collection.

Conservation status – distribution & *Ex situ* status

When discussing the conservation status of the Ebolavirus, one must consider two routes: the strains themselves and then the organisms that become vectors of the strains. To date, no vector has been identified for the Ebolavirus. The scientific community is in search of eradicating cases. The first was reported in Central and East-Central Africa in what had then been Zaire and Sudan and are now the Democratic Republic of Congo and South Sudan, respectively. Cases have been found throughout the region and also eastward. Cases have also been confirmed in Uganda, Gabon, Congo, Nigeria, Côte d'Ivoire, Liberia, Mali, Sierra Leone, Guinea, and Senegal. The Reston Ebola virus has been observed in The Philippines, indicating that the virus has spread beyond the continent of Africa. On 1 June 2020, the WHO detected new cases in the DRC and dispatched response teams.

Table 1. Human Pathogenic Ebola Virus Strains

Species	Countries Detected	Genome Publication	Country of Origin	Precedence
Zaire ebolavirus	Congo, DRC, Gabon, Guinea, Italy, Liberia, Mali, Nigeria, Russia, South Africa, Sierra Leone, Senegal, Spain, UK, USA	(Volchkov, *et al.*, 1997)	Zaire (DRC)	Articles references samples collected in 1976. Sample received from the Institute Voor Tropische Geeneskunde, Antwerp, Belgium
Sudan ebolavirus	Sudan, UK, Uganda,	(Sanchez & Rollin, 2005)	Uganda	Originated in northern Ugandan city of Gulu
Reston ebolavirus	Italy, Philippines, USA	(Groseth, Ströher, Theri-ault, & Feldmann, 2002)	Philippines	Originated in Asia among a group of cynomolgus monkeys (Macaca fascicularis) imported from the Philippines into the United States.
Taï Forest ebolavirus	Côte d'Ivoire	(Towner, et al., 2008)	Côte d'Ivoire	Only known case originated in the Taï Forest in the Parc National de Taï.
Bundibugyo ebolavirus	DRC, Uganda		Uganda	Originated in the townships of Bundibugyo and Kikyo in the Bundinbugyo District of Western Uganda.

The scientific-medical community pursues eradication of Ebolavirus *in situ* and preservation of only samples *ex situ*, for further research and development, which concerns the collection, processing, and sharing of Ebola samples.

Uses, R&D undertaken, actors involved & Market information

Samples of Ebolavirus are researched to develop vaccines and diagnostics. Current vaccines in development include replication-deficient adenovirus vectors, replication-competent vesicular stomatitis and human parainfluenza vectors, and virus-like nanoparticle preparations. As of 2020, only one treatment has been approved for sale, Ervebo (rVSV-ZEBOV), developed by the Public Health Agency of Canada and Merck, Inc. The pharmaceutical industry is exploring other options, with GSK, J&J, and Merck leading the race, in collaboration with governments, such as the USA and Russia.

None of the drugs for the treatment of EVD have been approved by the FDA (CDC, 2019). Nevertheless, the above-mentioned REGN-EB3 (US National Library of Medicine, 2018), and MAb114, developed by NIAID (Gaudinski, et al., 2019) have shown promise (Sabue Mulangu, 2019) and will be distributed to EVD patients (Maxmen, 2019). Other proposed treatments include Remdesivir (GS-5734), which has been repurposed in the fight against COVID-19 (Pardo, Shukla, Chamarthi, & Gupte, 2020).

Vaccine and drug developers are based in Europe or the USA. Crisis first-responders and researchers who collect samples have found that the market price for samples of 0.5mL fetch upwards of €3600 (Evans, Hills, & Levine, 2020). No significant compensation is enjoyed by the victims of the virus or the laboratories in the countries of the victims (McKenna, 2019), nor is the specific provenance of samples disclosed due to patient privacy (Table 1). One may argue that provenance is not relevant, as vaccine development does not require knowledge of the identity of the patient from whom the sample was drawn. However, given the lack of agency of patients with a life-threatening disease in lowest-income countries, prior informed consent seems allusive.

As of the time of this publication, the United States is not a Party to the CBD nor signatory to the Nagoya Protocol and, therefore, is not bound by obligations of ABS when accessed within US jurisdiction. Access is facilitated through reliance on synthetic variations, which are less accurate than genuine Ebolavirus isolates (Branswell, 2019).

Application of ABS and Criticism thereof

ABS does not seem suited to human pathogens as the objectives for public health are not conservation but eradication, and not sustainable use, but containment and vaccine development. Rapid access to samples is key for public health, containment and R&D for vaccines. Hence, ABS should address whether incentives can be created for identification and isolation of strains and their immediate sharing with the international research community.

The use of patents to incentivize R&D on pathogens contrasts with the lack of incentives to provide samples when the resulting technologies lie beyond the purchasing power of lowest-income countries afflicted. The challenge for framework treaties like the CBD and NP are to suggest how modalities of ABS can be adapted for the peculiarities of pathogens.

The American Medical Association (AMA) identifies utility, equity, justice and liberty as four justifications in favor of sharing benefits in exchange for improved access to samples. Utility means access to lifesaving interventions or data saves lives. Equity refers to financial gain not coming at the expense of the communities that provide the resource. So, justice would not obtain should samples be collected without providing future benefits. Liberty refers to collection contracts being signed by willing parties, which implies that sampling vulnerable populations during a pandemic is questionable.

Table 2. The Race for more Vaccines

Vaccine	Private Sector	Public Sector
rVSV-ZEBOV	Merck	Public Health Agency of Canada, NIAD, WRAIR
cAd3-EBO	GSK	NIAID, WRAIR
Ad26.ZEBOV MVA-BN Filo	J&J	NIAID

Summary

A modality which concentrates a benefit to the Party which first isolates and shares a viral strain would meet the criteria of the AMA and the objectives of the CBD and NP.

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Appendix V

Template for cases

Brief history

Milestones, main features, aspects variant from typical ABS cases.

Utilization of "DSI"

Conservation status – distribution

Range (current) and habitat (potential) / maps

***Ex situ* status of species**

Do regulatory controls exist? Have MTAs been concluded?

Uses

Value added and the chain from access to intellectual property.

Type of R&D undertaken and actors involved

Technology sectors and research streams (e.g., Pharma, seeds, extracts and so on)? Is utilization by public institutions, universities, share-held or privately held companies and so on?

Application of ABS

Market information

Products available, any data on revenue income

Relevant IP involved

Other details of relevance, including, if available, ABS challenges

ABS issues

Grounds by which stakeholders may have criticized ABS (e.g., fairness and equity, transparency, prior informed consent and so on). Have countries demonstrated cooperation with Contracting Party in MTAs?

Summary

References

Appendix VI

"Legal Elements for the 'Global Multilateral Benefit-sharing Mechanism' as contemplated in the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization"

Version 3.0

Manuel Ruiz Muller, Joseph Henry Vogel and Klaus Angerer

Preamble:

In recognition of genetic resources being, for the purpose of adding value through intellectual property, natural information disseminated and diffused over taxa and often of a transboundary nature,

Recognizing that through the granting of intellectual property rights, especially patents over inventions, many economic sectors, including the biotechnological, pharmaceutical and agroindustrial, have used natural information in varied ways, generating income that is seldom shared as a monetary benefit with the countries from which the natural information is found *in situ*,

Similarly recognizing that Article 10 of the Nagoya Protocol considers the possibility of establishing a Global Multilateral Benefit-sharing Mechanism, in cases where utilized genetic resources for Research and Development (R&D) are found in transboundary situations or where granting or obtaining prior informed consent is not feasible,

Aware of the inefficiency and inequity inherent to one country alone assuming the right to consent access for utilization of natural information, which is of a transboundary or shared nature among several countries,

Also recognizing that with respect to R&D, science has firmly established, since the middle of the 20th Century, that genetic resources are essentially information and that the reductionist perspective allows sound management and practical applications in diverse fields,

Aware of the necessity to better align incentives so that the third objective the Convention on Biological Diversity (CBD) concerning the sharing of benefits, may reinforce the first and second objectives, those being, respectively, conservation and sustainable use of biological diversity,

Suggesting that a fair and equitable sharing of benefits derived from the utilization of genetic resources, together with other measures adopted at the national level, help countervail the tendency to destroy habitats rich in biodiversity, genetic resources and natural information,

Recognizing that the definition established in the CBD of "genetic resources" as "material of real or potential value" has been misinterpreted as only tangible matter, thereby undermining any expectation of fairness and equity in the sharing of benefits,

Also recognizing that the term "natural information" captures cases where research from the biological medium extracts the object of access,

Maintaining that the concept of "information" alone is insufficient and must be qualified with "natural" to be distinguished from "artificial information" that is expressed in innovations of varied sorts, such as computers, software, artistic recordings, literary creations and so on, all of which may be protected through different types of intellectual property,

Also recognizing that the term "natural information", in the context of the Convention on Biological Diversity and the Nagoya Protocol, is understood as only biotic in origin,

Further maintaining that the concept of "natural information" becomes useful for technological applications in diverse industries and areas of human creativity, including biotechnology, biomimicry, pharmacology and pharmacognosy among many others, for which intellectual property-like protection constitutes an homology with the intellectual property rights of artificial information,

Recognizing that economic principles for the efficient regulation of goods and services which are information in character, have been rigorously developed,

Aware that efficiency in a multilateral mechanism for the sharing of benefits and the development of national regulations to facilitate access to natural information, are requisite to generate benefits that derive from utilization and thus guarantee a fair and equitable sharing in said benefit,

Emphasizing that widespread utilization of natural information best assures that benefits rebound effectively on conservation *in situ* and the sustainable use of biodiversity,

Recognizing that since the ratification of the CBD as international law, the contracts and bilateral agreements concluded for access to genetic resources and the fair and equitable sharing of benefits (ABS) have not proven themselves operative, thereby making necessary a multilateral approach to ABS,

Also concerned by the impossibility of achieving efficiency, fairness and equity in the sharing of benefits derived from the utilization of natural information by means of concluding bilateral contracts among countries and parties, private or public, for information dispersed and diffused among two or more countries in competition for the monetary benefit in exchange of access and utilization of the natural information,

Clarifying that this new approach to ABS by means of the Global Multilateral Benefit-sharing Mechanism is based upon *ex post* verification of access and successful commercial utilization of the natural information, by means of the intellectual-property system, that allows in turn an efficient sharing that is fair and equitable in monetary benefits,

Likewise recognizing that the multilateral system of sharing benefits for access and utilization of natural information can be implemented for holders of intellectual property in a stepwise fashion, beginning with the economic sectors and types of activities of greatest revenue,

Mindful that, as a general principle, the activities of biocommerce, biobusiness and other uses of biological diversity for which intellectual property rights are not sought over the value added to natural information, are guided by their own rules and principles, which are distinct from those in this Global Multilateral Benefit-sharing Mechanism,

Recognizing, in that regard, that a series of economic principles and legal instruments, already in effect at a national level, regulate production and value chains related to components of biodiversity, such as environmental impact statements, management plans, collection permits and primary processing, sanitary permits, among others,

Aware, moreover, of the intensive and extensive use of natural information extracted and now independent from the biological medium in many industries, with global sales in the hundreds of billions of US dollars annually,

Recognizing that countries, in the exercise of their sovereign rights, have the right to adopt and participate in a Global Multilateral Benefit-sharing Mechanism,

Recognizing that the intensity of drivers are distinct for extinction of marine and terrestrial species,

The Parties to the Nagoya Protocol approve the following Global Multilateral Benefit-sharing Mechanism on the following terms:

Section 1. On definitions

Article 1. The applicable definitions for the mechanism are:

Artificial Information: Any human-made distinction, non-uniformity or difference that is intentional.

Access and Utilization: The process by which one obtains natural information of genetic resources or biological material and adds value.

Bounded openness: The conceptual foundation which allows natural information to flow freely for R&D, until commercial success of an innovation at which time any innovation protected by intellectual property is obligated to share monetary benefits, the percentage of which would be defined according to the category of utilization and other characteristics that correspond to the value added.

Determination of the royalty rate based upon a set of characteristics in the utilization of natural information: Several criteria are to be considered by the Subsidiary Body on Technical and Technological Advice (SBSTTA) which sets the royalty percentage for access and the utilization of natural information. Among them are the type of intellectual property, the economic sector to which the value added corresponds and whether the use is direct or indirect.

Commercial success: The moment in which an obligation to share benefits among country(ies) of origin arises due to having added value to natural information through an intellectual property right that generated significant economic revenues.

Natural Information (abiotic): Complement of Natural Information (biotic) with respect to that which is not living and was never alive.

Natural information (biotic): Any unintentional distinction, non-uniformity or difference extracted from matter that is living or was once alive.

Country of origin of natural information: Country(ies) in which one finds the biological media of the natural information *in situ*.

Provider of natural information: Country or institution from which one accesses the natural information in conditions *in situ* or *ex situ*, as is the case.

Technical mechanism to determine the distribution of natural information: A group of institutions with recognized technical and scientific capacity to contribute toward determining the taxonomic diffusion of natural information and geographic distribution of species of said taxa that convey the natural information, to the extent such determinations are possible.

Biological medium: The vehicle of biological origin that conveys natural information.

Sufficient commercial success: The amount of deposited royalties to justify the expense to determine the diffusion of natural information across taxa and the geographic distribution of terrestrial species that carry said information.

User of natural information: A natural or artificial person who utilizes the natural information for the purpose of adding value through R&D and applies for and maintains an intellectual property right over said value.

Section 2. Objective

Article 2.- The objective of the global multilateral mechanism is to align incentives in a cost-efficient fashion for the conservation and sustainable use of biological diversity, based on a fair and equitable sharing, among countries of origin, of the monetary benefits derived from access and the utilization of natural information.

Section 3. General principles

Article 3.-The multilateral mechanism is based upon the principle of bounded openness for access to and utilization of natural information.

Article 4.- Core to the mechanism are facilitated access, multilateralism, transparency and the timely generation and exchange of information to assure the achievement of the objective.

Article 5.- To assure the generation of significant benefits and the subsequent fair and equitable sharing of benefits among the country(ies) of origin, the Parties will be guided by national legal and regulatory systems that facilitate access of genetic resources for the purposes of utilization of the natural information with the possibility to add value, as foreseen in Article 15(2) of the CDB, which implies that national regimes of access to genetic resources, as biological media or vehicles of this natural information, be simple and clear.

Section 4. On the fair and equitable sharing of benefits

Article 6.- The sharing of monetary benefits derived from access and utilization of natural information among countries of origin will be realized when the innovations or product that contains natural information are protected by intellectual property and achieves commercial success.

Said sharing will be proportional to the habitats conserved of the species from which one could extract the natural information, whenever such determination is possible and when not, proportional to a substantiated proxy made by the technical mechanism of the determination of the natural information.[1]

Article 7.- Access and utilization of natural information can occur in conditions *in situ* or *ex situ*. Whichever is the case, benefits will be distributed proportional to habitats, as stipulated in Article 6. In the event of species extinct *in situ*, the benefits will be channeled to the institution(s) which maintain(s) the specimens of said species *ex situ* for conservation, restoration and other purposes.

Article 8.- The Parties of the multilateral mechanism will adapt policies and regulations about intellectual property to require that an applicant for intellectual property disclose in a simple fashion whether natural information was utilized or not.

Article 9.- If the species for which natural information was accessed is known at the moment of filing an application for an intellectual property, the User will maintain confidential said information until such time of verified commercial success of the innovation which triggers the obligation to disclose said information to the mechanism.

If the species are unknown at the moment of applying for the intellectual property, identification will be performed by the technical mechanism of determination of the distribution of natural information upon commercial success of the protected creation or innovation, sufficient to pay the associated costs of the identification incurred.

1 In cases where the determination of the habitat is not feasible with any acceptable level of confidence, the diffusion may be substituted with the mere presence of the species, weighted by the geographic size of the country, where the substitution is subject to updating in the light of technological improvements and scientific knowledge.

Article 10.- The income generated by the fixed royalty established by the SBSTTA and applied to the net revenue of the commercialized good or service, will be deposited at the end of the tax period applicable to the User who commercializes the good or service that contains the natural information, in a fund of sharing benefits according to that established in Article 21 of the system.[2]

Incumbent upon the User of the natural information who has begun to commercialize the good or service that enjoys intellectual-property protection, is to inform the ABS Clearing-House Mechanism of the amount of net sales from the good or service. Non-disclosure entrains penalties and sanctions to be determined by the national competent authority in matters of access to genetic resources.

Article 11. The country(ies) of origin of the natural information will receive a percentage of the monetary benefits generated by the commercialization of the good or service resulting from the process of adding value to said natural information, proportional to the calculation of the habitats in which are found terrestrial species that contain said information, as long as said calculation is cost efficient.

Article 12. Should natural information be endemic to just one country, estimation of the habitat should be periodic. Any percentage diminishment of habitat should be doubled in the percentage diminishment of the royalty rate between periods, thereby avoiding critical depensation of the population and thus aligning incentives for conservation for endemic species.

Article 13.- When significant errors have been detected in the determination of the distribution of natural information made by the technical mechanism, procedures for review and re-calculation of the distribution of benefits will be executed, based upon the date of filing said information.

Article 14- In the case of non-monetary benefits and scientific institutional collaboration, the Parties will be able to maintain their policies and regulations about access and use of the components of biodiversity, including genetic resources, by means of institutional agreements, contracts, memoranda of understanding or other instruments to effects which may be defined internally and which conform to the principles of the CBD and the Nagoya Protocol.

Section 5. On the technical mechanism for determination of the distribution of natural information

Article 15.- The technical mechanism of determination of the distribution of natural information is designed to identify, as precisely as possible, the country(ies) of origin of the species from which said information could have been extracted. Identification includes the geography of the habitats, deploying the technology available at the time of commercial success to calculate said distribution, so that the percentage of benefits will be shared fairly and equitably.[3]

Article 16.- In cases where the expected costs to ascertain the distribution of species is greater than the monetary benefits to be shared, the accumulated benefits up to the expiry of the granted intellectual property, will be used to defray the costs for developing and maintaining the capacities and infrastructure of the technical mechanism for the determination of the distribution of the natural information.

Article 17.- The technical mechanism for the determination of the geographic distribution of natural information comprises those international institutions of recognized standing, working in activities of taxonomy, monitoring biodiversity, patterns of distribution, developing models of speciation and phylogeny and other activities to understand how biodiversity is distributed.

Article 18. Benefit sharing for marine species will be distributed among Parties which reduce drivers beyond existing commitments. To level the playing field in the decision to utilize marine or terrestrial genetic resources, the conditions and percentages negotiated for terrestrial species will apply to marine species.

Section 6. On the royalties for commercial or industrial successes

Article 19.- Depending on the commercial or industrial sector corresponding to the innovation or creation and the type of intellectual property solicited, among other relevant considerations, the Ratified Parties of the Global Multilateral Mechanism, by means of the SBSTTA, will fix a royalty percentage for approval by the Conference of the Parties (COP), that will be applied quarterly to the net sales generated for the good or service developed from the natural information and be effective over the lifetime of the right granted. Once the royalty is determined on basis of a set of characteristics, said percentage will be tentatively effective for a period of twenty years.

2 This fund may be integrated or separated from already established funds and will have the fiduciary character of escrow.

To encourage timeliness in reaching agreement about the royalty percentage, and only in the case where Parties prolong the negotiations, the percentage will be imposed in a random fashion, between upper and lower limits that are determined by the SBSTTA.

The Parties will review the royalty every five years since its establishment by the COP and can adjust it in conformity with technical and economic considerations that may have arisen.

Article 20.- To avoid stacking of royalties when a good or service has utilized multiple ensembles of natural information, the Ratified Parties will determine a ceiling of summed royalties to be paid, where the countries of origin receive royalty income according to the royalty percentage weighted by the number of distinct ensembles of natural information incorporated in said good or service, as is the case.[4]

Article 21.- The holder of an intellectual-property right will classify his good or service according to the categories established by the COP for determining which royalty is applicable for the value added to the natural information, upon having duly notified and informed the ABS Clearing-house Mechanism of the commercialization.

In the case of imprecise or erroneous classification and any resultant underpayment of royalties, the SBSTTA will calculate a compensatory amount that includes penalties and in the case of overpayment of royalties, a credit with interest.

Article 22. Natural information utilized in goods or services which are not protected by intellectual property right and lie in the public domain, are not subject to the principles and objectives of this multilateral system, inasmuch as they have not solicited nor obtained intellectual property rights.

Section 7. On the fund for sharing the benefits from the utilization of natural information

Article 23. The Ratified Parties will establish an International Fund of Sharing and Distribution of the Benefits Derived from the Utilization of Natural Information.

Article 24.- The International Fund will be constituted as an escrow, either integrated or annexed to already existing international funds to distribute the monetary benefits in accordance with that established by the technical mechanism for the determination of the distribution of natural information.

Article 25. *Ex situ* collections will participate as a group in the sharing of benefits arising from utilization of accessions. The group will consist of those collections for which the accession pre-dates ratification of the CBD and contain the natural information utilized. The technical mechanism will weigh the group as equivalent to the geographic area sufficient for one "minimum viable population".

Supplementary provisions

First.- The technical mechanism for the determination of the distribution of the natural information will be selected from among scientific international institutions of recognized standing. The mechanism will function with more than one institution to determine the distribution in accordance to specialization and strengths.

4 For example, assume that the COP defines a royalty for patents in a sector at 15%; imagine the case of a product which utilizes 5 distinct ensembles of natural information; each ensemble will receive 3% royalty which sums to 15%, thereby avoiding a stacking which would result in a 75% royalty.

Appendix VII

Data for Submission of Views on DSI

Gabriel J. Armador-Cruz

The data were collected from Google-Scholar Search of References in literature on "digital sequence information" conducted 30 October 2019 and from the 2019-2020 inter-sessional period "Submissions of views and information on digital sequence information on genetic resources", https://www.cbd.int/dsi-gr/2019-2020/submissions/

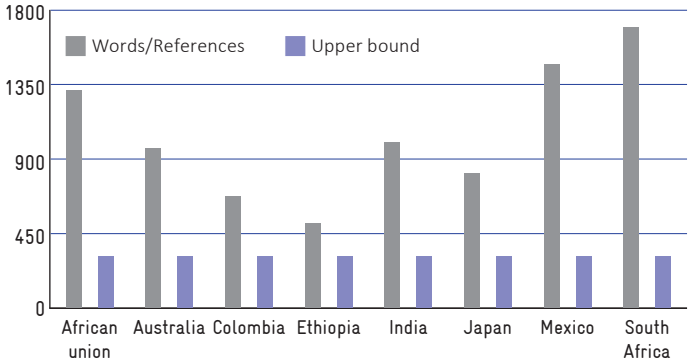
Google scholar page	Number of hits per page	Sample from Published Literature	Words	References	Words/References	$(X_i-\mu)^2$
1	10	4	8396	49	171.3	4604.1
2	10	6	6548	48	136.4	10564.6
3	9	7	839	5	167.8	5098.1
4	9	10	5969	21	284.2	2028.4
5	10	12	9859	95	103.8	18339.1
6	10	13	24879	53	469.4	52998.7
7	10	14	36805	243	151.5	7698.3
8	10	16	965	1	965.0	526784.6
9	9	20	2676	22	121.6	13821.4
10	10	28	6649	45	147.8	8362.2
11	10	33	3361	8	420.1	32733.6
12	10	43	5441	30	181.4	3344.8
13	9	52	5872	46	127.7	12443.1
14	10	62	15936	195	81.7	24799.2
15	10	64	2313	6	385.5	21403.5
16	10	66	6273	8	784.1	296942.5
17	10	71	4803	13	369.5	16967.9
18	10	77	3279	10	327.9	7867.6

Google scholar page	Number of hits per page	Sample from Published Literature	Words	References	Words/References	$(X_i-\mu)^2$
19	10	80	7549	35	215.7	553.0
	186	91	12230	97	126.1	12795.7
		105	8277	55	150.5	7869.4
		118	7274	48	151.5	7684.1
		121	2583	13	198.7	1640.9
		153	1655	6	275.8	1341.9
		165	13973	163	85.7	23555.1
		169	3787	19	199.3	1590.8
		172	29188	281	103.9	18313.9
		177	4563	38	120.1	14190.0
		178	11808	181	65.2	30263.2
		179	30281	349	86.8	23236.6

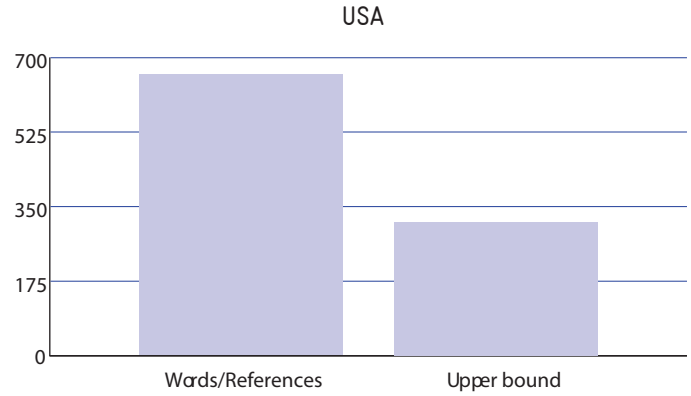
Average	239.2
S^2	41718.5
S	204.3
95% Confidence Interval	239.2 ± 73.1
	(166.1,312.3)

Parties	Words	References	Words/ Reference	Is it inside the 95% Confidence Interval? (Yes or No)	Upper bound
African Union	3942	3	1314	No	312.3
Argentina	1005	3	335	No	312.3
Australia	962	0	962	No	312.3
Belarus	840	0	840	No	312.3
Brazil	5128	10	512.8	No	312.3
Canada	3335	2	1667.5	No	312.3
Colombia	674	0	674	No	312.3
Costa Rica	1451	0	1451	No	312.3
Ethiopia	511	0	511	No	312.3
European Union	1332	0	1332	No	312.3
India	997	0	997	No	312.3
Iran	389	0	389	No	312.3
Japan	814	0	814	No	312.3
Madagascar	207	0	207	No	312.3
Mexico	1471	0	1471	No	312.3
Republic of Korea	465	0	465	No	312.3
South Africa	1695	0	1695	No	312.3
Switzerland	1356	0	1356	No	312.3

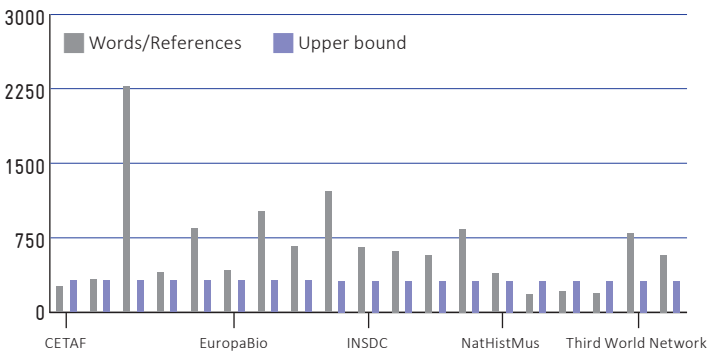
Words/References of Parties



non-Parties	Words	References	Words/ Reference	Is it inside the 95% confidence interval? (Yes or No)	Upper bound
USA	657	0	657	No	312.3



Words/References of Organizations and Stakeholders



Organizations and Stakeholders	Words	References	Words/ Reference	Within 95% confidence interval? (Yes or No)	Upper bound
CETAF	2868	11	260.7	Yes	312.3
DNFS	3300	10	330	No	312.3
CIPA	2271	0	2271	No	312.3
EcoHealth	394	0	394	No	312.3
EuropaBio	837	0	837	No	312.3
Ibol	1245	3	415	No	312.3
ICC	2020	2	1010	No	312.3
IFRA-IOFI	659	0	659	No	312.3
INSDC	1216	0	1216	No	312.3
JBA	1975	3	658.3	No	312.3
Joint Stakeholder Statement	1855	3	618.3	No	312.3
LERU	1163	2	581.5	No	312.3
NatHistMus	840	0	840	No	312.3
NHM-RGBK-RBGE	3128	8	391	No	312.3
ITPGRFA	1132	6	188.7	Yes	312.3
SPNHC	3072	14	219.4	Yes	312.3
Third World Network	2987	15	199.1	Yes	312.3
BIA	3192	4	798	No	312.3
Wellcome Sanger Institute	2903	5	580.6	No	312.3

Appendix VIII

Filmography

Carolina Sofía Menéndez-Reyes

Scarcity of time is a universal truth. Readers appreciate that scarcity whenever they tackle unfamiliar and difficult subjects. A well executed clip can facilitate understanding. Film can also compress a tremendous amount of information into just a few minutes. Through the Pause button, the viewer can stop and reflect; through the Rewind, repeat and reflect further. Although the temptation may be to substitute the film for the text, the most efficient use of film is as a complement to the text. Below are clips selected for their capacity to engage the viewer effectively. May the links endure.

Section	Fragment from the Report	Title of Clip	URL
2.1	[T]he **economic rents**, which is the compensation beyond what would be paid in a perfectly competitive market.	Explaining Economic Rent	https://www.youtube.com/watch?v=2yEC0ncStuM
2.3	The problem of fungibility is highly abstract but no less real. A mundane example would be a subsidy for street arborization when the recipient municipalities already plant trees. The money granted is fungible.	Fungibility	https://www.investopedia.com/terms/f/fungibility.asp
	[T]he criterion of **fairness and equity** in the CBD and Nagoya Protocol	Nagoya Protocol and ABS – Simply explained / Swedish EPA / (ABS Capacity Development Initiative)	https://www.youtube.com/watch?v=Bs45B30qmds
		THE NAGOYA PROTOCOL (UICN – ORMACC)	https://www.youtube.com/watch?v=lltjhz6iyoA
2.4	A **deadweight loss** for consumers, also called **excess burden**, is the value forgone for would-be Users of DSI who desist to use when a subscription fee is charged (see Box 3).	Whats Is Deadweight Loss?	https://www.youtube.com/watch?v=-mEn9zxQ0Q0

5.1	[W]hat is the value-in-exchange of the end-product However, that statistic does not capture the value in use. The paradox identified by Adam Smith...	La paradoja del valor Although the title appears in Spanish, the video is narrated in English.	https://www.youtube.com/watch?v=e7S8jWh6AEs
	Economics can make sense of how the alternative modalities impact utilization. To measure impacts, one must first measure the value of the utilization.	What is VALUE-IN-USE? What does VALUE-IN-USE mean? VALUE-IN-USE meaning, definition & explanation	https://www.youtube.com/watch?v=QLddaZfKcec
	Rather than grapple with consumer surplus, economists quantify a more tractable value, which is nonetheless challenging: the positive external effects of life extension. They call it social value.	Econ 120: Two-Minute Economic Lessons (Value)	https://www.youtube.com/watch?v=gYDbLCTHFxM
	Inelasticity means that the quantity demanded adjusts little when prices rise.	What is Elasticity?	https://www.youtube.com/watch?v=d5ayUVV_gKQ
	The abandonment of the patent allows the viewer to shift angles and expose another sweeping vista. In the abandonment, the applicants did not commit the fallacy of **sunk costs**, i.e. they accepted the loss.	The Sunk Cost Fallacy: What is it and why does it happen?	https://www.youtube.com/watch?v=AFPgxIJHxsE
	Price-discrimination seems like the obvious solution. However, different prices for different Users open the doors to arbitrage and leakage, i.e. piracy.	Price discrimination	https://www.youtube.com/watch?v=IZ1iAYhQnwg
5.2.4	The letters represent the order of extinction drivers: H (habitat loss), I (invasive species), P (pollution), P (human population growth) and O (over-harvesting).	E.O. Wilson & Elizabeth Kolbert	https://www.youtube.com/watch?v=GIlvstjsp8I

5.3.1	The potential royalty income, therefore, depends on the elasticity of demand for the genetic resources as inputs for production. Price elasticity of the final product reflects market conditions as well as the quantity currently traded.	Taxes on Producers-Micro Topic 2.8	https://www.youtube.com/watch?v=9gwTH4Yme8I
5.3.2	[P]rofitability of Big Pharma is determined not in the "market" but in the political arena, where compulsory licensing is a worst-case scenario, second only to a scrapping of the entire patent system.	Alexandria Ocasio-Cortez Stands Up to Big Pharma | NowThis	https://www.youtube.com/watch?v=HIQk5B0il-A
	Expenditures on pharmaceuticals per capita vary from country to country and nowhere are the differences greater than between the USA and the non-OECD countries.	The real reason American health care is so expensive	https://www.youtube.com/watch?v=tNla9nyRMmQ
		Why drugs cost more in America	https://www.youtube.com/watch?v=v7xmkzVU29Q
5.4	The public-good nature of the absence of communicable disease justifies that diagnostics and vaccines be free of charge to the populace, regardless of the economic status of the country.	A Global Vaccine?	https://www.nytimes.com/video/opinion/100000007359483/covax-vaccine-facility-america.html?playlistId=video/opinion
Appendix I	The Naked Mole-Rat (*Heterocephalus glaber*)	True Facts about the Naked Mole-Rat	https://www.youtube.com/watch?v=eHi9FvUPSdQ
Appendix II	Snails of the *Genus Conus*	Baldomero "Toto" Olivera (U. Utah, HHMI): Venomous Cone Snails	https://www.youtube.com/watch?v=L0OiS0a5KFc
Appendix III	Sea Sponge (*Tectitethya crypta*)	Sponges!	https://www.youtube.com/watch?v=m8a0oNsDEx8
Appendix IV	Ebola virus (*Filoviridae*)	Lessons Learned in Sierra Leone: 2014-2016 West Africa Ebola Outbreak	https://www.youtube.com/watch?v=fHnw9W_GdaM

Appendix IX

Lexicon

The fallacy of equivocation is the use of distinct meanings for the same word in an argument. We offer a lexicon to help the reader avoid equivocation. The entries are drawn from biology, economics, law and psychology. For definitions of terms not listed, we defer to the definition of the online *Oxford Learner's Dictionary*. Also included are generally understood terms when they hold special nuance for ABS. Given that the analysis of this report is primarily economic, we draw heavily from two canonical textbooks: the glossaries of *ECONOMICS*, 18th ed. by Paul A. Samuelson and William D. Nordhaus, hereafter, abbreviated (S&N) and *Public Finance*, 3rd ed. by Harvey S. Rosen (HSR). When an economic term appears in one of the textbooks but not in its respective glossary, we include the page number of its appearance after an the initials of the author(s). Sources of other terms may be found in references. Unattributed terms are based on our interpretation of the respective literatures.

Adverse Selection: "A type of market failure in which those people with the highest risk are most likely to buy the insurance. More broadly, adverse selection encompasses situations in which sellers and buyers have different information about a product, such as in the market for used cars" (S&N).

Artificial Information: Any human-made distinction, non-uniformity or difference that is intentional.

Bilateral approach to ABS: One provider negotiates with one user what will be the terms and conditions of the agreement or contract. *See also* **Multilateral approach**.

Bounded openness: "Legal enclosures which default to, yet depart, from *res nullius* to the extent the departures enhance efficiency and equity, which must be balanced when in conflict" (Peruvian Society of Environmental Law / SPDA, 2016).

Cognitive dissonance: Distortion in perceptions to relieve discomfort. With respect to the value of utilization of genetic resources, Providers and Users ignore modalities that would address the distribution of mathematical expectations (probability multiplied by the value of the event). Users may confuse the low probability of an event as if the expectation were also low; Providers may confuse the high value of an event as if the expectation were also high.

Consumer surplus: "The amount by which consumers' willingness to pay for a commodity exceed the price they actually pay" (HSR).

Deadweight loss: *See* **Excess burden**.

Digital Sequence Information: A highly controversial and widely rejected placeholder, which emerged at COP13 in response to denunciations of "digital biopiracy". Mindful of the placeholder status and well grounded objections to its usage, no definition is herein provided.

Economics: Common to the many definitions is "resource allocation". The three objectives of the CBD and the very title of the Nagoya Protocol lend themselves to the abstract reasoning associated with the discipline.

Economics of information: "Analysis of economic situations that involve information as a commodity. Because information is costly to produce but cheap to reproduce, market failures are common in markets for information goods and services as invention, publishing and software" (S&N). Classification of "genetic resources" as natural information triggers application of the economics of information.

Economic rents: Payment in excess of the price that would obtain if markets were perfectly competitive. *See* **Price-equals-marginal cost**.

Efficiency: "Absence of waste, or the use of economic resources that produces the maximum level of satisfaction possible with the given inputs and technology" (S&N). The non-discussion of efficiency in the COP may reflect the principal-agent problem.

Elasticity: "A term widely used in economics to denote the responsiveness of one variable to changes in another. Thus, the elasticity of X with respect to Y means that the percentage change in X for every 1 percent change in Y" (S&N).

Excess burden: "A loss of welfare above and beyond taxes collected. Also called welfare cost or deadweight loss" (HSR).

Externality: "An activity of one entity affects the welfare of another entity in a way that is outside the market" (HSR).

Fair and equitable: Equal treatment of economic rents, be they for artificial or natural information.

Fixed cost: "The cost a firm would incur even if its output for the period in question were zero". See also variable costs (S&N).

Free goods: "Those goods that are not economic goods. Like air or seawater, they exist in such large quantities that they need not be rationed out among those wishing to use them" (S&N).

Free riding: "[The] incentive to let other people pay while you enjoy the benefit" (HSR, p. 75).

Fungibility: "Fungibility is a central notion in economics, though often unnoticed and unnamed. It means merely 'substitutable' and is in origin a Latin legal term meaning 'such that any unit is substitutable for another' (from fungor meaning 'do, discharge').
"A debt can be discharged with any money, not merely moneys from a particular account" (italics added, abstract, McCloskey).

Government failure: Because industries successfully shift costs to third parties, markets fail to allocate resources optimally. Intervention is justified. However, the State often does not intervene effectively. The solution to government failure includes election of better administrations, independence of the technocracy from politics or privatization.

Labor theory of value: "The view often associated with Karl Marx, that every commodity should be valued solely according to the quantify of labor required for its production" (S&N).

Marginal cost: "The incremental cost of producing one more unit of output" (HSR) *See* also **fixed cost** and **variable costs**.

Multilateral approach to ABS: Providers and Users negotiate the terms and conditions that will govern any utilization (see Bilateral approach).

Mutually agreed terms (MAT): "[A]n agreement reached between the provider of genetic resources and a user with respect to the conditions of access to genetic resources in the provider country and the benefits to be shared between both parties, further to the commercial or other use of these resources" (UN CBD Secretariat). Under bilateralism, Providers lack agency to extract **economic rents**. *See*, **Fair and equitable**.

Natural Information (abiotic): Complement of "Natural Information (biotic)" with respect to that which is not living and was never alive.

Natural Information (biotic): Any unintentional distinction, non-uniformity or difference extracted from matter that is living or was once alive.

Nested dominance hierarchies: "Societies…are partitioned into units [and] can exhibit dominance both within and between the components...Team play and competition between human tribes, businesses, and institutions are also based upon nested hierarchies, sometimes tightly organized through several more or less autonomous levels…" (Wilson 1975, p. 287). Thirty-seven years after publishing those words, Wilson would double down: "In its power and universality, the tendency to form groups and then favor in-group members has the earmarks of instinct" (Wilson 2012, p. 59).

Opportunity costs: "The value of the next-best use (or opportunity) for an economic good, or the value of the sacrificed alternative"(S&N). Habitat loss has long been identified as the leading cause of terrestrial species extinction. The opportunity costs of conservation are a myriad of land uses.

Principal-agent problem: "In a situation where one person (the principal) wants another person (the agent) to perform a task, the principal may find it difficult to monitor the agent's behavior. The principal-agent problem is to design the agent's incentives so that the principal's expected gain is as high as possible" (HSR).

Price-equals-marginal-cost: The rule derives from the marginalist revolution of the 1860s, associated with Stanley Jevons, Leon Walras and Alfred Marshall. In competitive markets, price is driven down to marginal cost of production, which approaches zero for information goods. *See also* **economics of information**.

Price discrimination: "A situation where the same product is sold to different consumers for different prices" (S&N). For intellectual property, the practice is legal and economically justifiable. One price world-wide would be higher than current prices in low-income countries, thereby incurring huge losses of **consumer surplus** and provoking compulsory licensing in pharmaceuticals.

Prior informed consent: "[P]ermission given by the competent national authority of a provider country to a user prior to accessing genetic resources, in line with an

appropriate national legal and institutional framework" (UN CBD Secretariat). Like **Mutually agreed terms** (*see* above), a contradiction exists in the assumption of agency. Under bilateralism, justifiable rents have already been eliminated.

Public Good: "A good which is not rival in consumption; the fact that one person benefits from this good does not prevent another person from doing the same simultaneously" (HSR).

Race-to-the-bottom: A metaphor for fierce competition among Providers, where the bottom is the price paid for genetic resources expressed as a royalty percentage. Because the cost of physically accessing genetic resources may be as low as filling a zip-lock bag with scooped-up soil or gathering a few kilos of dry leaves, the price of genetic resources is largely the transaction costs of MTAs/BSAs.

Ramsey Rule: "To minimize total excess burden, tax rates should be set so that the percentage reduction in the quantity demanded of each commodity induced by the taxes is the same" (HSR).

Rents (economic): The difference between the price paid and that which would have paid in a competitive market in the long run.

Sovereignty: The supreme authority that resides in the people as represented by the State. As a result, the State has certain rights over genetic resources under its jurisdiction and in representation of the people. Contrary to pronouncements from Users and Providers, a Global Multilateral Benefit-Sharing Mechanism is unambiguously an expression of sovereignty.

Stare decisis: Latin for "stand by that which is decided", which obligates courts to follow historical cases when making a ruling on a similar case, often reasoning analogically.

Sunk costs: The situation where future marginal costs exceed future benefits. The rational choice is to abandon the decision previously made. However, **cognitive dissonance** kicks in. People do not lightly abandon costly decisions. Neither do ants. E.O. Wilson observes *"the more elaborate and expensive the nest is in energy and time, the greater the fierceness of the ants that defend it"* (italics in original) (Wilson 2012, p. 130).

Synthetic biology: No generally accepted definition exists. "The COP… acknowledged that the outcome of the work of the AHTEG on the operational definition is 'synthetic biology is a further development and new dimension of modern biotechnology that combines science, technology and engineering to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems'" (UNSCBD Secretariat).

Taboo: Proclivities to assimilate prohibitions remain in modern society, protestations to the contrary notwithstanding. Garrett Hardin's observes: "An element of behavior that is transferred from one culture to another is likely to suffer a sea change. So, it has been with taboo. Pacific islanders apparently have no hesitancy in explicitly giving taboo as a reason for stopping a discussion. By contrast, Westerners with their cherished tradition of free speech and open discussion, would be embarrassed to say (for instance), 'We will not discuss population because it is under a taboo.' Instead they change the subject" (p. 4).

Theory of Second Best: "In the presence of existing distortions, policies that in isolation would increase efficiency can decrease it, and vice versa" (HSR).

Transaction costs: "The costs that arise beyond the point of production of a good to effect its allocation" (Marneffe). In the context of ABS, think lawyers. MTAs will never be sufficiently standardized to eliminate the need for counsel.

Variable cost: "A cost that varies with the level of output". *See also* **fixed costs** (S&N).

Value in exchange: The price paid for a good or service.

Value in use: Two distinct meanings of the term appear in the economic literature. The meaning for this Report refers to the utility derived from consumption of a good and service, and not to the present net worth of an asset. To complicate matters even more, value in use should not be confused with use value of biodiversity, which is measured by the values-in-exchange in consumption and production.

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