Patents

https://doi.org/10.1038/s41587-023-01966-7

Are ecological processes that select beneficial traits in agricultural microbes nature's intellectual property rights?

Check for updates

Novel beneficial traits in agricultural microbes represent inventive steps of nature, but the inability of patent laws to reward nonhuman inventors has led to conflicts over microbial ownership rights and presents barriers to the sharing of benefits.

The human population is expected to reach 10 billion by 2050. Increasing agricultural production and reducing food waste are therefore critical for global food security[1]. New biotechnological innovations, protected by patents, are being used in agriculture to increase global food production. Increasing penetration of patent claims in agriculture has meant that resources such as seed and germplasm that were earlier perceived to be part of the common heritage have been subject to exclusion and privatization[2,3].

Of particular concern is the understudied but growing impact of patents over agricultural microorganisms[4]. These are microorganisms that are beneficial to crop plants and include *Rhizobium*, *Frankia*, mycorrhizal fungi and a range of plant-growth-promoting microorganisms that form symbiotic interactions with crop plants.

The first patent on a living organism was issued by the US Patent Office in 1873 to Louis Pasteur for a purified form of yeast, but this was an anomaly. Patents protecting life-forms did not become common for another century. This means that debates on the ethics and fairness of patenting life forms[5] are comparatively recent. In the USA, *Diamond v. Chakrabarty*[6] effectively ended the legal uncertainty in 1980 by treating a human-modified microorganism as a 'manufacture' under section 101 of the US Patent Act.

An aseptic microbial culture comprises clonal individuals, and any measurable sample will possess uniform properties and characteristics. Therefore, it is far easier to draw analogies between microorganisms and chemical compounds or other inanimate objects than it is to equate an animal or a plant to an inanimate object[7]. Patent attorneys have exploited the analogy with novel chemical products and manufacture to convince courts to uphold patents on microorganisms and other life forms[6,8]. That microorganisms — as distinguished from chemical compounds — are alive is without legal significance[6].

Unlike the US 'product of nature' doctrine that had been assumed to preclude such patenting, European jurisdictions, generally speaking, saw no specific need to limit the patenting of life forms. It was generally assumed that living things could not be invented. That said, Chakrabarty's bacterium was also patented in the UK without raising any controversy. The agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) did not require that patents be available for all life forms, only that they must be available for microorganisms. Article 27.3 of TRIPS allows member states to safeguard the rights and traditional knowledge of farmers through a *sui generis* protection of plant and animal varieties. But it does not, as mentioned, permit member states to exclude microorganisms from patents. Article 32.2 of EU Directive 98/44/EC identifies any biological material that is isolated from its natural environment or produced through technical methods as a human invention, even though it previously occurred in nature[9].

Here, we propose to redefine the legal narrative that is used to represent microbial resources as commodities in patent laws, including the norms that are used to justify patents. We emphasize the need for patent laws to recognize human symbiosis with ecological processes because this interaction has an important role in the evolution of beneficial agricultural microbial resources.

Microbial patenting

Patents over microbial and indeed living resources have developed around a human-centered utilitarian notion of nature derived almost entirely from Euro-American legal jurisprudence[10–12]. Patents over living resources used in agriculture are implied to contribute to the overall good of the agricultural community by serving as incentives for increased involvement of science and technology in agriculture. Yet the history of patents in information and communication technology has shown that patent entanglements actually serve as barriers to newer innovation[13]. Downstream rights claimed by the Oncomouse gene patent have shown that such complexities can exist even in biotechnology[14]. During the COVID-19 pandemic, patent restrictions delayed global access to vaccines and drugs[15,16]. A search on the Espacenet[17] worldwide database (subclass C12N) reveals that 256,945 patents relating to microorganisms (bacteria, fungi and viruses) were published between 2012 and 2022. The sheer scale of patent applications is likely to result in complications in the downstream application of patented microorganisms.

This has implications in agriculture, as microbial resources can make important contributions to crop productivity. Advances in knowledge about the ecological position of

microorganisms have led to increasing recognition of their potential as cost-saving inputs to sustainable agriculture[4]. Rhizobacteria and fungi have important functional roles in nutrient cycling and plant growth promotion. Microbial allelopathic impacts on other organisms have potential biocontrol applications[18]. Savings from the use of arbuscular mycorrhizal fungi, in terms of costs incurred for phosphate fertilization required to sustain similar levels of plant productivity, have been estimated at US$549 billion per year. Likewise, substitution of nitrogen fertilizers with rhizobial species has led to savings of up to US$1.7 billion[19]. Significant economic benefits from microorganisms, microbial genetic resources and products of microbial origin have made microorganisms attractive targets for patent applications[4]. Increasing enforcement of patents by private individuals, institutions, corporations and states can increase the barriers to accessing biological resources[20] for research and in agricultural practices. Patents on agricultural microbial resources could lead to a tragedy of the anti-commons[21] in scientific innovation as well as traditional farming. Farmers in countries that are less able to afford royalty costs of patented microorganisms are likely to lose out on the benefits.

Microbial scientists have tried to resist increasing restrictions imposed through patents and state legislation by advocating for a commons regime to allow more equitable access to microbial resources[4,22]. However, a commons regime only shifts 'ownership' from private to community and may still ignore the claims of farmers to access and use. It fails to offer level playing fields between financially and informationally strong corporations and disadvantaged Indigenous and other globally disempowered groups[23]. Moreover, a commons regime is still part of a wider anthropocentric framing and does not address the ethical questions involved in commodifying living entities of nature.

Existing legal principles for patents on life forms were developed in the 1980s[24]. Patent protection on genes and recombinant DNA that provide the genetic blueprint for synthesized proteins is analogous to patent protection of novel chemical entities. However, DNA sequence discovery has moved beyond cloning of short sections of genes to high-throughput sequencing of entire genomes, and its results are more closely analogous to new scientific information than a new chemical product[25]. The US Supreme Court has emphasized that the informational content of a genetic sequence has primacy over DNA's character as a molecular structure[26,27]. This decision does not have a clear counterpart in the European Patent Convention (EPC). Many of the arguments put forward in the *Myriad* case[26] were brought before the European Patent Office (EPO) to oppose a patent granted to the Howard Florey Institute for the human H2-relaxin gene[8]. The EPO, however, upheld the patent, citing provisions of the EPC and EU Directive 98/44/EC[28]. Regardless, unravelling a whole genome sequence provides valuable information that opens doors for future discoveries[25]. This information is an outcome of billions of years of evolution driven by natural selection.

The tension resulting from this information–structure duality, while raising questions about the ethics of patents on living resources, also brings up the issue of whether patent laws are up to speed with current understandings of ecological function, developments in social sciences and the accommodation of legal thought and situated knowledges from Indigenous cultures and the Global South. This is particularly pertinent in the matter of patents on microbial resources because patent laws view isolated microorganisms as human inventions and not living constituents of nature.

Human–nature partnership in the evolution of beneficial agricultural microbial resources

Mutualisms are key biological interactions that are at the heart of the exploitation of microbial benefits in agriculture. The evolution of beneficial mutualistic microorganisms in agricultural soils is influenced by crop-induced selection. Crops select beneficial rhizospheric microbes based on the 'goods and services' that they provide. In biological terms, 'goods and services' refers to benefits in terms of nutrient uptake, protection against pathogens, drought and salinity tolerance, and so on. Plants must balance the benefits from mutualistic microorganisms with their costs in terms of photosynthetic carbon allocation incurred to sustain the mutualistic microbe[29]. Therefore, factors such as rhizospheric availability of nutrients, competition from other plants, threats from pathogenic pests, water availability and others determine plants' requirement for a mutualistic interaction with a rhizospheric microbe. This plant-determined selection plays a key part in the evolution of rhizospheric mutualistic microorganisms[30].

Agricultural practices such as fertilization, irrigation, crop selection and rotation have contributed to the adaptation and domestication of microorganisms and consequently have had a determining role in the evolution of agricultural microbial resources[31]. Farm rhizospheric microorganisms are akin to species bred in captivity that have been suitably modified from their wild ancestors in ways that have made them beneficial to humans who control their reproduction and food supply[32–34]. Farmers therefore make an unconscious, but definitive, contribution through farming practices to driving the selection of beneficial agricultural microbial resources in the rhizosphere[4]. These contributions of ecological processes and farmer practices in the selection of beneficial traits in microorganisms are not recognized as valid claims for intellectual property in the existing patent regime.

Patent laws have lagged in incorporating legal developments concerning constituents of nature

The genome represents an organism's entire set of genes. The genetic code carried on a gene is analogous to language[35,36]. Information contained in the genetic code encodes specific phenotypic traits and is, metaphorically speaking, written by natural selection. Evolution through natural selection selects the information on the genome. Beneficial functional traits that grant economic value to microbial resources are a product of the information in the genetic code contained in the genome. These traits can be novel, have utility and represent an inventive step of ecology[37], the three criteria required to grant a patent. But patent law, premised on the assumption that inventors are human, struggles in dealing with nonhuman inventors[15]. Consequently, ecological processes that lack legal subjectivity in anthropocentric intellectual property rights frameworks are ineligible for patent claims (Fig. 1).

This is because TRIPS has employed a human-versus-nature dichotomy to govern patent laws. This paradigm is no longer defensible and has met with widespread critique from posthumanist theories that have been influenced by, and are in response to, the wider critique of the Anthropocene epoch[38]. Humans have dual roles as economic and ecological actors. As economic actors, they transcend the biological needs of the individual human and extract services from living and non-living constituents of the ecosystem. Simultaneously, humans are themselves part of the ecosystem, and their actions that affect living and non-living entities of nature qualify as natural phenomena[39]. The central flaw of

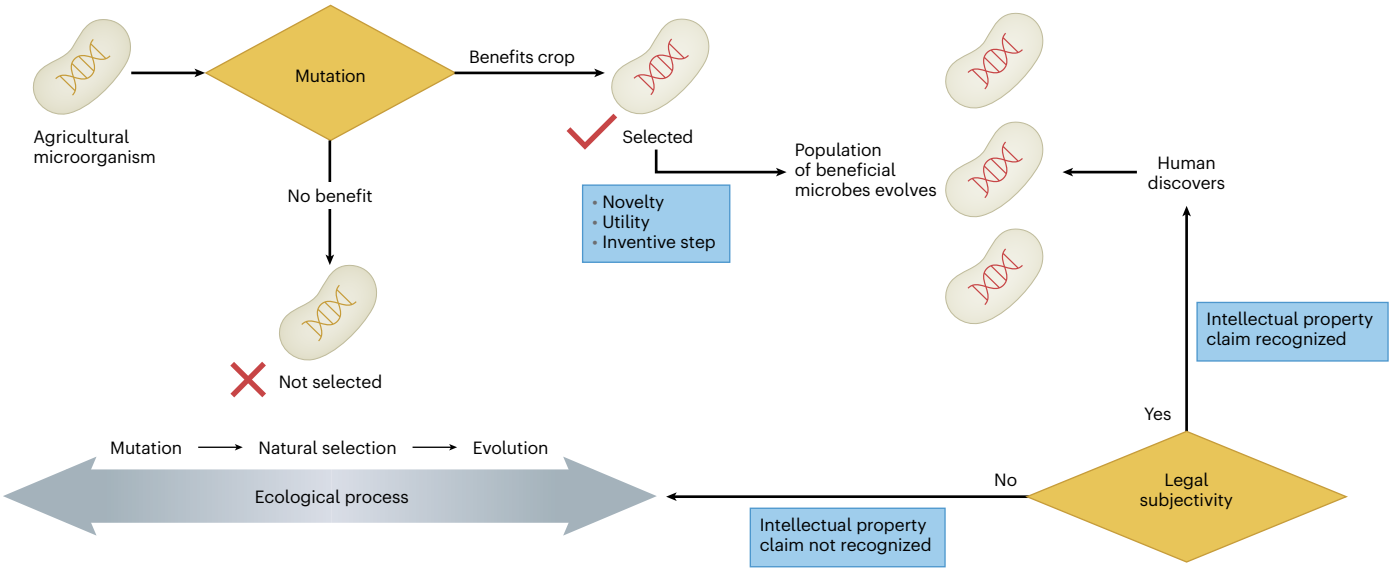

Fig. 1 | Evolution of a beneficial agricultural microorganism is a novel, utilitarian inventive step of nature. But lacking legal subjectivity, ecological processes of nature are not allowed intellectual property claims. A human discovering the same microorganism is, on account of legal subjectivity, allowed to make an intellectual property claim.

this human–nature dichotomy is the failure to recognize that humans are not the exclusive modulating species of the planet. All organisms contribute to workable ecological living places by modulating abiotic and biotic constituents[12,40,41].

Developments in natural sciences and legal debate dismantling human exceptionalism have introduced an ecocentric recognition of nature's rights independent of human interest in international environmental law[12,42–44]. These developments in international environmental law show how patent laws have failed to incorporate legal theories concerning constituents of nature from outside, and even inside, the Euro-American worldview. Western ecocentric posthumanist theories advocate a mutual relationality in which nature and humans are never independent and unaffected by each other but are always in relation[40,45]. This relationality can justify amendments granting legal subjectivity and rights to constituents of nature in intellectual property rights frameworks.

Legal subjectivity to agricultural microbial resources

Language enabled humans to bequeath meaning and cohesion to their physical and social surroundings and to their own place within it[46]. The ability to communicate is pervasive in nature, and microorganisms can perceive and transmit communicative signals[47]. The ability to communicate and make kinship are key criteria through which legal subjectivity is granted to and claimed by humans[46]. But kinship is not limited to the human species. All living tissues are ineluctably connected in a multi-species network, and humans are in a relationship with other species of the ecosystem[40,48].

Indeed, humans are holobionts of symbiotic interactions between bacterial and human cells organized into cellular communities, tissues and functional organs[49,50]. Holobionts are an assemblage of a host and a multitude of other species living in or around it that sustain life-making processes – symbiogenesis – through relational partnerships[51,52]. Agricultural microbes are manifestations of a symbiogenesis involving a holobiont assemblage of the farmer, the crop and rhizospheric microorganisms. Farmer practices such as crop selection and other agricultural practices lay the groundwork for ecological selection of rhizospheric microorganisms. This symbiotic 'kinship' between the farmer and the selected rhizospheric microbe provides a persuasive legal argument – founded on developments in international environmental law concerning the rights of nature's constituents – to grant legal subjectivity with an associated body of rights to agricultural microbes. This would include the right to fulfill their role in ecosystem function[44] and, by extension, the right to claim intellectual property for traits evolved to perform this role.

Precedents exist in which claimed kinship with humans has granted legal subjectivity and rights to constituents of nature[44]. New Zealand granted legal personhood to the Whanganui River by recognizing the river's kinship with the Whanganui Iwi tribe[53]. This trend has been echoed by legislative acts in Bolivia, Ecuador, Australia, Colombia[43,44] and Spain. Indeed, patent laws over agricultural microbes require a restructuring to something more than attributing exclusive ownerships rights. They must evolve as a device that recognizes human–nature relational symbiosis that drives natural selection not for the exclusive profit-making capacities of individuals, but for the benefit of the common good of humans and nature. It is this relationality that merits protection. And even though patents are typically awarded to the inventor[15], patent laws could be amended to distribute the rewards from beneficial traits of agricultural microbes selected by the human–nature partnership differently – perhaps between the local farmers and communities, the inventor discovering the microbe, and for conservation of nature's constituents and processes.

Conclusions

Dismantling the legal edifice of patent laws raised over a period of four decades since *Diamond v. Chakrabarty*[6] may not be a viable

option. However, there is a case to be made for incremental structural changes to patent laws. The transition of agricultural microbes from objects under human legal dominion to subjects with legal rights is an appropriate beginning. Legal theories, and thoughts from Indigenous cultures and the Global South advocating the rights of nature, need to be integrated with advances in microbial ecology, as do the social relations of farmers with soil and its living and non-living constituents, in order for the patent governance regime to recognize the role of ecosystem function and processes in the evolution of beneficial agricultural microorganisms. This can give birth to a new foundational principle for patent laws that will recognize the contribution of ecological processes in the selection of beneficial traits in agricultural microbes as intellectual property of nature. Because humans are a constituent of nature, this will enable a more acceptable as well as equitable access and benefit sharing from microorganisms used in agriculture.

David Kothamasi [1,2] ✉, **Saskia Vermeylen**[1] **& Sharma Deepika**[2,3]

[1]Strathclyde Centre for Environmental Law and Governance, University of Strathclyde, Glasgow, UK. [2]Laboratory of Soil Biology and Microbial Ecology, Department of Environmental Studies, University of Delhi, Delhi, India. [3]Department of Botany, Zakir Husain Delhi College, University of Delhi, New Delhi, India.

✉e-mail: dkothamasi@es.du.ac.in

Published online: 12 October 2023

References

1. Foley, J. A. et al. *Nature* **478**, 337–342 (2011).
2. Overmann, J. & Smith, D. In *Bioprospecting, Topics in Biodiversity and Conservation* (eds. Paterson, R. & Lima, N.) 51–79 (Springer International, 2017).
3. Reichman, J. H. In *Intellectual Property and Development: Understanding the Interfaces* (eds. Correa, C. & Seuba, X.) 295–314 (Springer Nature, 2019).
4. Kothamasi, D., Spurlock, M. & Kiers, E. T. *Nat. Biotechnol.* **29**, 1091–1093 (2011).
5. Soto, M. P. *Rev. Derecho Puertorriq.* **59**, 51–70 (2019).
6. *Diamond v. Chakrabarty* 447 US 303 (1980).
7. *Harvard College v. Canada* (*Commissioner of Patents*), [2002] 4 S.C.R. 45, 2002 SCC 76.
8. Epo.org. EPO – T 0272/95 (Relaxin/Howard Florey Institute) of 23.10.2002, http://www.epo.org/law-practice/case-law-appeals/recent/t950272eu2.html (2002).
9. Srinivas, K. R. *Int. Soc. Sci. J.* **188**, 319–334 (2006).
10. Sullivan, S., Igoe, J. & Büscher, B. *New Proposals J. Marx. Interdiscipl. Inq.* **6**, 15–19 (2013).
11. Fitz-Henry, E. In *Wild Law—In Practice* (eds. Maloney, M. & Burdon, P.) 133–148 (Routledge, London, 2014).
12. Vermeylen, S. In *Environmental Law and Governance for the Anthropocene* (ed. Kotze, L.) 137–162 (Hart Publishing, Oxford, 2017).
13. Wen, W. & Forman, C. *Commun. ACM* **59**, 42–43 (2016).
14. Murray, F. & Stern, S. *Innov. Policy Econ.* **7**, 33–69 (2006).
15. George, A. & Walsh, T. *Nature* **605**, 616–618 (2022).
16. Gold, E. R. *Nat. Biotechnol.* **40**, 1428–1430 (2022).
17. Espacenet. https://worldwide.espacenet.com (accessed 20 July 2022).
18. Deepika, S., Mittal, A. & Kothamasi, D. *J. Basic Microbiol.* **59**, 1229–1237 (2019).
19. Overmann, J. *Syst. Appl. Microbiol.* **38**, 258–265 (2015).
20. Reichman, J. H. In *Designing the Microbial Research Commons: Proceedings of an International Symposium* (ed. Paul, F.) 43–53 (National Academies Press, 2011).
21. Heller, M. A. & Eisenberg, R. S. *Science* **280**, 698–701 (1998).
22. Dedeurwaerdere, T. *Res. Microbiol.* **161**, 414–421 (2010).
23. Chander, A. & Sunder, M. *Calif. Law Rev.* **92**, 1331–1373 (2004).
24. Lemley, M. A. *AIPLA Q. J.* **22**, 369–425 (1994).
25. Eisenberg, R. S. *Am. J. Bioeth.* **2**, 3–11 (2002).
26. *Association of Molecular Pathology v. Myriad Genetics Inc.* 569 US 576 (2007).
27. Dreyfuss, R. C., Nielsen, J. & Nicol, D. *J. Law Biosci.* **5**, 550–589 (2018).
28. Cole, P. *Cold Spring Harb. Perspect. Med.* **5**, a020891 (2014).
29. Van't Padje, A., Werner, G. D. A. & Kiers, E. T. *New Phytol.* **229**, 2933–2944 (2021).
30. Chaparro, J. M., Badri, D. V. & Vivanco, J. M. *ISME J.* **8**, 790–803 (2014).
31. Douglas, G. L. & Klaenhammer, T. R. *Annu. Rev. Food Sci. Technol.* **1**, 397–414 (2010).
32. Diamond, J. *Nature* **418**, 700–707 (2002).
33. Legras, J. L., Merdinoglu, D., Cornuet, J. M. & Karst, F. *Mol. Ecol.* **16**, 2091–2102 (2007).
34. Makarova, K. et al. *Proc. Natl Acad. Sci. USA* **103**, 15611–15616 (2006).
35. Dutfield, G. In *New Frontiers in the Philosophy of Intellectual Property* (ed. Lever, A.) 172–202 (Cambridge Univ. Press, 2012).
36. Barbieri, M. *Naturwissenschaften* **95**, 577–599 (2008).
37. Pottage, A. & Sherman, B. *Figures of Invention: A History of Modern Patent Law* (Oxford Univ. Press, 2010).
38. Biermann, F. *Env. Polit.* **30**, 61–80 (2021).
39. Cepic, M., Bechtold, U. & Wilfing, H. *Ecol. Modell.* **465**, 109854 (2022).
40. Haraway, D. J. *Staying with the Trouble: Making Kin in the Chthulucene* (Duke Univ. Press, 2016).
41. Petersmann, M. *Earth Syst. Govern.* **9**, 1–8 (2021).
42. Emmeneger, S. & Tschentscher, A. *Georgetown Environ. Law Rev* **6**, 545–592 (1994).
43. O'Donnell, E. *Griffith Law Rev.* **29**, 643–668 (2020).
44. Darpö, J. *Can nature get it right? A study on rights of nature in the European context*, https://www.europarl.europa.eu/RegData/etudes/STUD/2021/689328/IPOL_STU(2021)689328_EN.pdf (European Union, 2021).
45. Murris, K. & Bozalek, V. *Int. J. Qual. Stud. Educ.* **32**, 872–886 (2019).
46. Pessers, D. In *Symbolic Legislation Theory and Developments in Biolaw* (eds. van Klink, B. van Beers, B. & Poort, L.) **4**, 201–212 (Springer Nature, 2016).
47. Wingreen, N. S. & Levin, S. A. *PLoS Biol.* **4**, e299 (2006).
48. Grear, A. In *Environmental Law and Governance in the Anthropocene* (ed. Kotze, L.) 77–95 (Hart Publishing, 2017).
49. Postler, T. S. & Ghosh, S. *Cell Metab.* **26**, 110–130 (2017).
50. van de Guchte, M., Blottière, H. M. & Doré, J. *Microbiome* **6**, 81 (2018).
51. Margulis, L. *Symbiotic Planet: A New Look at Evolution* (Basic Books, 1998).
52. Reitschuster, L. In *Critical Zones: The Science and Politics of Landing on Earth* (eds. Latour, B. & Weibel, P.) 350–353 (MIT Press, 2020)
53. Kramm, M. *J. Human Dev. Capabil.* **21**, 307–319 (2020).

Acknowledgements

D.K. received a Marie Skłodowska-Curie Actions Horizon 2020 Individual Fellowship under the project MICROB-COM, grant ID 894188. The authors thank G. Dutfield, E. T. Kiers, A. Cardesa-Salzmann and J. Young for advisory comments on the manuscript drafts.

Author contributions

D.K. and S.V. conceptualized the study. D.K., S.V. and S.D. provided input and concepts. D.K. wrote the first draft. All authors reviewed and made edits on the manuscript.

Competing interests

The authors declare no competing interests.