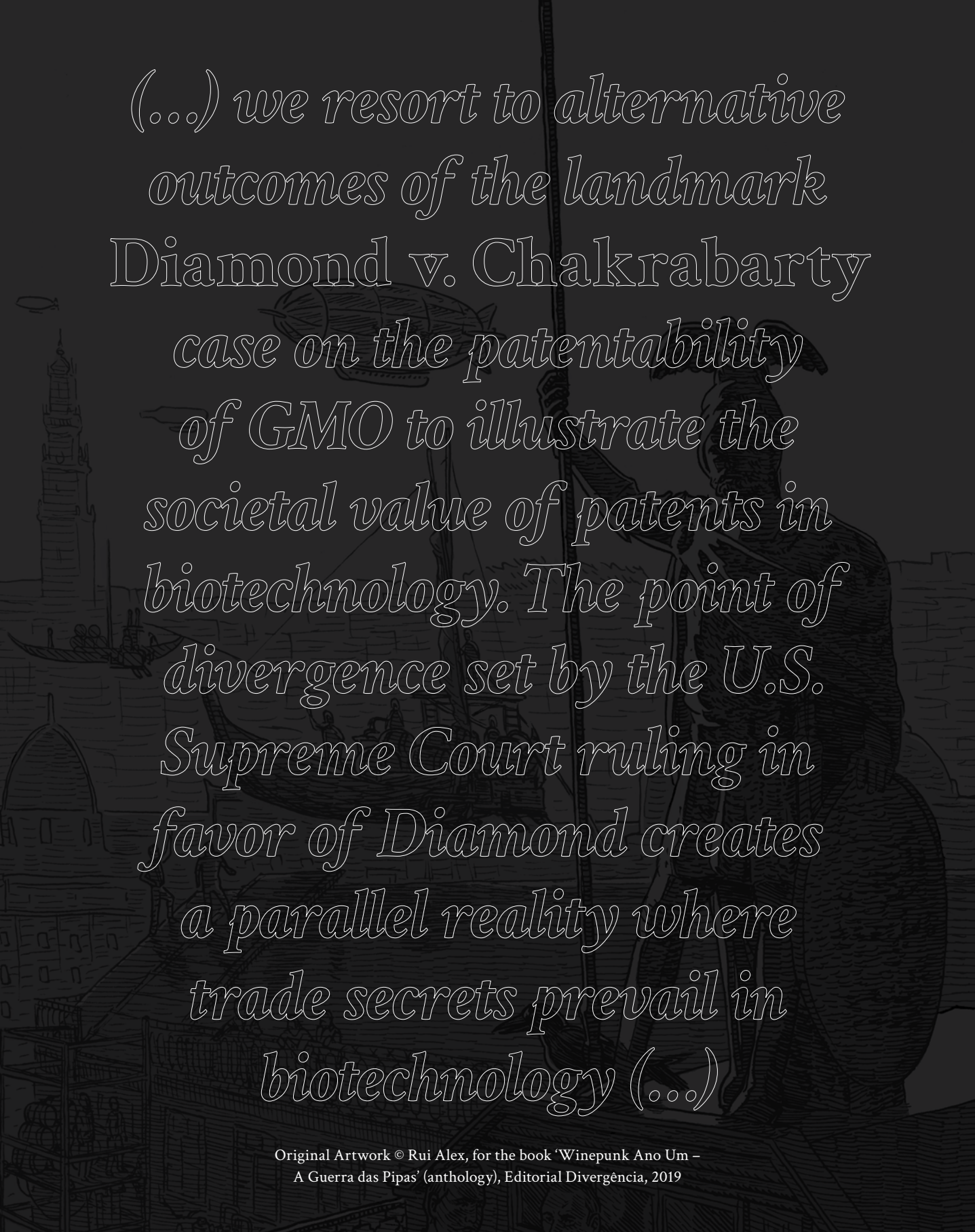

(...) we resort to alternative outcomes of the landmark Diamond v. Chakrabarty *case on the patentability of GMO to illustrate the societal value of patents in biotechnology. The point of divergence set by the U.S. Supreme Court ruling in favor of Diamond creates a parallel reality where trade secrets prevail in biotechnology (...)*

"Diamond wins: life turned trade secret" – alternate history to reflect on industrial property rights in biotechnology

HYPOTHESIS HISTORIA PERIODICAL

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Abstract. As of September 2022, the White House officially embraced biotechnology to generate innovative solutions for health problems, climate change, energy scarcity, and food insecurity. Genetically modified organisms (GMO) alone account for more than 160 000 biotechnological solutions for technical problems. All these solutions have been disclosed to the public as a requirement for obtaining patent rights, excluding third parties of commercial exploitation. In this paper, we resort to alternative outcomes of the landmark *Diamond v. Chakrabarty* case on the patentability of GMO to illustrate the societal value of patents in biotechnology. The point of divergence set by the U.S. Supreme Court ruling in favor of Diamond creates a parallel reality where trade secrets prevail in biotechnology, representing an opportunity to reflect on the instructiveness of patents.

Keywords: Industrial property (IP) rights; Bayh-Dole Act; Cohen-Boyer patent; genetically modified organism (GMO); recombinant DNA (rDNA).

1. Preamble: a new molecular toy called DNA

Studies in genetics leaped forward with the demonstration of DNA as the mediator of hereditary (1952, [1]), the elucidation of its double helix structure (1953, [2]), how it replicates (1958, [3]) and how it translates into molecular effectors, such as enzymes (1961, [4]). Thanks to these advancements, the instructions for the synthesis of proteins can now be precisely tracked down to DNA sequences. From a biotechnological standpoint, great interest resides in the possibility to produce useful peptides and proteins (e.g., insulin, growth hormone, etc.) in surrogate organisms carrying their respective DNA sequences. In the 1970s, breakthrough techniques based on enzymatic "cut-and-paste" of DNA fragments of diverse origins allowed to generate chimeric DNA *in vitro*. Soon after, chimeric DNA could be incorporated into microorganisms, creating life forms that produced non-native proteins. These endeavors in manipulating the genome of living organisms raised ethical and legal concerns. On the ethics side, there were concerns relating to biosafety and biocontainment as well as deep philosophical implications the novel organisms could bring to society. On the legal side, lawyers and politicians struggled to regulate these technologies, being simultaneously permissive enough to research and development and cautious in the face of the unknown. Around and across these central actors, lay people and corporations engaged actively in the discussion considering their moral beliefs or profit expectations, respectively. Here, we hypothesize about what it would have been if a legal event – the 1980 U.S. Supreme Court *Diamond v. Chakrabarty* case – had banned patenting of human-made microorganisms. In this paper, we make the case for the societal value of patents by imagining a society where *Diamond* had won and trade secrets had become the standard strategy to protect property rights on biotechnological inventions.

2. Re-defining biotechnology at the dawn of the recombinant DNA age

In 2005, the Organization for Economic Co-operation and Development (OECD) published a framework to enable the quantification of the economic impacts of biotechnology [5]. For that, the OECD hosted five *"Ad Hoc"* meetings from 2000 to 2004, which came to a *single definition* of biotechnology as "the application of science and technology to living organisms, as well as parts, products, and models thereof, to alter living or non-living materials for the production of knowledge, goods, and services."

The OECD's definition of biotechnology is deliberately broad, and, the actual scientific and technological processes applied to living organisms and their derivatives are not made explicit. However, when OECD experts exemplified techniques involved in biotechnological products, seven out of eight examples included the recombinant DNA (rDNA) technology.

RDNA techniques are those that make possible the generation of chimeric DNA molecules from fragments that otherwise could hardly occur together. The biochemist Paul Berg and colleagues pioneered these techniques in 1972, by demonstrating the insertion of DNA from a gut bacterium into a simian virus [6]. In an unprecedented move, the very scientists who developed this technique helped to convene a gathering with lawyers, journalists, and government officials, known as the Asilomar Conference of 1975, to debate how should these activities be regulated. A set of biosafety recommendations to handle rDNA resulted from the conference which later formed the basis for official guidelines, thereby securing societal approval of DNA modification techniques [7, 8].

In the meantime, by 1974, the University of Stanford and the University of California at San Francisco (UCSF) had applied for a patent on a dependable rDNA technique, developed by their

respective researchers Stanley Cohen and Herbert Boyer. This patent relied on small, autonomously replicating DNA molecules occurring in bacteria as vectors for generating chimeric DNA [9]. Moreover, the inventors claimed a method for producing foreign proteins in bacteria carrying rDNA molecules with the respective instructions. In other words, the inventors intended to exclude third parties from using an organism carrying an rDNA molecule for biotechnological purposes. Soon after the patent application, the abovementioned recommendations that emerged from the Asilomar Conference secured a general endorsement of Cohen-Boyer inventions. However, from a legal point of view, there was an issue hindering the applicants' intentions: a patent on human-made microorganisms had never been granted before. Fortunately for them, Chakrabarty had started walking down that road earlier.

3. Under the spotlight: patenting a bacterium made by a man

A patent (from the Latin, *patere*, "to lay open") is an array of rights and duties that can be granted to inventors of new technical solutions to known problems [10]. In most territories patents can only be granted to technical solutions that are, cumulatively, novel to the state of the art, involve an inventive step (i.e., are not obvious for a person skilled in the art), and have applicability in any field of industry or agriculture. The modern notion of a patent derives from the 15th century when the Venice State decreed the requirement of public disclosure of inventions for those seeking legal protection against infringers. In other words, patents offer the possibility to establish a commercial monopoly based on the disclosed invention, limited to the territory of the granting State, starting from the priority date, and lasting for a limited time frame. At the onset of grand World's Fair, the 1883 Paris Convention for the Protection of Industrial Property established important provisions to try to harmonize patent law overseas [11]. Among these provisions, it stated applicants could seek patents in other Signatory States in equal conditions to nationals and it recognized a right of priority so that applicants for a patent in one State could also apply for protection in any of the other Signatory States within 12 months, claiming the earlier priority date. Other common rules for patenting enacted by Paris Convention were the independent territorial granting (so that patent granting or refusal by one State would not determine the decision of applications in other States), the independence of patenting from the restriction of commercialization (i.e., patents could not be refused on the ground of restrictions or limitations to the sale of patented products or processes), and the compulsory licenses and forfeiture of patents (e.g., in case of unjustified inaction). The Convention also conceded that inventors have the right to be named as such in the patent – note that being a form of industrial property, patents are often owned by inventors' employees. That's why the first patent application on rDNA methods is known as the Cohen-Boyer patent, while UCSF and Stanford were the actual owners. At the time of the Cohen-Boyer patent application, the 1883 Paris Convention for the Protection of Industrial Property was the most widely adopted international patent treaty (77 territories). Importantly, the Patent Cooperation Treaty (PCT) had been concluded in 1970, in Washington, but would only enter into force by the first signatories States in 1978. Under the umbrella of the United Nations agency World Intellectual Property Organization (WIPO), the PCT would put forward standard procedures for patent filling, enabling applicants not only to have their priority right recognized but also to have their application formally approved in all signatory States [12].

As mentioned, the path for having human-made living microorganisms recognized as patentable

subject matter had been started before the Cohen-Boyer patent application. In 1972, the General Electric (GE) company applied for a patent claiming not only a process to generate oil-eating strains of bacteria of the genus *Pseudomonas* but also the bacteria themselves [13]. The inventor, Ananda Mohan Chakrabarty, had been hired by GE to develop a proteaceous cattle feed and, by doing research in his spare time, he ended up developing bacteria that also allowed to clean oil spills [14]. Specifically, the generated bacteria did not contain chimeric DNA molecules but rather resulted from the transfer of a whole DNA molecule from one strain to another. Compelled by the commercial potential of oil-eating bacteria, GE secured a priority date on the invention by filing a patent application on 07/06/1972, before Chakrabarty presented his findings at scientific meetings. Initially, the U.S. Patent and Trademark Office (USPTO) refused to grant a patent on oil-eating bacteria because living organisms were not understood as patentable subject matter. The disagreement between GE and the USPTO would go all the way to the U.S. Supreme Court, ending in the case known as *Diamond v. Chakrabarty* where Sydney A. Diamond was the Federal Commissioner of Patents, Trademarks, and Copyrights, representing the government [15].

The *Diamond v. Chakrabarty* case attracted the attention of the blooming biotechnology industries using the rDNA technology, which sent several *amicus curiae* briefs supporting Chakrabarty's position in Court; there was only one brief supporting the government's position, by the People's Business Commission (PBC) [16]. One pioneering biotechnology firm supporting Chakrabarty was Genentech, a company co-founded by Herbert Boyer. Genentech had a great economic interest in the outcome of the case since its production of insulin, achieved in 1978, was based on patent-pending rDNA technology implemented in bacteria. The briefs of the biotechnology lobby sought to disprove PBC concerns by reassuring the Court that, as seen with the Plant Variety Protection Act, granting patents on microorganisms would not "pollute the planetary gene pool in radical new ways" nor reduce the genetic diversity of life forms (as more productive ones became mainstream). In that regard, the PBC illustrated with the example of drug and chemical companies investing in "patents" (protection certificates) on enhanced seeds and plants, thus effectively narrowing and controlling farmers' choices. The biotechnology lobby maintained the opinion that patents were the best legal instruments to encourage technological innovation because the mandatory disclosure of the details of inventions would allow regulators and competitors to scrutinize and build on patented methods and products. As a veiled threat, the biotechnology lobby considered denying patents on life forms would throw the whole field of rDNA technology into the realm of trade secrets, which would rather conceal the source of new products and prevent further developments.

In a 5-4 decision, the U.S. Supreme Court decided in favor of Chakrabarty having a right to patent his oil-eating bacteria, on June 16, 1980 [16]. The majority opinion, delivered by Chief Justice Warren Burger, pointed out that the patent code was broad enough to cover human-made living organisms as "manufacture" or "compositions of matter". The dissenting opinion, presented by Associate Justice William J. Brennan Jr., remarked that "at times, human ingenuity seems unable to control fully the forces it creates", thus, property rights applied to plant varieties could not simply be extended to other living organisms without new law. Finally, all the judges agreed the Court was without competence to prevent or act on potential abusive practices and extrapolations arising from this decision, while pushing the responsibilities to Congress and the Executive.

The decision of *Diamond v. Chakrabarty* occurred

just before a series of events that occurred in 1980 and would shape the future of biotechnology [17]. As Chakrabarty won, on June 16, human-made microorganisms were considered patentable subject matter. On October 14, Paul Berg was notified he had been awarded the Nobel Prize in Chemistry for his research on rDNA. On the same day, Genentech had a blasting success on its initial public offering on New York Stock Exchange. On October 21, the Stevenson Wydler Technology Innovation Act was signed into law by U.S. President Jimmy Carter, encouraging the promotion and commercialization of government-owned patents, namely those emerging from publicly funded research and national laboratories. On December 2, the Cohen-Boyer patent was granted, six years after the patent application. Finally, on December 15, the Bayh-Dole Act was signed into law by a thwarted, lame-duck president Jimmy Carter (Reagan had won the election), enabling universities and non-profit research institutes to retain ownership and issue exclusive licenses of patents resulting from research supported by federal funds, in an attempt to foster knowledge transfer to the industry.

Overall, by the end of 1980, human-made living microorganisms had made their way from technically possible to ethically endorsed and finally recognized as patentable subject matter. Meantime, the hype around the possibilities of biotechnology, triggered by the spectacular demonstrations of new products, Nobel Prize recognitions, and openness to academia-industry partnerships, led arguably to overlook some loose ends. Asilomar Conference had issued recommendations regarding how rDNA technology should be handled, but little was said about its applications. The U.S. Supreme Court majority granted patents for human-made microorganisms but alerted for the lack of regulations on what should be admissible and for what purposes; moreover, the answer to the unveiled possibility of whether plants or animals created by humans would be patentable was deliberately postponed. But those demands were not sufficient to stop the biotechnology tsunami that had formed. During the 1980s, U.S. civil society did not firmly and formally opposed to patents on human-made organisms: the only mediatic lawsuit on the theme was pursued by the PBC's former member Jeremy Rifkin, resulting on a temporary halt of an open-field experiment with modified bacteria, in 1984 [18]. Soon, the USPTO would grant the first patents on genetically modified plants and animals [19, 20], extending the scope of the *Diamond v. Chakrabarty* decision by considering "non-naturally occurring, non-human, multicellular living organisms, including animals, to be patentable subject matter" [21]. After a patent on transgenic cancer-prone mice was granted to Harvard University [22], the public outcry finally translated to the prosecution of USPTO by the civil society [23]; despite the case was dismissed, it originated an unofficial 5-year moratorium on patenting animals in the United States. Heedless to *Diamond v. Chakrabarty* case until first animal patents drew public attention, the U.S. Congress was unable to timely provide a legal framework for patents on living organisms: several congressional bills have failed likely due to a combination of inertia, an high volume of material to be considered (statements of stakeholders to congressmen), and perhaps, an interest group impasse [24].

Ananda M. Chakrabarty died in 2020, and his oil-eating bacteria were never used. Notwithstanding, Chakrabarty's case legacy was vast: as of 2020, the Espacenet database of patents counted more than 140 000 unique inventions comprehending mutant or genetically engineered microorganisms (including viruses, bacteria, eukaryotic cell lines), plants, or non-human animals. From an economic perspective, in 2020, the U.S. biotechnology market size reached 286.1 million dollars, with a predicted compound annual growth rate of 13.9% until 2030 [25]. Not without criticism, though. In Europe, for

instance, non-governmental organizations fiercely opposed genetically modified (GM) products from early on, blocking the arrival of the first shipments of genetically modified maize and soybean from the United States, in 1996 (cited in [26]). Through effective campaigning, these organizations were able to boycott GM agro-food products in Europe, convincing even retail food chains to ban products derived from animals feed on GM feedstocks [27]. For a legislative point of view, due to ethical concerns, only in 1998, ten years after the original proposal, did the European Parliament approved the directive that harmonizes the legal protection of biotechnological inventions in the European Union member states [28]. Noteworthy, this directive excludes patents on plant and animal varieties, as well as on essentially biological processes for producing them. Notwithstanding present divergences on legal protection of biotechnological inventions across the world, let us go back to the United States and consider for a moment that, in 1980, a door for patents on living organisms was open. In this paper, we resort to an alternative outcome of the landmark *Diamond v. Chakrabarty* case to illustrate the societal value of patents in biotechnology. For that, we re-examine some of the present-day critique to patenting human-made living organisms from a worldview where Diamond had won, and, as suggested by the biotech lobby briefs, all rDNA innovation was thrown at the realm of trade secrets.

4. Private investigations: implications of research on living secrets

Trade secrets are a form of intellectual property defined as information with economic value that is secret and handled under confidentiality terms, both inside and between organizations [29]. Misappropriation of trade secrets is forbidden by law, but the independent discovery of the concealed information is not – unlike patents [30]. As long as no secrecy breach nor independent discovery happens, trade secrets can last indefinitely. Patents exclude independent discovery (novelty is a requirement for patent granting), but their scope, duration, and territorial protection are limited.

Even if Diamond had won and human-made microorganisms were considered non-patentable subject matter, there is no reason to believe that research or emerging business in rDNA would cease. For example, the production of recombinant somatostatin was reported in 1977 by the University of California. The rDNA pioneer biotech Genentech was founded in 1976 and announced the production of recombinant insulin in 1978, while no patents on rDNA were in force. The knowledge of the general rDNA technique used by Genentech was publicly available since 1973 [31]. We shall then focus on what could have happened if the research and commercialization of rDNA-based products and processes had proceeded in the realm of trade secrets. Some examples of possible consequences are given below.

4.1. No access to details on biotechnological products and processes involving human-made organisms

Trade secrets and patents are opposed in terms of disclosure of valuable intangible assets: trade secrets must remain confidential, while patent applications must be made public within 18 months from the priority date (for PCT signatories) [12]. Moreover, granted patents are also published in their final form, which is usually more stringent and refined in comparison to the patent application. In general, patent files include a title, an abstract, relevant background art, and a detailed description of the invention and its claims; altogether, these parts shall suffice for replication of the invention by a person skilled in the art. Nowadays, most

patent offices employ dematerialized publication of new patents through regular bulletins or gazettes (e.g., USPTO Electronic Official Gazette for Patents [32], European Patent Bulletin [33]). Importantly, the most recent files of patent applications and granted patents can also be searched by a multitude of fields, translated, skimmed, and downloaded with ease using search engines such as Google patents (120+ million patent documents) or EPO's Espacenet (140+ million patent documents). The search for relevant background art is facilitated by the use of classifiers, such as the International Patent Classification (IPC) or the Cooperative Patent Classification (CPC), related to the subject of the patent. These classifications are regularly updated to include and specify new subjects. Overall, patent documents comply with the basic principles of FAIR data [34]. They are Findable, using a unique identifier (patent number) and other rich metadata (e.g. inventor, applicant, priority date); Accessible, using free protocols, in open databases, without paywalls; Interoperable, as it uses a shared (legal) language or includes their own glossary, besides including references to other patents, to scientific articles and repositories; and Reusable, since patent text and figures are generally in the public domain (or, at least, free to reproduce *facsimile*, if the holder explicitly claims copyright on patent text or figures [35]).

What if Diamond had won? Imagine a researcher who would like to draft a research plan for a grant application aiming to study methods to produce synthetic fuels from cyanobacteria. In a capitalist economy where patents on living organisms were banned, we easily envision that companies developing methods to produce synthetic fuels (e.g., [36]) would seek to maintain a monopoly of their new biotechnological process, avoiding competition from other companies. Since patents were unavailable, the only industrial rights at disposal were trade secrets. Following that, we can hypothesize that companies would not disclose internal research and development data nor publish scientific papers on industrial processes. In consequence, the researcher would not be able to define comprehensively the state of the art under consideration, since relevant industrial processes would be confidential and not widely available for public scrutiny.

4.2. No access to human-made biological specimens used in biotechnology

The 1977 Budapest Treaty established a mechanism so that applicants for patents could fulfill the requirement of a comprehensive description of the hard-to-describe inventions involving biological materials [37]. Noteworthy, the Budapest Treaty was not intended to define a microorganism (for instance, animal cell lines are admissible) nor to regulate their patentability requirements (i.e., ratification did not imply the patentability of biological material). Instead, it focuses on defining International Depositary Authorities (IDA) recognized by the signatories where patent applicants could deposit and store their biological materials to comply with the public availability of information regarding the inventions. At IDA units, the incoming materials are checked for viability and purity and, if compliant, they are kept stored in stable conditions for at least 30 years. For instance, two particular strains of the bacterium *Bacillus thuringiensis* which are used in a patented process to control corn pests were not only described in the 1991 patent text but also deposited into the U.S. Agricultural Research Service Culture Collection, so they should have been available at least until 2021 [38]. Although patented organisms are not included in standard online catalogs of IDA, they are available for request upon identification of its deposit number, which is mentioned in the patent text, under the conditions defined by the Budapest Treaty. Coincidently, the Budapest Treaty entered

into force in the United States on August 19, 1980, hence about two months after Chakrabarty won his patent case.

What if Diamond had won? Imagine a biotechnology company had developed a genetically modified microorganism suitable for the production of cellulose for dressings (e.g., [39]). In a society where patents on living organisms were banned, we easily envision that such a company would seek to maintain a monopoly of its new biotechnological process, avoiding competition from other companies. Since patents were unavailable, the only industrial rights at disposal were trade secrets. Following that, we can hypothesize that such a company would maintain private collections of microorganisms. If, for instance, the company wished to scale up the production of cellulose through outsourcing, confidential agreement, and material transfer agreements would be put in place, to prevent competitors (and third parties) from obtaining access to the information and the microorganisms themselves. All in all, unless somebody was able to re-invent it independently or the secrecy was breached, biotechnologically important organisms to produce sustainable textiles could be maintained under secrecy forever.

4.3. Three exemplary alternate stories

Let us exemplify what if Diamond had won with three exemplary stories.

4.3.1. Monitoring genetically modified maize in Mexico

Maize is a crop central to Mexico, representing both a cultural heritage and a daily staple food for people. Mexican authorities have imposed strict regulations on crops of genetically modified maize on fears of crossbreeding with traditional cultivars [40]. Genetically modified maize seeds are patented in the United States and many other countries, including Mexico (e.g., glyphosate-resistant maize [41]), and, consequently, the location and sequence of the genetic modifications of these seeds are in the public domain. The fact that such molecular traits are known allows scientists and authorities to track contaminations by genetically modified maize [42]. *If Diamond had won*, probably the genetic traits of such seeds would be protected by trade secret, making it much harder, at least initially, to detect the presence of genetically modified or crossbreed seeds.

4.3.2. Subverting pesticide resistance of genetically modified plants

In general, patented inventions can be used, produced, and sold without limitations after the patent expires (usually, 20 years after the priority date). In many territories, patent law prescribes exceptions to patent infringement for certain uses of inventions before that date. Using patented inventions for private non-commercial purposes, and for research and development purposes are two common exceptions to patent infringement. Following that, do-it-yourself movements and scientists are not bound to ask for permission to apply patented processes or recreate patented products in their everyday activities. *If Diamond had won*, such uses would not be possible: either the processes/products would be concealed, or the holder could refuse to disclose them, or the holder could require strict confidentiality agreements for disclosing them. For instance, without access to details about the manipulations performed on genetically modified seeds, the bio-artistic Critical Art Ensemble would hardly be able to create an installation demonstrating the subversion of pesticide resistance mechanisms embedded in such seeds, as they did [43].

4.3.3. Fostering equitable access to pandemics-related products

March-in rights are provisions present in trade treaties and governmental acts that may suspend monopolies granted by patents in specific circumstances. For instance, the 1980 Bayh-Dole Act reserves the right to federal agencies to grant secondary licenses on patents resulting from federal funding "to alleviate health or safety needs which are not reasonably satisfied by the [primary] licensee" [44], although it never happened so far [45]. In December 2021, the World Health Organization established an Intergovernmental Negotiating Body to draft an instrument on pandemic prevention, preparedness, and response; the "Zero draft" of that instrument was presented in February 2023 [46]. Patents are mentioned twice in this draft: once related to access promoting distributed production and knowledge transfer and once associated with boosting research and development capacities. According to the draft, signatory parties shall increase transparency on information on pandemic-related products, including the provisions to enhance public reporting of relevant patents resulting from public funding; the signatory parties shall also require patent holders of pandemic-related products developed on public funds to waive (at least partially) the royalties of licenses by developing countries manufacturers during pandemics. *If Diamond had won*, these soft march-in provisions on the future instrument of WHO related to pandemics would be meaningless. For instance, vaccines based on genetically modified viral particles would not be patentable, submerging into the trade secret realm. How practical would be to transfer knowledge based on trade secrets and, importantly, regain its control after the pandemic's over, could be debated. We can hypothesize that biotech companies would be (even less) willing to accept their competitors getting waived licenses if they were trade secrets in the first place.

5. Outlook, limitations, and round table contributions

In this paper, we followed the tracks of patent law back to the *Diamond v. Chakrabarty* case, which has set a milestone in biotechnology as an industry. We reviewed the case within the scientific and industrial context to give an overview of the underlying forces and lobbies influencing the outcome of the case. Then, we hypothesize on what could have happened if not Chakrabarty but Diamond had won the case, on the assumption that biotechnology research, development, and innovation would dive into the realm of trade secrets (Table 1). We went on to materialize two consequences of such a model of development of biotechnology, namely the secrecy of the details of products and processes based on human-made living organisms, and the inaccessibility to those genetically modified living specimens. Finally, we exemplified three situations where the knowledge provided by patents on biotechnologies enabled or is expected to allow the monitorization, subversion, or equitable access to its products.

Although our scenarios point mostly to the disadvantages of banning patents on living organisms, we understand the arguments against our position. We briefly mentioned the dissident position expressed in the letter written by PBC and the warnings of the jury of the U.S. Supreme Court for the *Diamond v. Chakrabarty* case on the unintended consequences of allowing unregulated monopolies on living organisms. We can now appreciate those concerns were not without a reason, but, to our understanding, they are less related to patentability than to the deregulation of their commercial use. Problems emerge when companies can monopolize an entire field of technology by gathering a significant portfolio of patents or joining a cartel to form patent pools, jeopardizing industrial competition and contributing to artificial scarcity and overpricing of products [47]. Merging

Table 1. Summary of the reality and a proposed alternative scenario after the 1980 U.S. Supreme Court *Diamond v. Chakrabarty* decision on the patentability of genetically modified organisms.

Court decision and consequences thereafter	**Reality** Chakrabarty wins; first patent on GM[a] bacteria granted	**Alternative scenario** Diamond wins; no patent on GM bacteria granted
Preferred property rights for GM organisms	Patents (prevent rediscovery, grant time- and territory-limited monopoly for commercial use)	Trade secrets (rediscovery admissible; requires confidentiality agreements)
Access to information about GM technologies	From public databases (18th month after priority date)	Private (if no breach happens); under NDA[b], if the owner so wishes
Access to GM specimens	From the respective International Depository Authority	Private (if no breach happens); under MTA[c], if the owner so wishes
Scientific aspects	FAIR[d] patent files allow text and data mining for further R&D[e] on novel technical solutions	Behind-doors knowledge hinder R&D by third parties and blocks GM traceability
Entrepreneurial aspects	Patents leverage valuation of biotechnology companies	Investors less likely to invest in technologies that cannot give a commercial monopoly and that can be reproduced independently elsewhere
Societal aspects	Patents allow for monopolies on basic commodities; licenses can be waived in certain conditions and control regained later.	Hard to make the case for widespread waiving of licenses for trade secrets.

[a] GM – genetically modified [b] NDA – non-disclosure agreement [c] MTA – material transfer agreement; [d] FAIR – findable, accessible, interoperable, and reusable [e] R&D – research and development

of biotechnology companies, such as the case of GM seeds and pesticide company Monsanto and pharmaceutical company Bayer, put in the same hands "the poison and the cure" [48], raising a societal concern about the aims of such endeavors. In the context of international trade agreements, patents are used less as instruments to foster innovation (allowing a return on research and development) and more as a means to penetrate new markets with legal cover [49]. Developing countries, such as India, have faced the worst consequences of this form of technological neocolonialism when monopolistic practices destroyed local economies [50]. India and Brazil reacted by prohibiting the use of genetic use restriction technologies (GURT), through which holders of plant patents could prevent farmers from reusing second generation seeds; seeds bearing GURT (also known as terminator seeds) are currently not in field-testing nor in commercialization anywhere globally, following the recommendation of United Nations Convention on Biological Diversity issued in 2000 and reaffirmed in 2006 [51, 52]. There are further risks of patents becoming a financial bubble rather than a compensation for innovators, as the Director General of the World Intellectual Property Organization is supporting the use of patents as collateral to secure financing for business [53]. In summary, the abusive practices and risky moves on the commercial side of patents deserve a whole

reflection that exceeds the scope of this article.

The discussion at the round table[1] brought up other topics worth reflecting on how society recognizes inventors (specifically academics), whether patents hold a sociopolitical dimension, whether the outcome of the *Diamond v. Chakrabarty* would be different in different epochs or places, and if patents are bound to create inequalities between countries. We believe we addressed some of these issues in the *corpus* of this article, starting with the context of the *Diamond v. Chakrabarty* case that, in our opinion, vested a role of trojan horse for the erupting biotech ecosystem founded around the rDNA technology, in the United States, during the 1970s. About recognition of inventors, we showed that inventors have their right to be named in patents recognized by the Paris Convention, dating back to the XIX century; our personal experience, referred to during the presentation, testimonies that, as *curriculum vitae*, the Academy now acknowledges patents as being similar to scientific articles and, perhaps, even more important, as indicators of the relevance of a given research topic to meet market needs and as a potential source of income from licensing or assignment. Regarding the sociopolitical dimension of patented processes and products, and whether their commercialization brings inequalities, we believe that, as mentioned above, such topics deserve a whole analysis by themselves, out of the scope of this article.

In summary, starting from the *Diamond v. Chakrabarty* case, we aimed to contrast a world of patentable human-made organisms to an alternate society where biotechnological developments proceeded under the terms of trade secrets. From our point of view – as scientists, professors, and technology transfer officers, – the legal protection of patents provides a good opportunity for inventors to have their inventions acknowledged, rewarded, and made commercially available. At the same time, the public disclosure of detailed descriptions and the deposit of biological materials required by the patenting process offers greater transparency and the possibility to build on existing technologies. At least more than trade secrets.

1 Namely the Round Table Session #3 of the Second International Conference of 'What if?...' World History (WhatIf22)

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