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The Gene Editing Business: Rent Extraction in the Biotech Industry

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ABSTRACT

This article analyses the mechanisms governing the extraction, circulation, and distribution of rent in the biotech industry. Building on recent scholarship, it contributes to debates surrounding the importance of rent in technoscientific capitalism. We analyse genome editing as a global labour process. Part One examines the ongoing patent battle over CRISPR-Cas9 as a struggle for control over a foundational biotechnology increasingly central to several industrial sectors: a process of enclosure that facilitates a shift towards monopoly, rent extraction, and financial speculation. Part Two then details how patented CRISPR technologies are valorised through the construction of global, multi-layered infrastructures of rent extraction based on complex webs of financial and licensing deals. Part Three maps the uneven global geographies of CRISPR patenting. It considers how monopoly power emerges through the continuous conversion of public research into private assets, and how this enclosure reinforces profoundly unequal systems of distribution of royalties and rents in the global biopolitical economy. We interrogate how CRISPR technologies cement and expand neocolonial geographies of rent extraction, privatising the economic benefits and socialising the ecological risks. Finally, we argue that an increasingly monopolistic corporate biopower mediates how genome editing technologies are developed, and which mutant ecologies are socially produced.

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1. Introduction

New genome editing techniques such as CRISPR-Cas9 aspire to automate and standardise laboratory practices of genetic modification. They have been promoted as 'revolutionary' means of production; transformational tools poised to revitalise the global economy, reshape the pharmaceutical industry and salvage agribusiness by adapting its living means of production to changing climatic conditions. In the context of a global biopolitical economy increasingly reliant on a technoscientific knowledge of biological processes and new means of manipulating them, CRISPR constitutes a foundational

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technology that can be applied across several economic sectors from agriculture to medicine, pharmaceutics, ecological conservation, and an ever-expanding military-industrial complex.[1] Since its introduction in 2013, CRISPR has been used to induce targeted mutations in a wide variety of living organisms, including: microbes and yeasts, rice and wheat, nematode and silkworms, fruit flies and mosquitoes, beetles and butterflies, zebrafish and salmons, mice and rats, cows and goats, pigs and horses, cats and dogs, monkeys and humans (Cohen 2019; Vidya and Arun 2023). By redesigning the internal metabolism of living organisms employed in production processes, industrial conglomerates increasingly shift the countless biological vectors that constitute the global biosphere (Borg and Policante 2022; Cooper 2008; Helmreich 2008; Rajan 2006).

Individual scientists, public institutions and private companies are currently ensnared in a struggle over the contested ownership and control of this technique of genetic modification. In this article, we situate this global race for CRISPR patents in the context of a historical shift towards a rentier capitalism characterised by accelerating processes of financialisation and assetisation (Christophers 2020). We base our analysis of ongoing processes of assetisation of genome editing technologies — and their valorisation through global architectures of rent-extraction — on the study of a hybrid digital archive composed of: corporate documents; compulsory 10 K filings obtained through the US Security and Exchange Commission; patent records and reports available through the archives of the World Intellectual Property Organization; as well as peer-reviewed scientific articles on molecular biology and mainstream media representations of biotech futurism.

The first part analyses the struggle over CRISPR patents as a struggle for control over an increasingly important means of production. It builds on previous scholarship on financial assetisation (Birch 2017, 2020; Birch and Ward 2022); and highlights the stakes of recounting the history of CRISPR from this specific theoretical perspective. The emerging political economy of genome editing technologies offers a critical window onto the conflictual processes of enclosure through which publicly funded scientific research is converted into privately owned financial assets. We reconstruct the historical trajectory by which mutagenic techniques have been turned into a technoscientific apparatus that enables the transformation of isolated cells and living organisms into patentable 'biological artefacts'; a history rooted in the neoliberal counter-revolution of the 1980s, which continues with the ongoing enclosure of socially produced knowledge and the resulting commercialisation of genetic technoscience. It then maps the CRISPR patent landscape, focusing on the multiple fronts on which opposing corporate conglomerates clash for monopoly power over CRISPR genome-editing technologies — including courts of law, scientific journals, and the historiography of science.

Extending the existing literature on 'technoscience rent' (Birch 2017, 2020), 'rentier capitalism' (Christophers 2021; Demir 2007; Purcell 2017) and 'intellectual monopoly capitalism' (Durand and Milberg 2020; Pagano 2014; Rikap 2021), the second part details how socio-economic architectures of rent extraction are constructed, maintained, and scaled up in the genome editing industry. Taking apart the CRISPR patent pyramid, we identify

[1]In previous works (Borg and Policante 2022, pp. 259–263), we introduced the concept of "biopolitical economy" to indicate "a strategy of accumulation and a mode of government which relies on a technoscientific knowledge of biological processes and new means of manipulating them". The present article continues this critique of biopolitical economy by outlining the shifting contours of the genome editing industry, which plays an increasingly important role in adjusting multiple life processes to serve industrial production and capital accumulation.

three co-constitutive corporate 'strata' mediating the application of genomic technoscience in contemporary neoliberal societies. Patent holders, vassal platform companies, and sublicensing product companies are increasingly entangled in an intricate web of financial investments and licensing deals. We consider these licensing deals as performing a double role in the biotech sector. On the one hand, they enable the extraction, circulation and distribution of rents. On the other hand, they represent highly formalised forward-looking statements that herald future milestone payments and royalty streams upon commercialisation of CRISPR-based services and products. These promissory futures attract speculative investments and support the financial valuation of CRISPR companies even in the absence of substantial profits. Rather than seeing this dynamic as resulting from fraudulent practices, we present this speculation in CRISPR assets as a systematic expression — and paradigmatic example — of technoscientific financialisation.

The third part builds on political-ecological approaches to rent, which emphasise its dual character as a contested social relationship and as a redistributive mechanism (Andreucci et al. 2017). Reflecting on rent as a contested social relation, part three singles out four fundamental threats to the monopoly power of CRISPR companies: rival challenges, patent circumventions, regulatory shifts, and political contestations. It then analyses the juridical and bureaucratic labour mobilised by companies such as Caribou and Editas to entrench their monopoly power and pursue the expanded reproduction of architectures of rent extraction. Reflecting on rent as a redistribution mechanism, we ask what geographies of rent extraction are constructed through the ever-shifting patent constellations that characterise the genome editing industry. First, looking at the politics of funding, we consider how patented genome editing technologies facilitate the conversion of public research on CRISPR systems into private rents. Then, we consider how the unequal geographies of CRISPR patents replicate and reinforce a global infrastructure of rent-extraction that has been channelling IP rents from the world to the US for at least three decades. Finally, we consider the socio-ecological impact of a genome editing technology governed through transnational licensing and sublicensing chains, stacking up rents at each link.

We conclude by questioning the consolidation of a corporate biopower that increasingly mediates the application of genomic technoscience on global ecologies, privatising the economic benefits and socialising the substantial environmental risks of mutagenic practices.

2. Genomic Enclosures and Biotech Assets

The recent introduction of genome editing technologies has transformed how life is imagined, manipulated and exploited for profit. It has stimulated a new understanding of the relation between nature and culture, ontology and technology, society and the self; novel technological fixes to various economic, social and ecological problems; and the promise of an acceleration of agricultural and industrial production on a global scale. CRISPR-Cas9, in particular, has been celebrated as a revolutionary mutagenic technique.[2] By inducing targeted genetic mutations in living organisms, CRISPR has opened

[2]Artificial mutagenesis is a technoscientific practice aimed at inducing DNA mutations in living cells through a variety of laboratory techniques, including X-ray mutagenesis, recombinant DNA and novel methods of genome editing. Early 20th-century practitioners of this discipline used chemical bombardment and nuclear irradiation to accelerate the rate of genetic mutations in living organisms. Since the 1970s, recombinant DNA techniques have enabled the splicing

highly charged expectations for an impending future in which genomic science and the biotechnology industry will be increasingly able to 'control evolution' (Doudna and Sternberg 2017), 'improve lives' (Feng 2013), 'protect the Earth's biodiversity' (Dance 2015; Phelan 2015), 'change society' (Rosner 2016), 'edit the human race' (Kuchler 2021) and even 'save the world' (Royal Society of Biology 2016).

In this sociotechnical imaginary (Jasanoff and Kim 2013), CRISPR figures as a central machine of an impending bio-industrial revolution. According to the Royal Swedish Academy of Sciences, which awarded the 2020 Nobel Prize in Chemistry to Emmanuelle Charpentier and Jennifer Doudna for developing 'one of gene technology's sharpest tools,' 'these genetic scissors have already taken the life sciences into a new epoch and, in many ways, are bringing the greatest benefit to humankind' (Nobel Prize Committee 2020). In this 'new epoch', genome editing is increasingly central to business operations in several economic sectors, including agriculture, aquaculture, livestock breeding, pharmaceutical production, and the chemical industry. Across these branches of industry, the metabolism of living beings is being re-designed to facilitate, extend and secure industrial production. In agriculture and forestry, CRISPR has been aimed at accelerating the growth rate of crops and trees, while adapting their physiology to industrial harvesting and climate change (Borg and Policante 2024; Zhu, Li, and Gao 2020). In aquaculture and the livestock industry, corporate laboratories aim to adapt animal bodies to life in factory farms (Singh and Ali 2021; Yang et al. 2022). In pharmacology, bacteria and yeasts are systematically bio-engineered to adjust their metabolism and maximise the synthesis of valuable proteins (Khan, Tye, and Noordin 2020).

One fundamental characteristic makes the CRISPR-Cas assemblage particularly attractive for industry. Contrary to the recombinant technologies of the first wave of genetic engineering, it can be industrially produced, commercialised as a standardised tool, and put to work on virtually any DNA segment (Barrangou and Doudna 2016). It, thus, enables a significant reduction in the costs of genetic modification. Molecular biologist James Haber recently estimated that the combined cost of Cas9 and a guide-RNA comes to about $30, making it over 150 times cheaper than previously popular systems of genome modification, such as zinc finger nucleases (ZFNs) or transcription activator-like effector nucleases (TALENs) (Ledford 2015). As Emmanuelle Charpentier puts it, CRISPR's selling point is rather straightforward: 'With CAS9, anyone can use the tool. It's cheap, it's fast, it's efficient, and it works in any size organism' (Rogers 2015, p. 14). Given its potential to expand and accelerate laboratory processes of genetic modification, reducing the labour time embodied in genetically modified organisms, the CRISPR assemblage has been celebrated as 'the Model T of genetics' (Specter 2015): an easily scalable technology that has the potential to generate a bio-Fordist revolution.

On this basis, many celebrate the dawn of genome editing as constituting a democratisation of genetic engineering.[3] Jennifer Doudna (2019), for instance, claims that CRISPR

of selected genetic sequences into a host genome and the generation of transgenic living organisms. Recently, CRISPR has become the central method for artificial mutagenesis. By mobilising and directing Cas enzymes, biotech laboratories are able to induce multiple targeted genetic mutations in a growing variety of living cells.

[3]As an operative metaphor, genome editing constitutes an attempt to mark a radical discontinuity in the history of genetic modification. The transition from 'genetic engineering' to 'genome editing' implies a two-sided transformation. Firstly, it indicates a change of scale: the target of genetic redesign is no longer single 'genes', but the entire 'genome'. Second, it suggests that the labour of genetic modification is now better described as a form of 'editing'. While recombinant DNA technologies have long enabled the transfer of genetic material from one organism to another, CRISPR

is 'a democratising tool' which enables laboratory workers around the world 'to do experiments that in the past had been prohibitive.' CRISPR biotechnologies, however, have rapidly been enclosed and placed under control by a small group of powerful economic actors, fighting over a highly speculative market. Decades of collaborative scientific research — conducted in hundreds of institutions all around the world — contributed to isolating and elucidating a complex biological system, which has been gradually converted into a genome editing tool. While entrepreneurial scientists and laboratory workers strived to mould the bacterial immune system of *Streptococcus pyogenes* into a means of genetic modification, patent lawyers endeavoured to render this emerging biotechnology into a proprietary financial asset by kick-starting a highly contested patenting process. This section focuses on the contested process of *assetisation* of the resulting biotechnology. It reconstructs how CRISPR has been claimed as an exclusive invention, how it has been enclosed as a patented monopoly asset and subsequently turned into a powerful machinery for capital accumulation through rent extraction. It offers a timeline of this complex nexus of scientific, commercial, and juridical events, whose convergence has shaped the genome editing industry (see Figure 1). Finally, it reflects upon how this transformation dovetails with a general financialisation of the global economy and the consolidation of a rentier capitalism underpinned by monopolistic rent-yielding assets (Birch and Ward 2022; Christophers 2021; Hudson 2021).

This slow process of *financial translation* relies on the persistence of a neoliberal legal framework that has sustained the financial growth of the biotech industry for almost half a century. The patentability of biotechnological assemblages such as CRISPR has been made possible by a juridical doctrine first established in the 1980s, following a controversial US Supreme Court decision concerning the property of a new species of 'multiplasmid, hydrocarbon-degrading *Pseudomonas* bacteria,' originally developed in the laboratories of the Research and Development Centre of General Electric in New York (Jasanoff 2012, pp. 172–181; Sherkow and Greely 2015; Webber 2014). During this landmark case, laboratory procedures of genetic modification were socially re-constructed as *manufacturing processes* by which biological materials and living organisms are given 'new forms, qualities, properties, or combinations, whether by hand-labor or by machinery' (US Supreme Court 1980).

Since then, the products of mutagenic procedures can be presented as biological artefacts and, therefore, as patentable objects. The claim that genetically modified biological systems are 'products of manufacture' became central to corporate strategies of appropriation, legitimising patents on countless living organisms. It was — and it remains to this day — the key doctrine of *genomic enclosure*: the fundamental legitimising idea sustaining the financial architectures of the global biotech industry (Borg and Policante 2022, pp. 45–63). This rather technical and obscure regulatory shift — later imposed worldwide through the World Trade Organisation's framework on intellectual property rights (Parry 2004; Shiva 1998; Williams 2000) — was the spark that ignited the transformation of genomic science into a global industry. It turned genetic modification into a

mobilises the CAS9 enzyme to knock out a targeted genetic sequence without necessarily inserting exogenous genetic material. This form of artificial mutagenesis is often presented as editing the 'book of life', a simple labour process performed with a bioinformatic 'word processor'. This rhetoric obscures the fact that there have been no 'radical discontinuities' in the history of genomic biotechnologies, but rather a gradual and methodical search for technoscientific mastery over evolutionary processes (Borg and Policante 2022).

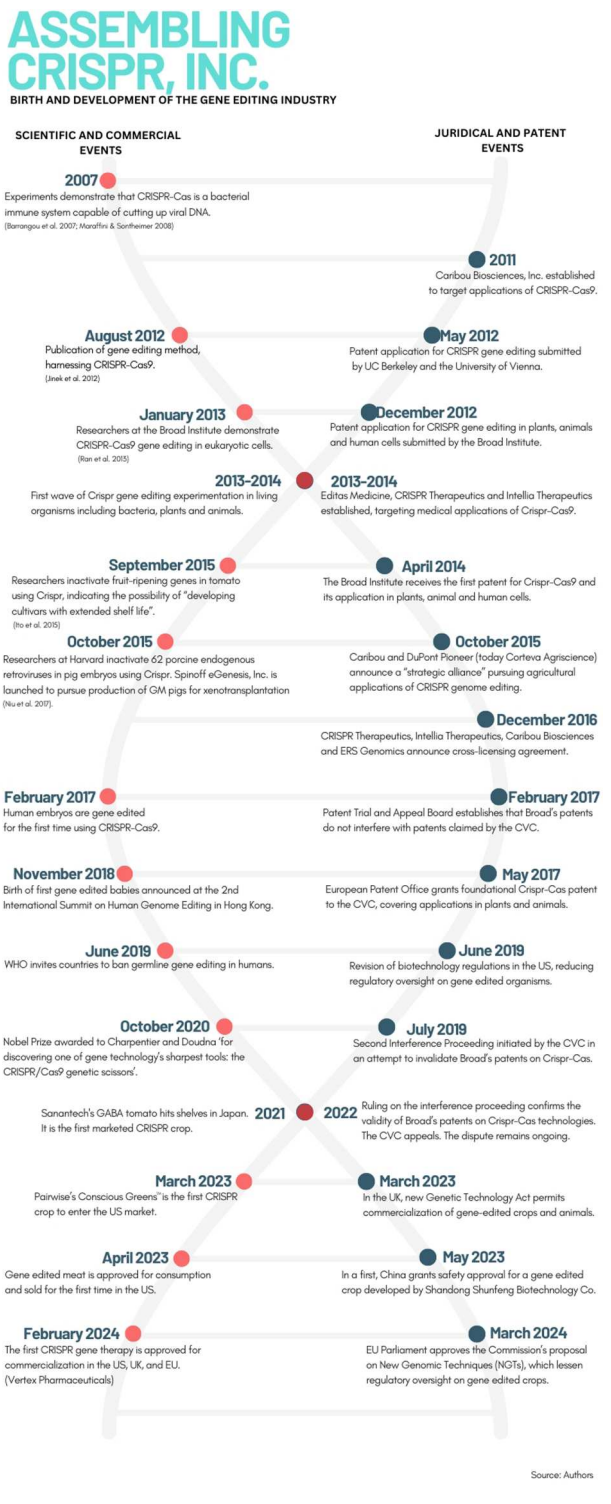

Figure 1. ASSEMBLING CRISPR, INC. – Birth and Development of the Genome Editing Industry. Source: Borg and Policante (2024) "The Gene Editing Business: Rent Extraction in the Biotech Industry".

Note: The chart shows the entanglement of scientific, commercial and juridical events that converged in shaping the genome editing industry. The events chosen are simply representative of much larger historical trends (see also: Borg and Policante 2022).

standardised methodology for the production of patentable biotechnological artefacts such as isolated GM cell lines and genetically modified bodies.

Until the recent introduction of genome editing techniques, biotech companies mostly relied on recombinant DNA techniques to transfer genetic material across species and, therefore, steer the metabolism of various living organisms employed in production (Modak et al. 2022). Genentech spliced bacterial cells with human genes to induce them to produce human growth hormone and insulin (Hughes 2001). Biopharmaceutical companies spliced yeast cells with viral genes to synthesise recombinant vaccines (Kim, Yoo, and Kang 2015; McAleer et al. 1984). In Monsanto's laboratories, technicians spliced crops with bacterial genes to synthesise bacterial toxins (Andrews et al. 1987; Gassmann and Reisig 2023). The resulting genetically modified cells and organisms could be patented as *living financial assets*, which gradually transformed processes of production across pharmaceutical laboratories, agricultural fields and industrial conglomerates. Recombinant DNA techniques became a branch of technoscientific industrial production, supported by exclusive monopoly rights.

The combined techno-juridical shift produced by patented rDNA also opened new avenues of investments and financial speculation. On 14 October 1980, just months after the Supreme Court's decision, Genentech — a company formed by venture capitalist Richard Swanson and biochemist Herbert Boyer to capitalise on the latter's research on recombinant DNA — obtained its brand-new Nasdaq ticker symbol GENE and offered over one million shares of its stock to public investors (Hughes 2001; Rifkin 1998). By the end of the day, the biotechnology firm was valued at $532 million. It achieved this without having ever introduced a single product into the marketplace. Herbert Boyer became an instant millionaire, reaping nearly $70 million in one single day (Hughes 2011, pp. 158–164).

It was a threshold moment, inaugurating a phase of capital accumulation characterised by an ever-closer entanglement of public science and corporate business; a tendency which was further reinforced by the introduction of the *Patent and Trademark Amendments Act* in December 1980. This neoliberal reform enabled universities to claim patents based on publicly financed research. It also provided them with economic incentives to promote those forms of research most likely to generate monetisable patents, and then seek out licensing partnerships with corporate actors (Argyres and Liebeskind 1998; Jasanoff 2019, p. 30).

Molecular biology was one of the scientific disciplines most affected and shaped by this neoliberal turn. The early development of molecular biology as a field took place under the intimate patronage of the Rockefeller Foundation, which facilitated a revolving door between science and industry (Kay 1992). During the 1980s and 1990s, molecular biologists and the rising biotech industry grew more and more ensnared in a thick web of financial partnerships, licensing deals and court litigations (Mirowski 2011, pp. 148–159). The University of California and the University of Stanford were at the forefront of this commercialisation of genetic technoscience (Birch, Chiappetta, and Artyushina 2020). Through their patent portfolio on recombinant DNA techniques, obtained in the years immediately following the landmark Supreme Court ruling of 1980, they controlled the foundational technologies of the emerging biotech industry (Wright 1986). This monopolistic control enabled them to capture substantial rents on the capital circulating through the rapidly growing biotech industry (Bera 2009; Hughes 2001). Since the

1980s, an elaborate *architecture of rent extraction, circulation and distribution* has mediated the application of genomic science and genomic biotechnologies in contemporary neoliberal societies.

Using recombinant techniques, biotech start-ups developed and patented genetically modified organisms designed to enable the production of a variety of commodities — including recombinant insulin, hormones and antibodies; transgenic seeds and genetically-modified laboratory mice. Then, they often licensed them out to industrial corporations with the capacity to scale up production and facilitate commercialisation. This corporate strategy of *accumulation by bio-assetisation* effectively turned many biotech companies into a new stratum of the global rentier class, extracting a percentage of the profits realised by industrial corporations in the form of guaranteed streams of royalties (Borg and Policante 2022, pp. 39–43). Finally, a small part of these royalties would be redistributed to the two academic institutions controlling the foundational patents on recombinant DNA. During the seventeen years between the approval of these patents and their expiration in 1997, $254 million in royalties from 468 biotech companies went to the University of California and the University of Stanford (Feldman, Colaianni, and Liu 2007).

In the early 2000s, the expiry of the foundational patents on which the architecture of the genomic industry had been founded since its inception coincided with its rapid financial decline (Bera 2009; Hughes 2001). Biotech companies, like their 'dot-com' counterparts, continued to struggle generating revenues despite enormous valuations on financial markets. Moreover, a lot of these companies faced a dramatic 'patent cliff' as many of their most valuable patents — claimed right after the juridical shift set in place by *Diamond vs. Chakrabarty* in 1980 — approached their expiry date (Deloitte 2010; Schellekens 2004). The 'biotech bubble' met the same fate as the dot-com bubble: Nasdaq's Biotech Index soared by 700 per cent between its inception in 1993 and its peak in 2000, before bursting (Demers and Joos 2004). This financial crisis — unravelling in parallel with an epistemological crisis undermining the reductionist central dogma of molecular biology (Lewontin 2001) — sparked a decade-long investment slump that 'effectively froze risk investment in traditional biotechnology' (Cooke 2013, pp. 796–797; Smith et al. 2009).

The introduction of CRISPR-Cas9 has fired up a new wave of financial investments in the stagnant genomic industry. It promised to automate the production of genetically modified organisms — including patented varieties of bacteria, crops, and animals — making laboratory processes significantly faster and cheaper.[4] A new generation of scientists turned into biotech entrepreneurs, with investment funds and multinational corporations bankrolling their attempts to turn gene editing into a means of capital accumulation. In 2011, Doudna founded Caribou Biosciences with the slogan 'Engineering any genome, at any site, in any way.' Soon, it established ties with major agrochemical corporations such as DuPont Pioneer with the expressed goal of developing CRISPR for agribusiness (Grobler, Suleman, and Raj 2021; Montenegro de Wit 2020). Other

[4]CRISPR fosters a deskilling of the labour force employed in the biotech sector. Talking about the ways in which CRISPR is changing the production processes of laboratory mice in companies such as Taconic Biosciences and Jackson Laboratories, Rudolf Jaenisch boasted that "When you made knockout mice before, you needed some skills. Now, you don't need them anymore. Any idiot can do it." (Cohen 2016). In this way, according to recent estimations, CRISPR has brought down the production cost of genetically modified mice by 30 per cent, making the average cost of development of a new strain around $100,000.

companies — including Bayer-Monsanto, Cibus, Catalyxt, Syngenta, Arcadia and BH Biosystems — entered the rapidly expanding market for gene-edited crops.

In parallel, another group of companies emerged with the aim of developing new CRISPR tools for the pharmaceutical and clinical industry. In 2013, Doudna teamed up with George Church, Feng Zhang and David Liu to launch Editas Medicine with $43 million in financing from three prominent venture capital firms; while Emmanuelle Charpentier founded CRISPR Therapeutics, with a similar business plan and $25 million in venture capital (Borg and Policante 2022, pp. 89–104; Cohen 2017). In 2014, Doudna — together with CRISPR researchers such as Barrangou, Maraffini and Rossi — left Editas to join Intellia Therapeutics. By the end of 2015, these three companies alone had raised over half a billion dollars in investments (Megget 2016). As of 2023, that figure has exploded to over $2.2 billion (Crunchbase 2023).

This early wave of corporate excitement added urgency to a question that remains unresolved to this day: Who owns CRISPR? The ongoing clash for CRISPR patents can be traced back to 2012 when two separate conglomerates claimed exclusive ownership over the newly minted molecular machine. In May 2012, the patent offices of the University of California and the University of Vienna were the first to file a provisional patent application on the use of CRISPR-Cas9 as a genome-editing tool on the basis of research published by Jennifer Doudna and Emmanuelle Charpentier. Yet, it was the Massachusetts Institute of Technology (MIT), Harvard University and the Broad Institute who, based on experiments performed by the research group led by Feng Zhang, first obtained several patents covering techniques for the deployment of CRISPR-Cas9 in eukaryotic cells (Cohen 2017; Sherkow 2018).

This sparked a decade-long legal confrontation to establish ownership over a technology whose applications affect all those industries that work with and through living bodies and their metabolic systems, including agriculture and forestry, livestock breeding, and the pharmaceutical industry (Ledford 2022; Sheridan 2014; Sherkow 2022; Storz 2023). The 'Battle for CRISPR' is at once juridical, scientific, economic, social, political and historiographic. Since the answer to the question 'Who owns CRISPR?' very much depends on the answer to the question 'Who invented CRISPR?', the conflict is rapidly exceeding the walls of specialised courthouses. It has spilt onto a multitude of unexpected terrains from academic journals to science magazines, documentaries, websites and Nobel Committees. The historiography of science and technology has become fundamentally entangled in the narrative and discursive processes that shape financial valuation in highly speculative markets (Petersen and Krisjansen 2015; Vint 2019).

For instance, the publication of a historiography of CRISPR authored by Eric Lander (2016) — then president of the Broad Institute — rapidly turned into a clamorous political case. The piece was widely seen as an attempt to influence the patent battle in favour of the MIT-Harvard-Broad faction by recounting twenty years of CRISPR research as a succession of small, incremental steps, finally culminating in a decisive experiment performed by Zhang, which successfully deployed the technology to edit a eukaryotic cell (Kozubek 2018, pp. 24–35; Ledford 2016). In response, the circle of scientific, institutional and financial supporters of the Doudna — Charpentier faction, generally referred to as the CVC (California-Vienna-Charpentier), produced a deluge of alternative accounts in which Zhang's experiments appeared as an obvious, inevitable corollary to their all-important, foundational research (Doudna and Sternberg 2017; Zwart 2018).

Despite obvious differences, both narratives represent the history of science as a discontinuous terrain, punctuated by sudden inventions born from the minds of isolated researchers, who deserve to monopolise the technologies developed through their single-handed efforts. It is not by chance that Lander's historiography of CRISPR bears the title 'The Heroes of CRISPR,' betraying a long-standing heroic model of invention that has been the object of sustained critique since the 19th century (MacLeod and Radick 2013). In previous works, we have suggested that a radically different account of the history of CRISPR emerges from a 'history of technoscience from below', emphasising the fact that technological change results from complex processes of co-production of knowledge that always involve a multitude of nameless people across time and space (Borg and Policante 2022, pp. 97–102). The global rush for CRISPR patents then appears as the last chapter of a much longer history by which powerful groups have enclosed and privatised the wealth produced by diffused processes of research and knowledge creation (Boyle 2003; Marx 1993, p. 207; Vercellone 2007).

Following this process of enclosure, the global patent landscape has been continuously expanding while remaining highly fragmented and unstable (Martin-Laffon, Kuntz, and Ricroch 2019). In the European Union, the CVC has obtained control over most applications of the CRISPR-Cas9 gene editing apparatus (Heiseke and Jaenichen 2023).[5] In the US, however, control over the CRISPR-Cas9 genome-editing tool continues to be shared between the Broad and the CVC (Paradise 2023). Most recently, in a decision published in March 2022, the US Patent and Trademark Office reaffirmed the validity of the patents obtained by the Broad Institute. The court asserted that Jennifer Doudna and Emmanuel Charpentier were the first to demonstrate the use of the CRISPR-Cas9 system in laboratory procedures *in vitro*, but that scientists at the Broad Institute were the first to find a replicable method to make the gene editing system work directly in eukaryotic cells (Ledford 2022). In the United States, therefore, the patent landscape remains uncertain: the CVC controls several key patents; but the Broad Institute remains in possession of the most lucrative intellectual property monopolies, covering the application of CRISPR-Cas9 in plants and animals, including human bodies. This magmatic terrain, however, might soon shift again since Charpentier, UC Berkeley, and the University of Vienna have appealed once more the decision of the Patent Office (Paradise 2023).

The persisting uncertainties surrounding the ownership of genome-editing technologies complicate the activity of companies working towards commercial applications of CRISPR-Cas9. Some of these companies have negotiated licences with both the CVC and the Broad Institute. Others have so far preferred to avoid negotiating any licence agreement 'until all of the uncertainty surrounding inventorship and priority among the groups with CRISPR-Cas9 patents is resolved' (Caribou Biosciences 2023). Finally, those that have acquired licences with the University of California may be negatively affected by the ruling and could be forced to obtain additional licences from the Broad Institute or abandon their line of research.

[5]A recent development, however, may considerably weaken the CVC's capacity to extract license fees in the European Union. In August 2024, a technical appeals board of the EU Patent Office determined that two of the CVC founding patents do not adequately describe the procedures necessary to perform CRISPR gene editing. As a result, it invited the Patent Office to invalidate the two patents. In response, the CVC declared its intention to pre-emptively withdraw the two patents under scrutiny (Regalado 2024).

Vertex Pharmaceuticals, for instance, has already received regulatory approval in both the UK and the US to sell a CRISPR treatment for sickle-cell disease, which operates directly on human cells (Wong 2023). As Casgevy™ enters the US and EU market, Vertex will transfer a milestone payment of $200 million (plus 40 per cent of any future profits) to CRISPR Therapeutics, from which it sublicenses the gene editing technology (CRISPR Therapeutics 2023b). Given the ongoing patent dispute, however, Vertex remained exposed to the possibility of costly lawsuits from the Broad Institute. To avoid litigation, it then announced a second sub-licensing deal with Editas Medicine transferring $50 million upfront, plus annual fees of up to $40 million until 2034. Editas will then transfer a percentage in the mid-double digit of this rent to the Broad Institute (Regalado 2023).

Ultimately, this intricate web of licensing and sublicensing deals — each implying the circulation of royalties and rents — can only be sustained by imposing high profit margins on gene therapies and gene-edited organisms. Casgevy™ is currently priced at $2.2 million per treatment. This pricing strategy is likely to limit access to the drug, a tendency that is not new in this sector. Already in 2017, commenting on the likely impact of CRISPR patents on future drug prices, Jim Kozubek pointed out that 'as investors engage in layers of transactional deals along the top of the food chain, the costs of gene therapies go up while the financiers may shift blame for a lack of patient coverage to insurance companies' (Kozubek 2017). As of 2024, most gene therapy products have extremely high price tags that do not always reflect manufacturing costs, but rather the inflated profit margins imposed by pharmaceutical corporations placed at the tail end of *licensing and sublicensing chains* stacking up rents at each link (Kannan and Najjar 2020, p. 68; Kozubek 2018; Kleutghen 2018).

The battle over CRISPR patents has implications that go beyond issues of economic redistribution. What is ultimately at stake in debates surrounding the patenting of CRISPR-Cas9 technologies is not only who will cash in years of royalties, whose magnitude is nearly impossible to estimate precisely, but also who will control future developments in genome editing. The enclosure of socially produced knowledge concentrates monopoly power over foundational technologies in the hands of private institutions beyond democratic control, raising several highly contested issues. Who will control the new technoscientific capacity to edit genomes and direct bodily and social metabolic processes? Who will be granted access and who will be excluded from vital decisions surrounding the targeted mutagenesis of living cells? What architectures of rent extraction will emerge in the rapidly shifting landscapes characterising the global biotech industry? In the next section, we turn to some of these questions by mapping the shifting contours of genomic capital and the rising bio-fin-tech industrial complex.

3. Architectures of Rent Extraction and Promissory Genomic Futures

Genomic futures remain a site of contestation and contradiction (Policante and Borg 2024). While many hail CRISPR-Cas9 as a democratising technology, the reality is that its industrial applications remain strictly bound to the monopolistic power of a few institutions that control foundational patents, whose validity is increasingly being imposed around the world. To utilise CRISPR-Cas9 as an industrial means of production, corporations must necessarily obtain licences in exchange for fixed yearly rents as well as

hypothetical royalties on any future commodity developed using the technology. The development of CRISPR-based commodities, however, is both costly and risky as a business proposition. Costly because it is a highly capital-intensive affair, which requires levels of fixed capital and financing only available to a select few biotech firms (Jasanoff, Hurlbut, and Saha 2015; Montenegro de Wit 2020). Risky because it remains uncertain that these financial investments will ever lead to the development of profitable industrial processes of commodity production. In this highly volatile context, patent protections and multiple layers of rent extraction shape the peculiar landscapes on which various factions of CRISPR, Inc. compete and cooperate in contradictory ways.

In recent years, critical literature has stressed the increasing importance of rent in the global economy. Emphasising the importance of this transformation, some scholars have suggested that the increasing centrality of rent and finance signals a new phase in the history of the capitalist mode of production that could be characterised as a form of 'rentier capitalism' (Christophers 2020; Demir 2007; Purcell 2017). Others have theorised the emergence of an 'intellectual monopoly capitalism' in which corporations increasingly rely on the extraction of rents from enclosed knowledge through global systems of 'value appropriation,' which bring 'more polarization, inequalities and marginalization at every possible level' (Durand and Milberg 2020; Pagano 2014; Rikap 2021, p. 9). In view of these theoretical propositions and macro-analyses, it is necessary to advance detailed and granular studies of how socio-economic architectures of rent extraction are constructed, maintained and scaled up in an increasingly financialised world market.

In order to contribute to this endeavour, this second part examines the hierarchical, multi-layered corporate structures that are necessary to conduct operations of rent extraction on the basis of existing intellectual property monopolies on CRISPR-Cas9. We strive to 'un-blackbox' rent extraction by analysing: how rents are extracted and made to circulate through the intricate webs of licensing and sublicensing chains that characterise the genome editing industry; and how these licensing deals further operate as promissory statements, informing financial valuations by creating expectations of future royalty streams. By mapping the labyrinthine maze of corporate and financial deals that currently govern the extraction and circulation of genomic rents in the global biopolitical economy, the section intends to contribute to understanding how monopoly power over CRISPR technologies is imbricated with the financialisation of life in its multiple forms.

The CRISPR patent landscape is an unstable, contested and shifting terrain, which is at the centre of a political and juridical confrontation that is increasingly global. However, a rapidly expanding *infrastructure of rent extraction* is already being erected on top of this harshly disputed territory, fragmented into multiple patent enclosures. This imbricated infrastructure — which enables the extraction and circulation of CRISPR rents through the global economy — can be schematically conceptualised as being composed of three interdependent strata (see Figure 2 for a visual representation). The multiple institutions that have obtained some degree of control over CRISPR-Cas9 technologies through patents and intellectual property rights constitute a primary stratum, including: public academic institutions such as the University of California and the University of Vienna; private, tax-exempt, nonprofit organisations such as the Broad Institute; and individuals such as Emmanuelle Charpentier. These actors are currently locked in a struggle for control over the CRISPR-Cas9 assemblage as a foundational technology

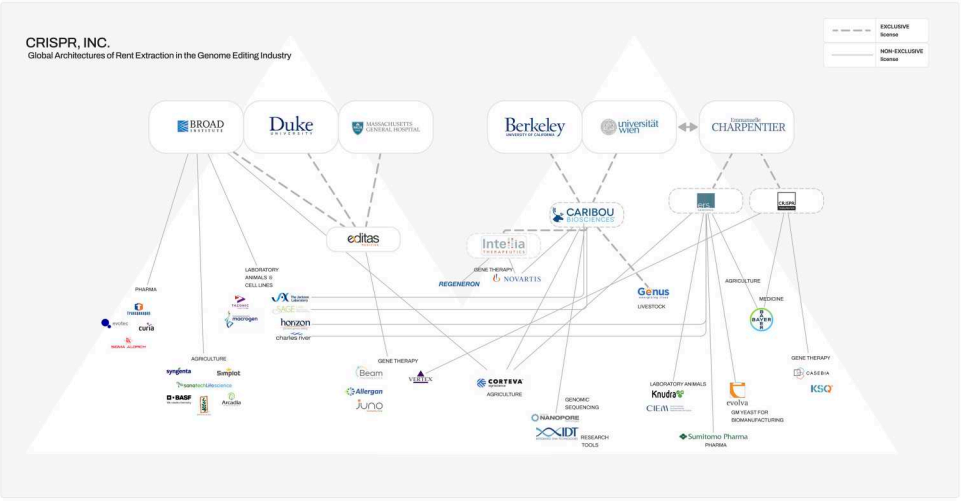

Figure 2. CRISPR, INC. - Global Architectures of Rent Extraction in the Genome Editing Industry. Source: Borg and Policante (2024) "The Gene Editing Business: Rent Extraction in the Biotech Industry".

Note: The chart portrays the global architecture of the genome editing industry as of April 2024. Genome editing technologies are licensed from patent holders (placed at the top) to corporations further down the chain. Meanwhile, rents are syphoned from the base to the upper strata. Corporations shown at the base are selected representatives of a much larger and constantly expanding set of sublicensing corporations.

for the emerging genomic industry. They form shifting and unstable alliances and groupings, which currently pit the University of California and Vienna against the Broad-MIT-Harvard system.

To fund this long-standing struggle over ownership, each of these institutional groupings has established their respective vassal platform companies: corporate spin-offs founded to mediate between the patent holders and the biotech-industrial complex, facilitating licensing processes and the extraction of rents. Caribou Biosciences, Inc. has received 'an exclusive worldwide license, with the right to sublicense, in all fields to the foundational CRISPR-Cas9 patent family co-owned by UC, Vienna, and Dr. Emmanuelle Charpentier' (Caribou 2023, p. f-19). ERS Genomics and CRISPR Therapeutics control a similar exclusive patent portfolio through their direct association with Emmanuelle Charpentier. Finally, Editas Medicine has been endowed with an exclusive licence over gene editing applications in human cells from the Broad Institute. An industry commentator, writing on Labiotech, describes the commercial logic behind this: 'In this highly competitive field, it is more efficient to grant rights in bulk to a single company and let them negotiate individual licences with third parties' (Cynober 2019).

These vassal platform companies have attracted significant capital investments since their creation around 2013. In terms of market capitalisation as of December 2023, CRISPR Therapeutics dwarfs the others at $5.56 billion; followed by Editas at $896.78 million and Caribou at $502.29 million. Yet reviewing the 10 K filings of these US-based companies, it is clear that they are far from being profitable and do not count on ever being so. CRISPR Therapeutics states that 'because of the numerous risks and uncertainties associated with developing gene editing product candidates, we are unable to predict the extent of any future losses or when we will become profitable, if

at all. Even if we do become profitable, we may not be able to sustain or increase our profitability on a quarterly or annual basis' (CRISPR Therapeutics 2023a, p. 53). Similarly, Caribou Bioscence's 10 K report states that 'we have incurred significant net losses since our inception and anticipate that we will incur continued net losses for the foreseeable future' (2023, p. 51); while Editas Medicine's filing states that 'we have never generated revenue from product sales and may never be profitable' (2023, p. 54).

Some platform companies — such as CRISPR Therapeutics and Caribou Biosciences — do strive to develop future products and services on the base of their exclusive licences. Yet, they also operate in the present: through the systematic extraction of rents from numerous sublicensing companies, which constitute the broad economic base that sustains the CRISPR patent pyramid. Global corporations like Bayer-Monsanto, BASF, Corteva, Novartis, Juno, Vertex and Allergan — operating across several economic sectors — have acquired non-exclusive sublicenses that enable them to utilise CRISPR-Cas9 in processes of production of patentable assets and commodities. Caribou Biosciences (2023, p. 82), for instance, reports to have so far 'entered into over 25 sublicensing agreements in a variety of fields such as human therapeutics, forestry, agriculture, research reagents, transgenic animals, certain livestock targets, internal research, bioproduction, cell lines, and microbial applications.'

Most of these sublicensing agreements establish a fixed sublicensing fee to be paid annually and per cent royalties on any revenues resulting from the commercialisation of commodities and services developed with the licensed 'genome-editing platform technology' (Caribou 2023, p. 106). Platform companies collect fees and royalties from sublicensing companies, conveying a variable share of these CRISPR rents to the patent holders placed higher up in the global architecture of rent extraction. From this point of view, they essentially operate as financial intermediaries. Caribou Biosciences, for instance, has committed to paying to the University of California: (1) an 'annual license maintenance fee'; (2) per cent royalties on revenues resulting from products developed by Caribou 'subject to a minimum annual royalty'; (3) a 'specified percentage of sublicensing revenue' received by Caribou from third companies; (4) a full reimbursement for the 'prosecution and maintenance costs of the CVC IP' (Caribou 2023, p. 29, f-19).

The architecture of rent extraction constructed by Harvard University and the Broad Institute to capitalise on their IP assets follows a similar structure. The Broad Institute continues to directly manage the licensing of CRISPR-Cas9 in several industrial fields, including: the commercialisation of 'products or services in the field of livestock applications', 'plant-based agricultural products', as well as 'animals or animal cells for the creation and sale of organs suitable for xenotransplantation into humans' (Editas 2023, p. 15). In the 'field of the prevention and treatment of human disease,' however, Editas is endowed with 'an exclusive, worldwide, royalty-bearing, sublicensable license to the Harvard/Broad Cas9-I Patent Rights to make, have made, use, sell, offer for sale, have sold, import, and export products and services' (Editas 2023, p. 15). Under this agreement, Editas performs various functions in the extraction and circulation of rents in the global biopolitical economy. The company extracts monopoly rents from sublicensing companies, and it exercises the right to enforce 'the Harvard/Broad Cas9-I Patent Rights' in any court of law. It then transfers back to the licence holders both a 'double-digit percentage of the sublicense income' and 'any sums recovered' in lawsuits.

Additionally, it pays an 'annual licence fee,' 'milestone payments' and 'percentage royalties' on any product approved for commercialisation (Editas 2023, pp. 17–18).

This byzantine corporate pyramid indicates how complex and labour-intensive the extraction of rents in the global bioeconomy really is. Multiple forms of technoscientific work — by accountants, asset managers, lab technicians, molecular biologists, and more — are needed to monetise those assets either directly (by developing a marketable commodity from them) or indirectly (by licensing them out to other companies). While platform companies such as Editas and Caribou have not been able to generate profits through the commercialisation of CRISPR-Cas9, they constitute operative elements of a much larger and increasingly stratified architecture of rent extraction. This condition is neither novel nor exceptional to the global biotech industry. 'Accumulation through intellectual rentiership' has been shown to be crucial to the industrial strategies set in place by major high-tech corporations characterised by low profitability margins, such as Amazon, Tesla and Uber (Coveri, Cozza, and Guarascio 2022; Rikap 2022, 2022b).

Since the 1990s, many biotech companies have been characterised by a similar reliance on intellectual property assets to sustain their business operations. As noted by Melinda Cooper (2008, pp. 144–145), for instance, Geron Corporation reported in 2003 'that it had never made a profit on its therapeutic products and does not expect to 'for a period of years, if at all.'' Analysing the apparent contradiction between a lack of profits — coupled with uncertainty about the potential for future profits — and high market valuations, Cooper argues that financial investment is driven by a promissory futurity, based 'not so much the commodification of biological life … but rather its transmutation into speculative surplus value' (2008, p. 148). In a context of 'fundamental uncertainty,' Geron's faith in the future is sustained only by 'its claim on the intellectual property rights of all future inventions using its products.' Shifting the focus from commodification as a central category for explaining valuation, Cooper understands this as a process of 'transmutation of self-regenerative life into self-valorizing capital' (2008, p. 149).

But how can we open up the black box of biotech patents as simply constituting a form of 'self-valorizing capital'? Elaborating on this question, Kean Birch (2017, 2020) has pointed to the promissory aspect of financial assets, and the role it plays in the construction of stock prices. The persisting contradiction between the high financial valuation of companies such as Caribou Biosciences and their lack of market revenues is partly dependent on investors' belief in the often-rehearsed promise of an impending CRISPR revolution in medicine and agriculture. As noted by Nik Brown (2003, p. 4), biotech 'is today synonymous with the language and imagery of futuristic breakthroughs.'

In CRISPR companies' 'future-looking financescapes' (Helmreich 2008, p. 465), projections occupy a key role, profoundly shaping technoscientific practices of financial valuation, attracting investments and boosting stock value (Fortun 2001, p. 139). The promissory futures of a CRISPR revolution are diffused in the cultural atmosphere through informal channels such as journalistic accounts, documentaries and sci-fi fantasies (Borup et al. 2006). Licensing and sublicensing deals — with their elaborate promises of future 'milestone payments' and 'royalty streams' upon commercialisation — represent more formalised promissory statements, which support the financial valuation of Editas and Caribou.

The ever-shifting confidence in the *future* CRISPR revolution not only fundamentally shapes the *present* financial value of firms such as Caribou Biosciences, Editas Medicine and CRISPR Therapeutics; it also shapes their capacity to attract the funds necessary to pursue commercialisation. As of December 2022, Editas had accumulated over $1 billion in deficit. In the absence of any commercial profits, the monopoly rents obtained through sublicensing deals offered a fundamental source of revenue. Juno Therapeutics and Allergan Pharmaceuticals alone paid over $200 million to Editas for sublicensing CRISPR-Cas9 as a means of pursuing their businesses (Editas 2023, pp. 13–14). However, Editas has only remained operational through continuous injections of investment capital, registering 'an aggregate of $898 million in net proceeds through the sale of shares' (Editas 2023, p. 51). CRISPR platforms' capacity to continue attracting investments is essential to their long-term business strategies. Caribou, for instance, stresses in its official documents that 'we will need substantial additional financing to develop our product candidates and implement our operating plans. If we fail to obtain additional financing, we may be delayed or unable to complete the development and commercialization of our product candidates' (Caribou 2023, p. 4).

Reflecting upon the widespread dependency of many biotech firms on continuous investments by Big Finance, Big Pharma and Big Agribusiness, Philip Mirowski went as far as arguing that the whole biotechnology industry consists in a highly financialised Ponzi scheme whereby a firm 'regularly incurs more liabilities than it accrues cash flow, with the trick being to lure exponentially increased investment and then to cash out before the inevitable collapse ensues' (2012, 296). This characterisation captures the speculative nature of many financial investments in the biotech sector, including investments in key platform companies controlling exclusive licences on CRISPR-Cas9. As many of these companies explicitly stress, there is no certainty that gene editing will ever lead to the commercialisation of profitable commodities in the global market. For instance, Editas, Inc. presents its mission as 'translating the promise of gene editing into a broad class of differentiated, transformational medicines for previously untreatable or under-treated diseases' (2023, 6). Yet is quite explicit in its compulsory 10 K filing that 'important risks and uncertainties' may 'cause our actual results to differ materially from those indicated by forward-looking statements' and that investors 'should not place undue reliance' on them (2023, 3, 106–107).

However, Ponzi schemes involve a degree of intentional fraud, which there is no basis for. Mirowski's characterisation relies on a firm belief in the 'inevitable collapse' of the inflated promise of a biotech 'revolution' powered by gene editing technologies. If we were to conceptualise CRISPR, Inc. as a Ponzi scheme, the direct victims would be rather unlikely characters. As of December 2023, Caribou Biosciences' largest investors are global investment funds such as BlackRock Fund, Avidity Partners and Paradigm Biocapital together with pharmaceutical, agrochemical, biochemical, and biotechnological conglomerates such as Bayer-Monsanto, Pfizer and DuPont. Not surprisingly, many of these same companies are also principal investors in Editas, Inc. — Caribou's direct competitor. Rather than a fraudulent corruption of financial markets, the impetus behind the spectacular speculation in CRISPR assets can be understood as a systemic expression of technoscientific financialisation (Brown 2003; Fortun 2001; Li and Qi 2022). As argued by Jamie Peck (2013:, 19), neoliberalism tends to 'fail forward.' It is a

'churning and contradictory process of flawed experimentation, albeit with a failure-and-crisis driven forward momentum.'

The persistent promise of technoscientific control over the metabolic processes of living organisms is enough to attract billions of financial investments and philantrocapitalist grants that contribute to the construction of the complex biotechnological assemblages — composed of machines, knowledges, ideas, regulations, patents, databanks, genomic arks, frozen embryos, proteins, enzymes and mountains of deoxyribonucleic acid — that are mobilised by the genomic industry. Whether these investments in gene editing will produce substantial future profits remains to be seen, but global ecologies have already been profoundly transformed by the combined application of multiple techniques of targeted mutagenesis (Magalhães, Brito, and Silva 2022; Paredes 2021). Even if CRISPR itself fails, the promise of steering evolution is a long-standing goal of biological science and its allure is unlikely to fade, granting ever-new rounds of investments in molecular biology and the biotech sector (Lewontin 2001, p. xxii).

Meanwhile, in the absence of present profits, the control of foundational patents on CRISPR-Cas9 sustains the volatile financial valuation of CRISPR platform companies (Coriat and Orsi 2002; Zeller 2007). These CRISPR assets must be *monetised* not only to generate revenues in the present, but also to support highly speculative promises of future revenues, which play a key role in financial valuation. This monetisation of patented assets, as this section has shown, takes place through the construction of highly contingent and contested infrastructures of rent extraction. Yet, neither patents nor infrastructures of rent-extraction are established once and for all in the global biopolitical economy. As we will see in the next section, rent remains a contested and unstable social process of appropriation that must be constantly policed, reproduced and reinforced to persist over time.

4. Genomic Neocolonialism and Uneven Patent Geographies

Rent extraction is often portrayed as a parasitic activity that simply relies on passively leeching off industrial production and entrepreneurship (Hudson 2012, Veblen 2017, p. 20; p. 140; Yrigoy 2020, pp. 82–83). Yet, it requires continuous bureaucratic and juridical work of law-making, enforcement and policing. The expanded reproduction of architectures of rent-extraction employs a growing army of lawyers, lobbyists and technical experts who appropriate a substantial portion of the rents generated by intellectual property monopolies. The early 2000s saw a sharp rise in patent litigation both in the United States and in the EU (Cohen, Gurun, and Kominers 2016); while, in the first half of the 2010s, patent litigation slowed down only to pick up again with the beginning of the Covid-19 pandemic (Aon 2023).

This increase in litigation has been associated with the rising number of patents and the increasing complexity of the global patenting system (Alcacer, Beukel, and Cassiman 2017). However, the ongoing reconfiguration of corporate power has also had a decisive impact on raising the costs associated with reproducing intellectual property monopolies. In 2023, roughly 42 per cent of patent litigation cases filed in US courts of law involve technology companies operating in the digital, pharmaceutical and biotech sectors (Aon 2023). As the business strategies of many of these companies heavily rely on architectures of rent-extraction founded on intangible assets such as brands and patents,

infringement litigation has emerged as both a prominent strategy of capital accumulation and an offensive mechanism that discourages competition (Kafouros, Aliyev, and Krammer 2021).

Particularly high levels of patent litigation have been associated with the activities of so-called 'non-practicing entities' (NPEs), which are generally characterised as 'firms that generate no products but amass patent portfolios for the sake of enforcing IP rights' (Bergin 2022; Cohen, Gurun, and Kominers 2016, p. 521). In 2021, NPEs filed a staggering 63 per cent of patent litigations in the United States. In the European Union, the activity of NPEs — while less researched — is also on the rise (Papst 2010; Sterzi, Maronero, and Orsatti 2021).Although CRISPR platform companies such as Caribou and Editas pursue research and development activities aimed at commercialisation, they also engage in the same, highly conflictual practices of patent monetisation that characterise NPEs.

As we have seen, patents on CRISPR-Cas9 underlie elaborate structures of rent extraction based on licensing and sublicensing, which allow multiple actors to monetise highly unstable and contested intellectual property monopolies. The creation of these intellectual monopolies, as Kean Birch (2020:, 15) points out, represents an active process of juridical production since 'things are transformed into assets, they do not automatically take on the asset form.' Yet, things are never turned into assets once and for all. Intellectual monopolies need to be constantly propped up and secured. Assetisation, as a social process, must be continuously reproduced. In this third and final section, we focus on how patent holders secure their monopoly power over gene editing technologies from rival corporations, regulatory states and antagonistic political movements while working to expand their channels of rent extraction around the globe. Bureaucratic labour, capital investments and political lobbying all contribute to this expanded reproduction of genome editing technologies as financial assets.

CRISPR platform companies not only play a key role in extracting rents from patented assets; they also contribute to securing the patent portfolio detained by both the Broad Institute and the CVC. In fact, both Caribou's and Editas' licensing contracts contain clauses that oblige them to reimburse patent holders 'for expenses associated with the prosecution and maintenance' of their property rights (Caribou 2023, p. 29; Editas 2023, p. 17). Given the extremely volatile and contentious patent landscape, these expenses have a considerable impact on the companies' budget. According to Editas' reports, over three years the company reimbursed the Broad Institute an aggregate of $32.5 million for the 'prosecution and maintenance of the Harvard/Broad Cas9-I Patent Rights' (Editas 2023, p. 141). Similarly, Caribou reimbursed $15.6 million to the University of California to cover the legal and administrative fees necessary to maintain, protect and possibly expand their patent portfolio (Caribou 2023, p. f-19).

Sharing the substantial financial burden associated with reproducing and securing intellectual monopolies has been one of the drivers that led to increasing cooperation between the US-based Caribou Biosciences (which originally obtained its exclusive licence through a deal with the University of California and Vienna) and the two Swiss companies formed to manage Charpentier's patent monopoly: CRISPR Therapeutics and ERS Genomics. Under the pressure caused by several challenges to their monopoly power, the three CRISPR firms have joined in an alliance to coordinate the defence and enforcement of their patent portfolio. The deal includes a global, mutual recognition

of the legitimacy of the patents they control and a system for sharing the expenses associated with enforcement and litigation (Caribou 2023, p. 36, 88). The formation of this strategic alliance exposes the fact that occasional collaborations exist in contradictory constellations with widespread competition amongst CRISPR firms.

Both the University of California and the Broad Institute — together with hundreds of other institutions controlling patented CRISPR constructs — have agreed to make their intellectual properties available to academic organisations pursuing basic research through AddGene, a non-profit repository of CRISPR technologies (La Manna and Barrangou 2018). Since 2013, AddGene has shipped hundreds of thousands of CRISPR plasmids to five thousand organisations in over a hundred countries (Pyhtila et al. 2023). Through this policy, CRISPR companies support basic research by enabling free access to their patent monopoly. This is often presented as a charitable concession by patent owners applying forms of 'ethical licensing' (Nature Biotechnology 2022; Panagopoulos and Sideri 2021). It is a concession, however, that has the additional advantage of encouraging forms of scientific experimentation with CRISPR gene editing that may eventually lead to further revenues. Stimulating basic research provides further opportunities for enclosing the resulting knowledge. Moreover, even if basic research is not subject to rent extraction, any spin-off company intending to capitalise on that research is likely to become a source of royalty income to at least one of the CRISPR patent holders.

Extracting these future rents, however, depends on the capacity of CRISPR platform companies to continuously reproduce and expand their patent holdings. Millions of dollars are spent every year to preserve those patents' capacity to continue generating rents in the future, warding off four fundamental threats: rival challenges, patent circumventions, regulatory shifts and political contestations. First, Editas expends considerable resources to prevent the CVC from *undermining* its patent portfolio. The corporation emphasises that the patents on which it holds an exclusive licence are 'subject to priority and validity disputes' and that if 'we or our licensors are unsuccessful in any of these proceedings, we may be required to obtain licenses from third parties, which may not be available on commercially reasonable terms or at all' (Editas 2023, p. 5). Conversely, Caribou Biosciences stresses that the intellectual property on which it has built its business is 'the source of several disputes in the USPTO, the EPO, and other patent offices' and that if it was to lose these legal disputes — including the one funded by Editas and the Broad Institute — its 'ability to continue to receive licensing revenue and enter into new licensing agreements related to the foundational CRISPR-Cas9 intellectual property will be substantially impaired' (Caribou 2023, p. 76).

A second risk stressed by both Caribou and Editas is that other biotech companies may soon be able to *circumvent* their patent monopolies 'by developing similar or alternative technologies or products in a non-infringing manner' (Editas 2023, p. 75). While the CVC and the Broad strive to reproduce and protect their monopolistic control over CRISPR-Cas9, rival biotech corporations have already patented alternative CRISPR gene editing methods that mobilise different enzymes. Inscripta, for instance, has patented a CRISPR-Mad7 construct, which has been presented as an alternative 'IP-friendly CRISPR enzyme' (Rojek et al. 2021). A new generation of CRISPR genome editors — such as base editing, prime editing and epigenome editing systems — is already partially supplanting the CRISPR-Cas9 editing system (Ledford 2023).

Third, both companies express preoccupation towards any future 'patent reform legislation' — in the US or abroad — that 'may weaken our ability to obtain new patents or to enforce our existing patents' (Caribou 2023, p. 79; Editas 2023, p. 75). The recent ruling by the US Supreme Court in *Association for Molecular Pathology v. Myriad Genetics, Inc.* is presented by Caribou as a paradigmatic example of how such *regulatory shifts* may unpredictably invalidate a company's patent portfolio. In the context of widespread protests against the monopolisation of testing procedures on breast cancer based on the BRCA1 and BRCA2 genes, the Court determined that a 'naturally occurring DNA segment is a product of nature and not patent eligible merely because it has been isolated' (USSC 2013). The decision invalidated Myriad Genetics' patent portfolio, effectively disrupting its monopoly over a potentially life-saving testing technology. It also halted the proliferation of corporate patents on isolated human genes, partially restraining and reshaping the development of the genomic industry (Nye 2019).

While CRISPR-Cas patent monopolies are not directly threatened by this juridical shift, they are also becoming a target of multiple *political contestations*. Scientists have argued that the patents overstate the 'inventiveness' of what are rather limited modulations of biological processes and that, therefore, they should be invalidated as an unwarranted appropriation of natural processes (Contreras and Sherkow 2017; Hochster 2022). Meanwhile, activists and social scientists contest the same patents as representing an enclosure of collectively produced knowledge, emphasising the extent to which the logic of patenting misrepresents the collaborative nature of scientific research (Kozubek 2018, pp. 20–21; Matthews 2022).

These political disputes could lead to juridical shifts, which would threaten the rent-extractive practices put in place by CRISPR platform companies. Caribou reports that 'the laws and regulations governing patents could change in unpredictable ways, […] which could have a material adverse effect on our existing patent portfolio and those of our licensors.' It then adds that, even in the absence of significant shifts in patent law, 'more restrictive government regulations or negative public opinion would have a negative effect on our business or financial condition' (Caribou 2023, p. 67). In other words, political debates surrounding gene editing technologies — and their political, economic, social, and ecological implications — partially undermine the promissory futures carefully fabricated by biotech corporations. By subverting speculations on CRISPR assets, public protests have a direct and immediate financial impact in the present.

The necessity of managing and directing public perceptions of genome editing has led to growing lobbying and public outreach by biotech companies both in the US and the EU (CEO 2021; Florko 2019; Goodman 2023, pp. 53–70). The constant labour employed to protect and enforce CRISPR patents is indicative of the extent to which rent — as a redistributive mechanism that facilitates the accumulation of financial and technoscientific capital — remains a contested social relationship of power. Andreucci et al. (2017, p. 28) have emphasised this dual character of rent as 'a social relation and a distributional process that is increasingly central to the reproduction of contemporary capitalism.' If rent is both a socially constructed process (Part 1) and a form of economic redistribution (Parts 2-3), we can now ask: from where to where does the value get redistributed? What geographies of redistribution can be gleaned from the ever-shifting CRISPR patent constellation?

Schematically, we may distinguish between practices of *vertical extraction of value* (by which diffused processes of social production of knowledge are enclosed by private corporations acquiring intellectual property monopolies) and practices of *horizontal extraction of value* (by which rents and royalties are channelled into global infrastructures of rent-extractions tilted towards the hegemonic centres of intellectual monopoly power). Focusing on practices of enclosure of knowledge, the monetisation of CRISPR assets redistributes resources from the public to the private sector. In this way, state research funding is converted into private streams of rent. As Mariana Mazzucato (2011, 2015) has convincingly shown, private capital continues to rely on state investments in basic scientific research. Throughout the 1990s, early research in genome sequencing and targeted genetic modification benefited from large state investments (Eagan 2020; Pohlhaus and Cook-Deegan 2008). Public institutions from multiple states still provide the primary source of funding in molecular biology — including most basic research on CRISPR-Cas immune systems in bacteria (Fajardo-Ortiz, Shattuck, and Hornbostel 2020, 2022; Grobler, Suleman, and Raj 2021; Levrier 2021; Martin-Laffon, Kuntz, and Ricroch 2019).

The key role played by different US governmental agencies in funding CRISPR research is indicative of the extent to which genome editing is considered a foundational technology that may support the activities of multiple industries: what in Marxian terms may also be defined as a 'general condition of production' (Marx 1993, pp. 526–531). As such, genome editing attracts the interest of a wide variety of public institutions operating across different governmental and politico-economic spheres, including: health (National Institute of Health, National Institute of General Medical Sciences, National Cancer Institute); energy (Department of Energy); agriculture (Department of Agriculture, Agricultural Research Service); and the military, where the Department of Defense, the Defense Advanced Research Projects Agency, and the Defense Threat Reduction Agency play a major supporting role (Fajardo-Ortiz, Shattuck, and Hornbostel 2020, 2022; Gundersen-Rindal et al. 2017). Each of these institutions has its funding programmes, which shape in distinct ways what kind of genome editing research is pursued, and what type of targeted mutations are experimented on living organisms.

Philanthropic organisations play a pivotal and under-theorised role in mediating processes of neoliberal appropriation of this publicly funded research. As stressed by a growing literature, they function as a technoscientific conveyor belt that translates the scientific knowledge produced by public institutions into applied techniques, which can be more easily taken up by industry (Birn 2014; Kumar and Brooks 2021). In the specific context of CRISPR research, philanthropic organisations such as the Bill & Melinda Gates Foundation, the Burroughs Wellcome Fund, and the Howard Hughes Medical Institute have played an important role, allocating most of their funding to the conversion of basic research on bacterial CRISPR systems into applied research aimed at the construction and improvement of genome editing tools. As noted by Fajardo-Ortiz and colleagues, these philanthropic organisations further 'the socialization of risk and the privatization of profits that comes from the basic/applied division of labour between the public and the private sector' (Fajardo-Ortiz et al. 2022, p. 453). The Broad Institute is a paradigmatic example of how philanthro-capitalist practices can facilitate the accumulation of capital. As a non-profit, tax-exempt research organisation, it receives streams of funding from public institutions and charities to further its

research. Yet, the economic benefits of that research are largely appropriated by its spin-off corporation: Editas Medicine, Inc.

By appropriating public research conducted all around the world, with the facilitating mediation of philanthro-capitalist foundations, private corporations can dedicate most of their financial resources to the development of gene editing strategies aimed at directing the metabolism of bacteria, plants and animals (Fajardo-Ortiz et al. 2022). These applied techniques — as well as the resulting gene-edited organisms — can then be patented. CRISPR technologies, in other words, are patented assets that are employed by licensing corporations to produce more patented assets. According to a recent study, the genome editing patent landscape went from 96 patent families in 2014 to over 7,400 in 2020 (IP Studies 2020). Some of these patents claim improved or modified versions of the gene editing tool; some claim particular procedures to master its application in different living cells and bodies; others claim monopoly ownership over organisms whose genome has been modified with the use of CRISPR-Cas9. In this sense, CRISPR patents can be read as an example of enclosure in a specifically neoliberal form by which a handful of companies are privatising the economic benefits — and socialising the substantial socio-ecological risks — of genome editing technologies emerging from social cooperation on a global scale (Coriat and Weinstein 2012; Laplane and Mazzucato 2020; Orsi and Coriat 2006; Rikap 2021).

Multiple studies have mapped a geographical bias in this rapidly expanding 'global CRISPR patent landscape', with an overwhelming majority of foundational CRISPR patents being held in the United States (Chowdhury and Gargate 2021; Ghosh 2020; Martin-Laffon, Kuntz, and Ricroch 2019). According to a recent quantitative review, US-based institutions hold most foundational patents on the CRISPR-Cas9 gene editing system and control over 47 per cent of patents related to its technical improvement and industrial applications (Martin-Laffon, Kuntz, and Ricroch 2019, pp. 614–615). Many of these patents are originally deposited in the United States. They are then replicated in other countries to ensure patent enforcement across borders. As of December 2023, the files publicly available at the World Intellectual Property Organization indicate that the foundational CRISPR patent originally deposited by the CVC at the US Patent Office in May 2012 has now been registered in at least 59 other countries (WIPO 2023). The patent web spun by the CVC encompasses global economic powers — such as the US, EU, China, Japan, and Russia — as well as indebted economies in the Global South such as India, Kenya, Thailand, Peru, Ecuador, and the Philippines (ERS Genomics 2023; UC Berkeley 2019; WIPO 2023).

In recent years, several Chinese institutions have also affirmed themselves as global centres of gene editing research. In fact, according to recent estimates, Chinese institutions control over 60 per cent of existing patents applying CRISPR genome editing to crops and livestock (Martin-Laffon, Kuntz, and Ricroch 2019, p. 618; Levrier 2021). China Agricultural University and the Chinese Academies of Sciences and Agricultural Sciences are at the forefront of this mobilisation. These patents, however, are rarely extended to other countries and, therefore, have been interpreted as serving mostly a protectionist purpose (IP Studies 2015; Martin-Laffon, Kuntz, and Ricroch 2019).

This uneven global patent geography is enforced by the World Trade Organisation (WTO) and the World Intellectual Property Organization (WIPO) through the Trade Related Aspects of Intellectual Property Rights (TRIPS). Ratified in 1994, the TRIPS

represented a globalisation of the US patent regime, which transformed biological processes and objects into patentable artefacts. In the lead-up to and aftermath of TRIPS, scholars and activists highlighted how the globalisation of this patent regime was the vehicle by which corporations based in the Global North appropriated and enclosed biological resources — and traditional knowledges of those biological resources — from the Global South (Mgbeoji 2001; Hayden 2003; Parry 2004; Shiva 2016, p. 6). These bioprospecting practices continue to this day and increasingly inform emerging research on CRISPR genome editing technologies. For instance, CRISPR-Mad7™ — a genome editing tool engineered, patented and commercialised by Inscripta, Inc. and licensed by corporations such as Ginkgo Bioworks — mobilises the *Er*Cas12a enzyme found in 'a bacterial strain isolated in Madagascar which, presumably, shows a greater protein sequence divergence from its closest relatives due to long-term separate evolution' (Pietralla et al. 2023, p. 402).

Writing on copyright as 'colonial doctrine,' Alpana Roy (2008, p. 124) has argued that IP protection via TRIPS constitutes a 'neocolonial instrument': 'a product of the European Enlightenment […] infused with the ideals of the liberal legal tradition,' which enshrines specifically Western ideals 'such as 'private property', 'authorship' and 'possessive individualism'' as 'universal principles of property law.' The coloniality of the global patent framework stems from the concept of patents itself, but also from the specific political geographies that characterise the implementation of the TRIPS agreements. In this vein, Poku Adusei (2008:, 28) points out that countries in Sub-Saharan Africa, after being marginalised from TRIPS negotiations, have been compelled to operate as 'toll collectors for giant pharmaceutical corporations.' The recent proliferation of bilateral investment treaties and regional pacts has further solidified intellectual property monopolies, eroding the limited flexibilities still granted to sovereign states under the TRIPS regime (Dreyfuss and Frankel 2014, p. 56). As a result of ongoing processes of juridical harmonisation and standardisation, patents are increasingly becoming *global assets*, which can be invested in with more secure expectations of future financial returns.

The redistribution of technoscientific rents remains profoundly unequal. In 2001, companies 'in the capitalist metropolises received 97 percent' of the total licence payments circulating in the global economy (Zeller 2007). Two decades later, Chinese companies have started to capture larger portions of these global rents, but companies based in the US and Canada continue to occupy a hegemonic position. In 2019, they still appropriated 31 per cent of worldwide intangible rents (Buckley et al. 2022). Intellectual monopolies — globalised and enforced through the WTO, but also increasingly through alternative investor-state arbitration procedures that grant even more protection to patent holders — continue channelling streams of rents to the Global North, while leading to prohibitive prices for pharmaceutical and medical products (Das 2020; Mgbeoji 2012; Motari et al. 2021). It is in this sense that Jayati Ghosh (2015) has suggested that global patent law represents one of the essential foundations of the 'institutional architecture' of 'the next imperialism.'

CRISPR patents are a constituent part of this neocolonial geography fuelled by practices of rent extraction. While no statistical data are yet available, the globalisation of genome editing technologies is likely to reproduce uneven global geographies of circulation of capital. Given the concentration of foundational patents in the United States,

the more CRISPR-Cas9 is applied in global production, the more rents are likely to flow towards that part of the world — at least until patents on the basic technology as they currently stand are upheld, and the four major threats to them are kept at bay. Critical literature has contributed to describing the multiple neocolonial practices of commodification and rent extraction that characterise the biotech industry (Bezner Kerr and Wynberg 2024; Feeney-McCandless 2022; Lapegna and Perelmuter 2020; Pfrimer and Barbosa 2017). The introduction of CRISPR-based techniques offers opportunities to extend such practices in time and space. For instance, patents on many transgenic crops originally introduced in the 1990s have already expired, eroding the monopolistic positions held by companies such as Monsanto (Filomeno 2013; Pérez Trento 2021, p. 165). By introducing a new generation of genome-edited organisms, agribusiness companies can restore their monopolistic positions and revive their rent-extractive practices.[6] The adoption of CRISPR technologies may also open new frontiers of capital accumulation. Several countries that have limited the commercialisation of transgenic crops will not extend the same regulations to the new generation of genetically modified organisms (Policante and Borg 2024).

In recent years, however, a growing global movement has arisen in opposition to CRISPR patents. Its emergence mirrors larger debates surrounding patents in the life sciences. Since the Covid-19 pandemic, pharma companies have been subject to global pressures for a waiver on mRNA vaccines — another major product of the genomic industry (Bajaj, Maki, and Stanford 2022; Singh et al. 2023; Thambisetty et al. 2022). This pressure has so far been successfully resisted by pharmaceutical corporations (Paremoer and Pollock 2022). According to Amspor Hagan (2023), millions of people have been consequently confined in a 'violent condition of waithood' from potentially life-saving interventions, while pharmaceutical corporations accumulate super-profits by preventing other institutions — such as the WHO-backed Afrigen — from producing equivalent products.

While most of the recent debates on intellectual monopolies — and their neocolonial geographies — have been focused on mRNA vaccines, many of the questions posed equally apply to other products of the genomic industry. In the specific context of emergent discussions on CRISPR-Cas technologies, the movement has been concerned with how monopoly power tends to privatise the economic benefits of increasingly widespread genome editing practices while socialising the substantial socio-ecological risks. A growing number of voices are thus demanding that either patent holders waive — partially or completely — their monopolistic control (Gundavajhala 2023; Kamwendo 2022; Nature 2021; van der Oost and Fresco 2021); or that sovereign states invalidate the patents by leveraging article 27.2 of the TRIPS Agreement, which grants the possibility of preventing the exploitation of patents 'to protect human, animal or plant life or health or to avoid serious prejudice to the environment' (Matthews 2022).

[6]A paradigmatic example of how genome editing technologies enable the extension of rent-extractive practices is represented by the growing practice of "gene editing GM traits." For instance, Inari, Inc. has already patented "INHT31 soybean plants comprising an edited MON-89788 soybean trait." This is the trait originally associated with Genuity®, Monsanto's variety of glyphosate-tolerant soy introduced in 2007. According to Inari, "the suite of GM traits to be delivered through gene editing will have the same functionality as those currently on the market, which have been proven effective by growers" (Inari 2022). In this way, Roundup-Ready crops – and many of the environmental, economic, and social questions associated with their protracted use (Lapegna and Perelmuter 2020; Pérez Trento 2021) – are being reinvented as innovative CRISPR crops, protected by newly coined patents.

These demands must be contextualised as being part of a new, rapidly emerging genomic politics. In the context of widespread bio-fin-tech futurism, these political struggles range from: the contested ownership and control over isolated genetic sequences and genetically engineered organisms; the risks associated with altering global ecosystems by purposefully modifying the metabolism of bacteria, plants and animals; the violence inherent to genetic experimentation with sentient animals; the erasure of Indigenous knowledges, worldviews and relationships with lived ecologies; the unequal access to health caused by skyrocketing rates of profit and multiple layers of rent extraction; the difficulty of preventing gene therapy products from being turned into means of further pharmaceuticalisation of everyday life; the known and unknown risks associated with direct manipulations of the human genome; the emergence of new forms of neoliberal eugenics, medical racism and ableist discrimination. The list is set to grow longer as genome editing practices are increasingly adopted by industrial corporations operating across borders.

Multiple and interlinked global movements — mobilising against racism, colonialism, ecological violence and patriarchal gender oppression — are challenging the political, economic and regulatory regime currently facilitating the exercise of corporate monopoly power on genome editing technologies. They also indicate the necessity of a wider political and democratic debate that would include the socio-economic, ethical, and ecological concerns most clearly stressed by Indigenous and peasant movements around the world (Tauli-Corpuz 2001). These struggles pose fundamental questions: How will bioengineered bacterial, animal and plant bodies transform the way people live and work in agricultural lands, industrial facilities, barnyards and slaughterhouses, biotech labs and medical clinics? How will they affect lived ecologies? What types of multi-species worlds are being constructed through bioengineering practices, by whom and according to what political visions?

5. Conclusion

This article has analysed how the global patent regime encloses public research and facilitates the transformation of CRISPR technologies into privately owned assets. It has shown how a maze of rent extraction has been erected on the unstable and fractured colonial geographies of intellectual property protection. CRISPR assets channel public funding towards multiple forms of experimentation with gene editing technologies, which mostly serve the accumulation strategies of industrial conglomerates looking to 'improve' the living means of production mobilised in their global commodity-chains. Once projected on a planetary scale, gene editing technologies reinforce unequal geographies of rent extraction. They enable new forms of imperialist appropriation based on highly concentrated intellectual property monopolies. Analysing the assetisation, monetisation and expanded reproduction of CRISPR-Cas technologies provides important insights into the shifting landscapes of intellectual monopoly capitalism.

However, the politics of CRISPR futures extend beyond settling what type of access and benefit-sharing agreements should apply to gene editing technologies and gene-edited organisms. Establishing ownership over CRISPR is the key to controlling who will get to shape the genomic composition of countless biological organisms and thereby transform global ecosystems and lived environments. Currently, the global

governance of gene editing technologies has been mostly concentrated in the hands of private corporations (Jasanoff, Hurlbut, and Saha 2015; Policante and Borg 2024).

Recognizing its newly acquired political role, the Broad Institute has strived to include socio-political, ecological and ethical considerations in its licensing strategies. In a document titled 'Policy Considerations,' the organisation recognises that 'just as in biomedicine, the use of genome editing in agriculture raises important ethical and safety concerns.' It then declares the intention to impose 'important restrictions' to the commercial distribution of CRISPR-Cas technologies, including 'the prohibition to using the licensed technology' for specific purposes, such as: 'to create sterile seeds'; 'to modify tobacco' for the production of addictive products; to advance research towards risky 'gene drives,' which rapidly spread by increasing the likelihood that edited genes will be passed onto the next generation (Broad Institute 2016).

These voluntary limitations, which currently restrain Broad's licensing strategy, have been celebrated as a positive example of 'ethical licensing' (Sherkow 2017) and 'private governance' (de Graeff et al. 2018). According to Grobler and colleagues (2021, p. 175), they represent a powerful justification for monopoly ownership over genome editing technologies since exclusive corporate control 'protects the technology from being exploited for unethical use.' Yet, the political power granted to private corporations raises a number of highly contested issues: What kind of regulatory guidelines and economic interests will influence the application of gene editing technologies on living organisms around the globe? To what extent are patents on foundational technologies such as CRISPR-Cas9 privatising governance, taking vital decisions out of democratic debates? What would a more radical democratisation of gene editing technologies entail?

As recently noted by Indigenous scholars Riley Taitingfong and Anika Ullah (2021) in their discussion concerning the impact of genome editing technologies on Indigenous communities, communal networks of knowledge-sharing and open assemblies for inclusive decision-making on the common genomic heritage may represent a first step towards empowering communities and countering corporate control (Blasimme 2019; Hartley, Taitingfong, and Fidelman 2022). New methodologies to measure the economic, social, and ecological impact of such technologies may also play a role in informing public debate and open decision-making concerning how to develop, regulate or even ban specific research programs and technoscientific applications (Florio 2019). Ultimately, a shift away from neoliberal models founded on the systematic privatisation of knowledge might open new ways of conducting scientific research in the interest of preserving and fostering life in the global ecological commons (Florio 2023; WFSD 2018).

These political debates, concerns and struggles are not entirely new. In many ways, genome editing technologies represent only the most recent development in a long quest for increasing control over living processes (Bonneuil and Thomas 2009; Borg and Policante 2022; Kloppenburg 2005; Krimsky 2019). As has long been recognised by STS scholars and many others, technologies are material embodiments of historically and geographically uneven socio-ecological relations. As such, they incorporate the multiple, intertwined contradictions characterising racial capitalism, patriarchy and imperialism (Åsberg and Lykke 2010; Mascarenhas 2018; McKittrick 2020; Noble 2018; Weheliye 2014). The manifold histories of genetic technologies are inseparable from the intersections of racialised, gendered, ableist and ecological violence that crisscrossed the early history of molecular biology and that continue to shape its development in the

present (Barnhill-Dilling, Rivers, and Delborne 2020; Di Chiro 2007; Garland-Thomson 2020; Harry, Howard, and Shelton 2001; M'charek 2021; Tauli-Corpuz 2001).

However, the introduction of genome editing technologies also marks a significant landmark in this long historical trajectory. CRISPR techniques facilitate an unprecedented automation of laboratory procedures of genetic modification (Cohen 2016; Wang and Doudna 2023). This development lowers the cost of engineering living bodies as means of production, functionally moulding their metabolism and physiology. Confining debates around the political economy of CRISPR to narrow questions of patent regimes risks obscuring the consolidation of a growing *corporate biopower* to decide which targeted genomics mutations are done, how, why, by whom, and for whom. Conversely, narrating the story of genome editing technologies as simply part of capital's teleological march obscures the political ruptures immanent in contemporary struggles over the molecular means of production.

In this article, we have strived to offer an account of the web of power that sustains and mediates current applications of genome editing technologies. We reflected on the implications of corporate control over a foundational technology of the emerging biopolitical economy. Yet, we also strived to show the extent to which these architectures of power remain profoundly unstable and contested. The scientific epistemologies and corporate networks underlying gene editing technologies — their embodied and reified sociotechnical histories — are as unstable as the architectures of rent extraction erected upon them.

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