

Essays

Redesigning the Antibiotic Market for Survival: How Artificial Intelligence May Address the Economic Failure in Combating Antimicrobial Resistance

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Antimicrobial resistance (AMR) represents one of the most severe global health crises of the twenty-first century, responsible for roughly 1.27 million direct deaths in 2019 and projected to cause 1.91 million attributable deaths annually by 2050. Yet no genuinely new class of antibiotics has reached patients in over three decades, not because the science has failed, but because the market has. The inverted incentive logic of antibiotic development, in which the most medically valuable drugs are deliberately rationed and modestly priced, renders the category commercially unsustainable. This essay argues that generative artificial intelligence offers a structural solution to this impasse by fundamentally compressing discovery costs and enabling a licensing-based platform business model that decouples commercial sustainability from the revenue constraints inherent to antibiotic sales. Drawing on recent empirical breakthroughs, the essay demonstrates that the technology underpinning this model has already been validated. The proposed platform architecture resolves the three structural contradictions, namely prohibitive discovery costs, concentrated revenue risk, and thin pipelines, that have driven major pharmaceutical firms out of antibiotic research.

In 1945, upon receiving the Nobel Prize for the discovery of penicillin, Alexander Fleming issued a warning that would later prove prophetic: the indiscriminate use of antibiotics would inevitably select for resistant bacteria, rendering infections untreatable once again. Eight decades later, that prediction has materialized into one of the most severe health crises of the twenty-first century. Antimicrobial resistance (AMR) refers to the acquired ability of microorganisms to survive the very drugs designed to eliminate them. AMR was responsible for approximately 1.27 million direct deaths in 2019 (Antimicrobial Resistance Collaborators, 2022), a figure projected to rise to 1.91 million attributable deaths annually by 2050, with an additional 8.22 million deaths each year in which drug-resistant bacteria play a contributing role (Naghavi et al., 2024). The economic consequences are equally alarming. World Bank estimates suggest that AMR could reduce global GDP by as much as \$3.4 trillion annually by 2030, with the heaviest burden falling on low- and middle-income countries (Jonas & World Bank Group, 2017). The World Health Organization ranks AMR among the ten gravest threats to global public health. Yet no genuinely new class of antibiotics has reached patients in more than three decades (World Health Organization, 2022), despite unprecedented advances in the science of drug discovery (Hutchings et al., 2019).

Indeed, the central failure lies not in scientific capability but in the market itself. Developing a new antibiotic requires investments ranging from one to two billion dollars (DiMasi et al., 2016); however, the resulting products are prescribed only for short treatment courses, sold at relatively modest prices, and, when particularly effective, deliberately reserved as last-resort therapies to slow the emergence of resistance (Outterson & Rex, 2020). The stewardship practices that are medically essential therefore render antibiotics commercially unattractive. As a consequence, more than a dozen major pharmaceutical companies have exited antibiotic research since the turn of the millennium (Plackett, 2020), while several biotechnology firms that successfully brought new antibiotics to market later declared bankruptcy (Årdal et al., 2019). This commercial retreat continues to intensify. The 2026 Antimicrobial Resistance Benchmark reports a continued contraction of antibiotic development pipelines among major pharmaceutical firms, with antimicrobial R&D projects declining by roughly 35% since 2021 as companies redirect capital toward more profitable therapeutic categories (Access to Medicine Foundation, 2026).

This essay argues that generative artificial intelligence offers a structural solution to this impasse by fundamentally reshaping the cost architecture of antibiotic development to the point where an entirely new category of pharmaceutical business becomes commercially viable. AI

makes possible a discovery-and-licensing platform in which companies computationally design innovative molecular candidates, validate them in silico, and license the resulting intellectual property to pharmaceutical partners for clinical development and global commercialization. Importantly, the technological foundations for this model have already been empirically demonstrated.

The Structural Failure of the Antibiotic Market

To understand the transformative potential of artificial intelligence in this domain, it is necessary to examine why the antibiotic market has failed in ways that conventional policy instruments alone cannot resolve. The core issue is structural. Unlike almost every other pharmaceutical category, antibiotics operate under an inverted incentive logic. An oncology drug can generate billions in annual revenue because it is administered over months or years at premium prices. A successful antibiotic, by contrast, is prescribed for days, priced for broad accessibility, and, when especially effective against dangerous pathogens, deliberately rationed to delay the emergence of resistance (Morel & Mossialos, 2010). In effect, the commercial reward declines in direct proportion to the drug's public health value. Few other categories of medicine exhibit such a severe misalignment between societal value and commercial return.

This inverted logic creates a textbook example of market failure, albeit one with uniquely destructive downstream consequences. The social return associated with a novel antibiotic effective against carbapenem-resistant Enterobacteriaceae or extensively drug-resistant *Neisseria gonorrhoeae* is enormous, measurable in hundreds of thousands of lives and billions in avoided healthcare costs (Laxminarayan et al., 2013). Yet the private return available to firms developing such drugs falls so far short of required investment levels that capital markets have effectively classified the sector as uninvestable (Towse et al., 2017). The case of Achaogen is particularly illustrative. In 2019, the company declared bankruptcy only months after receiving FDA approval for plazomicin, a novel aminoglycoside antibiotic. Scientifically, the company succeeded; commercially, it failed almost simultaneously (Årdal et al., 2019). The signal to investors was unmistakable, and the global pipeline has narrowed accordingly. As of late 2022, only a limited number of truly novel-mechanism antibiotic candidates remained in clinical development worldwide (Butler et al., 2023; Theuretzbacher et al., 2019).

Governments have recognized this problem and responded on two fronts. On the supply side, push incentives such as grants, tax credits, and publicly funded research programs aim to reduce the upfront cost of discovery (Renwick et al., 2015). On the demand side, pull incentives such as prizes, advance market commitments, and subscription-based procurement models attempt to decouple revenue from sales volume. The United Kingdom's NHS pilot, which pays pharmaceutical firms a fixed annual fee for access to antibiotics regardless of prescription volume, represents perhaps the most ambitious example to date (Outterson & Rex, 2020). These mechanisms represent meaningful policy innovation, yet they share a common limitation: they pri-

marily address the revenue side of the equation while leaving the underlying cost structure of discovery largely unchanged. A drug that still requires over a billion dollars to develop remains a precarious commercial proposition irrespective of how revenue is ultimately structured. It is precisely this cost architecture that AI has the potential to transform.

How Generative AI Transforms the Cost Architecture of Discovery

Traditional antibiotic discovery follows a linear and extraordinarily expensive process. Researchers assemble or purchase libraries of existing chemical compounds, often numbering in the millions, and screen them through laboratory assays against target bacteria in search of rare molecules demonstrating antimicrobial activity. The limited number of successful hits then undergo iterative rounds of chemical optimization to improve potency, minimize toxicity, and refine pharmacokinetic properties. Only after these stages can a candidate proceed into preclinical and clinical development. From initial screening to regulatory approval, the process typically requires ten to fifteen years (Plackett, 2020). Attrition rates are extraordinarily high: for every drug that ultimately reaches patients, approximately ten thousand compounds are evaluated and discarded throughout the process (Paul et al., 2010).

Generative AI compresses this process and, in several important respects, fundamentally restructures it (Stokes et al., 2020). Rather than screening libraries of known chemicals, generative algorithms design entirely new molecular structures de novo, producing compounds that have never existed in nature or in synthetic databases (Gómez-Bombarelli et al., 2018). In a study published in *Cell* in August 2025, researchers from MIT's Antibiotics-AI Project employed fragment-based variational autoencoders and chemically reasonable mutation algorithms (CRoM) to design tens of millions of hypothetical compounds and computationally evaluate their antimicrobial properties (Krishnan et al., 2025). The most promising candidates proved structurally distinct from existing antibiotics and appeared to function through entirely novel mechanisms, disrupting bacterial cell membranes through pathways that current drugs do not exploit (Krishnan et al., 2025). Importantly, these AI-designed molecules demonstrated potent activity against drug-resistant *Neisseria gonorrhoeae* and methicillin-resistant *Staphylococcus aureus* (MRSA), two of the most urgent threats identified on the WHO Bacterial Priority Pathogens List (World Health Organization, 2024).

The economic implications of these developments are substantial. First, the most expensive stages of traditional drug development—candidate identification and lead optimization—can increasingly be executed computationally rather than through extensive laboratory experimentation, reducing discovery-stage costs by roughly an order of magnitude. Second, generative AI dramatically expands the searchable molecular universe from millions of known compounds to billions or even trillions of theoretically possible structures. This significantly increases the probability of identifying antibiotics with genuinely novel mechanisms

of action, precisely the category of drug the world most urgently requires and the category least likely to emerge through incremental modifications of existing scaffolds. Third, the computational speed of AI systems enables simultaneous exploration of candidates targeting multiple bacterial pathogens, an approach that would be prohibitively expensive under conventional laboratory-based workflows. Collectively, these advantages create the conditions for an entirely different type of pharmaceutical business model.

The ARM Holdings of Antibiotics

The convergence of these capabilities enables a business architecture that would previously have been commercially unsustainable. Consider a company positioned at the intersection of computational biology, pharmaceutical chemistry, and machine learning engineering, whose central operation consists of the continuous AI-driven generation and computational validation of novel antibiotic candidates. Critically, such a company would not carry drugs through the entire process of clinical trials and industrial manufacturing, the very trajectory responsible for bankrupting previous antibiotic developers. Instead, the platform would license its molecular intellectual property—including validated compound structures, mechanism-of-action data, and preclinical efficacy packages—to established pharmaceutical firms already possessing the regulatory expertise and clinical infrastructure necessary for large-scale commercialization.

A useful analogy can be drawn from the semiconductor industry. ARM Holdings does not manufacture chips; instead, it designs chip architectures and licenses them to firms such as Apple, Qualcomm, and Samsung, which integrate them into their own products. ARM generates substantial revenue through intellectual property licensing while avoiding the immense capital expenditures associated with fabrication. An AI-powered antibiotic platform would operate in structurally similar fashion, generating molecular intellectual property computationally and licensing it to a diversified network of global pharmaceutical partners operating across different geographies, therapeutic indications, and market segments.

This model addresses the three structural contradictions that have long constrained the antibiotic market. First, discovery costs decline substantially because computational generation and optimization replace years of physical laboratory screening (Mak & Pichika, 2019). Capital requirements consequently become compatible with venture-scale financing rather than requiring the balance sheets of multinational pharmaceutical corporations. Second, revenue becomes diversified across multiple licensing agreements spanning different regions, pathogens, and commercial partners rather than depending on the direct sales performance of a single product within a market deliberately constrained by stewardship practices. Third, risk is distributed across a continuously replenished portfolio of candidates rather than concentrated in one or two assets whose clinical failure could threaten the company's survival. In effect, the model decouples commercial viability from the revenue

limitations inherent to antibiotic sales, and it is precisely this decoupling that renders the enterprise investable.

From Public Investment to Private Platform

The proposed model does not rely solely on private capital. Its viability is reinforced by a broader ecosystem of public funding and institutional commitment that has accelerated considerably in recent years. GSK's November 2025 announcement of a £45 million partnership with the Fleming Initiative at Imperial College London represents one example among many. The initiative specifically targets Gram-negative bacteria, the pathogen class most resistant to current therapies and most neglected by commercial R&D investment, while integrating AI and high-throughput automation into discovery workflows (GSK, 2025). In the United States, ARPA-H launched the TARGET program (Transforming Antibiotic R&D with Generative AI to Stop Emerging Threats), channeling government investment into generative AI and deep learning for antibiotic development in a manner more closely resembling defense-sector procurement than traditional biomedical grant funding (ARPA-H, 2024). Academic research has evolved in parallel. De la Fuente's group at the University of Pennsylvania now trains machine learning systems on the proteomes of extinct species, including Neanderthals and woolly mammoths, identifying antimicrobial peptide sequences that evolution discarded but that still demonstrate activity against contemporary resistant organisms (Osiro et al., 2025). Collectively, these initiatives represent more than isolated investments; they reflect the emergence of an institutional infrastructure built around the premise that AI will become central to future antibiotic discovery.

A licensing platform built on AI-driven molecular generation integrates naturally into this ecosystem. Public grants and ARPA-H contracts absorb risk concentrated in the earliest stages of computational research, precisely where private investors are least inclined to commit capital. The FDA's Qualified Infectious Disease Product (QIDP) designation extends market exclusivity by five years for qualifying molecules, materially improving the value proposition for pharmaceutical firms evaluating licensing opportunities (Outterson & Rex, 2020). Subscription procurement systems, in which governments pay for guaranteed access to antibiotics irrespective of prescription volume, create a revenue floor that transforms licensing arrangements from speculative ventures into more predictable commercial relationships (Outterson & Rex, 2020). Positioned at the intersection of these mechanisms, the platform effectively becomes the connective infrastructure linking public investment, private commercialization, and clinical deployment.

Global Equity and the Architecture of Resilience

The burden of antimicrobial resistance is also distributed unevenly across the world. Mortality rates are highest in sub-Saharan Africa and South Asia, precisely the regions where healthcare infrastructure is weakest and access to advanced antibiotics is most limited (Antimicrobial Resis-

tance Collaborators, 2022). An AI-driven licensing model offers a practical mechanism for addressing this inequity. Tiered licensing structures, whereby molecular intellectual property is licensed at commercial rates to firms serving high-income markets while being offered on concessionary or royalty-free terms to manufacturers serving lower-income regions, align with existing pharmaceutical access frameworks and with the equity provisions outlined in the WHO Global Action Plan on Antimicrobial Resistance (World Health Organization, 2016).

Beyond equity considerations, the platform model also strengthens global health resilience. If multiple AI-driven discovery firms enter the market simultaneously, each generating novel candidates targeting different pathogens, the resulting ecosystem would produce a diversified global antibiotic pipeline whose continuity no longer depends on the survival of any individual company. This resilience is precisely what the current system lacks. The insolvency of a single firm can jeopardize access to critically important therapies, as nearly occurred with plazomicin following Achaogen's collapse in 2019. A distributed ecosystem of AI-based discovery platforms licensing molecules to diversified manufacturing networks across multiple jurisdictions would be structurally more robust and more consistent with the supply-chain resilience principles that increasingly shape international business strategy in the post-pandemic era.

Conclusion

At its core, the antimicrobial resistance crisis reflects a failure of market design: a structural misalignment between the immense social value of new antibiotics and the limited private returns available to those who develop them. Generative artificial intelligence has the potential to intervene directly at the root of this misalignment by reducing discovery costs, expanding the explorable molecular universe by orders of magnitude, and enabling a platform-based licensing model that decouples commercial sustainability from the constrained economics of antibiotic sales. The underlying technology has already been demonstrated. The supporting ecosystem of public investment is rapidly emerging. What remains absent is the enterprise capable of connecting these components into a scalable global system: a privately financed, internationally licensed, AI-powered discovery platform dedicated to producing the antibiotics the world most urgently needs. For the next generation of international business leaders, building such an enterprise may represent not only one of the most significant commercial opportunities of the coming decade, but also one of the most meaningful contributions business can make to the future of global public health.

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