BIOTECHNOLOGY AND CYCLE OF REPLACEMENT: ECONOMIC INCENTIVES AND ETHICAL RISK

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ABSTRACT

Planned obsolescence is typically associated with consumer electronics and industrial manufacturing, where products are intentionally designed to become outdated or nonfunctional after a certain period. In biotechnology, however, planned obsolescence manifests through more complex mechanisms involving patented biological systems, proprietary laboratory technologies, pharmaceutical reformulations and recurring dependency on genetic or diagnostic platforms. This article examines the emergence of planned obsolescence within biotechnology and evaluates its scientific, economic and ethical implications. The results indicate that biotechnology companies increasingly rely on upgrade cycles, subscription-based research systems and restricted biological ownership models that parallel traditional industrial obsolescence strategies. This discussion highlights the consequences for healthcare accessibility, scientific independence, agricultural sustainability and global inequality. The article concludes that while technological advancement remains essential for innovation, stronger regulatory oversight, open-source biotechnology initiatives and interoperable scientific platforms are necessary to prevent excessive technological dependency and the monopolization of biological resources.

Keywords: biotechnology, planned obsolescence, intellectual property, pharmaceutical innovation, technological dependency, bioethics.

INTRODUCTION

Biotechnology has become among the most transformative scientific fields of the twenty-first century, influencing medicine, agriculture, environmental science and industrial production [1]. Innovations such as CRISPR-Cas9 gene editing, synthetic biology, personalized medicine and genomic sequencing have dramatically expanded the ability of humans to manipulate living systems [2]. However, alongside these advances, concerns have emerged regarding corporate control, technological dependency and the commercialization of biological resources [3].

One important but understudied issue is planned obsolescence in biotechnology. Planned obsolescence refers to the deliberate design of products or systems with limited functional lifespans, encouraging continuous replacement or dependency [4]. While historically associated with electronics and consumer goods, similar strategies are becoming increasingly visible in biotechnology industries [5].

In biotechnology, obsolescence does not necessarily involve physical degradation. Instead, it may appear through:

- Patented seed systems that prevent reseeding [6],
- Proprietary laboratory platforms requiring exclusive reagents [7],
- Pharmaceutical reformulations extending patent protections [8],
- Software-dependent diagnostic technologies [9],
- Subscription-based genomic analysis services [10].

These systems create recurring economic dependence

and reinforce corporate control over essential biological technologies [11].

The growing integration of digital infrastructure with biotechnology has intensified these concerns [12]. Biotechnology companies increasingly combine hardware, software, data ownership and intellectual property into closed ecosystems that limit interoperability and long-term user autonomy [13].

The objective of this article is to analyse the mechanisms of planned obsolescence in biotechnology and evaluate their effects on scientific innovation, healthcare accessibility, agriculture and ethical governance [14].

EXPERIMENTAL

Research design

This study employed a qualitative analytical methodology based on a literature review, industrial case analysis and comparative technological assessment [15]. The investigation focused on identifying recurring patterns of planned obsolescence across multiple biotechnology sectors [16].

The research examined four major areas:

1. Agricultural biotechnology [6],
2. Pharmaceutical biotechnology [8],
3. Genomic diagnostics and laboratory systems [9],
4. Synthetic biology and programmable organisms [2].

Data collection

Scientific articles, biotechnology policy reports, patent analyses and industrial publications published between 2010 and 2026 were reviewed [15]. Information was collected from biotechnology journals, regulatory agency reports, corporate technology documentation, intellectual property databases and academic analyses of bioethics and innovation economics [14]. Major biotechnology corporations, including Illumina, Bayer and Syngenta were evaluated as representative examples of industrial biotechnology ecosystems [7].

Analytical framework

The study categorized planned obsolescence mechanisms into four operational types [5]:

Comparative analysis was conducted to evaluate the similarities between biotechnology and obsolescence and traditional industrial product cycles [17].

RESULTS AND DISCUSSION

Agricultural biotechnology and seed dependency

The analysis revealed that agricultural biotechnology is among the clearest examples of planned obsolescence [6]. Genetically modified crops are frequently protected under intellectual property agreements that prohibit seed savings and replanting [18].

In traditional agriculture, farmers preserve seeds from previous harvests for future cultivation [6]. Modern patented seed systems replace this cyclical sustainability with annual purchasing requirements [11].

Particularly controversial was the development of Genetic Use Restriction Technologies (GURTs),

Table 1. Types of planned obsolescence.

Type of Obsolescence	Description
Functional Obsolescence	Technologies become unsupported or incompatible.
Biological Obsolescence	Organisms engineered for limited reuse.
Regulatory Obsolescence	Older products phased out through regulatory redesign.
Economic Obsolescence	Recurring dependency through patents or subscriptions.

sometimes called "terminator seeds", which were designed to produce sterile offspring [18]. Although these technologies were never widely commercialized because of ethical opposition, they illustrate how biological systems can be engineered for controlled obsolescence [16].

This creates several consequences:

- Increased farmer dependency on corporations [6],
- Reduction in agricultural biodiversity [16],
- Higher production costs [5],
- Concentration of food system control [11].

These findings suggest that agricultural biotechnology transforms biological reproduction into a controlled commercial process [18].

Pharmaceutical obsolescence and patent extension

Pharmaceutical biotechnology frequently employs lifecycle extension strategies that resemble planned obsolescence [8]. Companies may introduce modified formulations or delivery mechanisms shortly before patent expiration to maintain market exclusivity [5].

Examples include the following:

- Extended-release formulations [8],
- Combination therapies [8],
- Biologic replacements for conventional drugs [1],
- Incremental molecular redesigns [8].

Biologic medicines are especially important because they are difficult to reproduce, making biosimilar competition limited and expensive [1].

These analyses indicate that healthcare systems can become economically dependent on continuously updated therapies, even when older alternatives remain medically viable [16]. This contributes to rising healthcare costs and unequal access to advanced treatment technologies [14].

Proprietary diagnostic platforms

Modern biotechnology laboratories increasingly depend on closed technological ecosystems [7]. Sequencing technologies, diagnostic devices and bioinformatics software often require proprietary consumables and licensed software updates [9].

For example:

- Certain sequencing instruments operate only with manufacturer-approved reagents [7],
- Software compatibility may expire after hardware updates [9],
- Cloud-based genomic analysis systems may require continuous subscription payments [10].

This article technological lock-in similar to digital consumer ecosystems [13].

Smaller research institutions and laboratories in developing countries are disproportionately affected because equipment replacement and software licensing are financially burdensome [16].

Consequently, scientific research becomes increasingly centralized among well-funded institutions and multinational corporations [3].

Synthetic biology and engineered lifecycles

Synthetic biology introduces new dimensions of planned obsolescence because living organisms themselves can be programmed with functional limitations [2].

Examples include the following:

- Nutrient-dependent engineered microbes [2],
- Environmental kill-switch systems [2],
- Temporary therapeutic organisms [1],
- Controlled replication mechanisms [18].

While many of these systems are designed for biosafety purposes, they also reinforce ownership and technological dependence [14].

The convergence of biology and software engineering may eventually enable the following:

- Subscription-based biological functions [13],
- Cloud-controlled bioengineering [12],
- Licensed genetic modules [18],
- Temporary programmable organisms [2].

These developments raise profound ethical regarding the ownership of living systems and long-term biological autonomy [14].

Ethical and societal implications

The results demonstrate that planned obsolescence in biotechnology extends beyond economics into broader societal concerns [16].

Healthcare inequality

Advanced biotechnology treatments may become accessible primarily to wealthy populations because of recurring costs and proprietary control [14].

Scientific dependency

Closed laboratory ecosystems reduce scientific

independence and limit reproducibility [7].

Food security risks

Dependence on patented agricultural systems may reduce resilience and increase vulnerability to supply disruptions [6].

Environmental sustainability

Frequent replacement of laboratory instruments and consumables to the accumulation of electronic and biometric waste [17].

These findings suggest that biotechnology obsolescence has systemic consequences that differ significantly from those of traditional consumer-product obsolescence because biological technologies directly affect public health and food systems [16, 19].

CONCLUSIONS

This study demonstrates that planned obsolescence has become an increasing relevant phenomenon within biotechnology [5]. Unlike traditional industrial products, biotechnology obsolescence operates through intellectual property systems, biological dependency, software integration and propriety research ecosystems [11].

The investigation identified four primary forms of biotechnology obsolescence:

- Biological dependency in agriculture [6]
- Patent-driven pharmaceutical replacement [8],
- Proprietary laboratory infrastructure [7],
- Programmable limitation in synthetic biology [2].

These systems create recurring economic dependency while concentrating technological power within a limited number of corporations [3].

Although continuous innovation remains necessary in biotechnology, excessive dependence on proprietary systems may undermine scientific accessibility, healthcare equity and agricultural sustainability [16]. The integration of digital technologies into biological systems further amplifies these concerns [12].

Future biotechnology governance should prioritize the following:

- Open scientific standards [20],
- Interoperable laboratory platforms [7],
- Ethical patent regulation [14],
- Public biotechnology infrastructure [15],
- Sustainable technological design [17].

Ultimately, biotechnology should balance commercial innovation with long-term societal benefits [14]. Without appropriate ethical and regulatory safeguards, planned obsolescence in biotechnology risks the transformation of essential biological resources into permanently controlled commercial dependencies [11].

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