ARTIFICIAL INTELLIGENCE (AI) IN LIFE SCIENCES: A REVIEW

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Abstract
Artificial Intelligence (AI) is transforming life sciences by enabling faster and more accurate analysis of biological and medical data. From predicting protein structures with Alpha Fold to understanding gene regulation with Alpha Genome and diagnosing diseases with AI-assisted pathology, these technologies are shaping modern biology and medicine. AI also plays a role in single-cell data analysis, drug discovery, and agriculture. This paper reviews major applications of AI in life sciences, highlights recent advances (2024–2025), and discusses challenges and future directions.
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Abbreviations: *scVI (single-cell variational inference), scANVI (Single-cell Annotated Variational Inference.*

Introduction

Life sciences deal with the study of living organisms, including their structure, function, and interactions. With the growth of advanced technologies, massive amounts of biological data are now generated through DNA sequencing, protein imaging, and medical diagnostics. Analyzing such large datasets is challenging for humans alone.

Artificial Intelligence (AI) helps in solving this problem by using machine learning (ML) and deep learning (DL) algorithms to recognize patterns, make predictions, and discover new insights (Topol, 2019). Applications of AI in life sciences include **protein structure prediction, single-cell analysis, disease diagnosis, and drug discovery**. This paper reviews these applications with examples of recent developments.

2. AI For Protein And Genome Research

2.1 Protein Structure Prediction with AlphaFold

Proteins are vital molecules in living organisms, and their structure determines their function. Experimental methods such as X-ray crystallography are time-consuming and costly. In 2021, DeepMind introduced **Alpha Fold**, which predicted protein 3D structures with high accuracy (Jumper et al., 2021). This was considered one of the biggest breakthroughs in biology.

2.2 AlphaGenome: Understanding Non-Coding DNA

In 2025, Deep Mind launched **Alpha Genome**, an AI system that predicts how DNA sequences—including non-coding regions—regulate gene expression. This is important because most diseases are linked to regulatory DNA variations (Deep Mind, 2025).

2.3 AI-Designed Proteins

In 2024, researchers created a synthetic protein called **esmGFP** (an AI-designed fluorescent protein). This protein was not found in nature but was designed using AI simulations of evolutionary processes (Lin et al., 2024). This shows that AI can be used not only to study life but also to create new biological molecules.

3. AI In Single-Cell Research

3.1 scVI and scANVI

Single-cell sequencing helps understand how individual cells behave in health and disease. AI models such as **scVI** (single-cell variational inference) use deep generative models to analyze millions of single-cell datasets efficiently (Lopez et al., 2018). Later, **scANVI** improved accuracy by combining labeled and unlabeled data (Gayoso et al., 2022).

3.2 Recent Advances (2024–2025)

- **ChromFound** (2025): A foundation model trained on nearly 2 million cells to study chromatin regulation (Zhou et al., 2025).
- **Instruct Cell** (2025): An AI assistant that allows users to analyze single-cell data using natural language instructions (Wang et al., 2025).
- **Deep Seq** (2025): Combines AI with web search to automatically label cell types with high accuracy (Liu et al., 2025).

These advances make single-cell analysis more accessible and powerful for biomedical research.

4. AI In Digital Pathology And Medical Diagnosis

4.1 Early Applications

In 2016, the CAMELYON16 challenge showed that AI could detect breast cancer metastases in lymph node slides with higher accuracy than most human pathologists (Bejnordi et al., 2017).

4.2 Clinical Applications (2024–2025)

- In 2025, researchers at the University of Cambridge developed an AI tool that diagnoses

coeliac disease from biopsy slides faster than pathologists (Sample, 2025).
- **GPT4DFCI** (2024) was developed to assist pathologists by combining AI image analysis with scientific evidence retrieval (Chen et al., 2023).
- **PatchSorter** was introduced as an AI-assisted labeling tool to help pathologists manage digital slides efficiently (Rajpurkar et al., 2024).

4.3 Market Growth

The global AI pathology market is projected to reach **$800 million by 2030**, with companies such as PathAI and Roche investing heavily (Grand View Research, 2023).

5. Broader Applications of AI In Life Sciences

5.1 Drug Discovery

AI speeds up drug discovery by predicting molecule-target interactions. For example, Insilico Medicine used AI to design drugs for fibrosis, which entered clinical trials (Zhavoronkov et al., 2020). In 2024, AI identified inhibitors of Parkinson's-related protein aggregation much faster than traditional methods (Lee et al., 2024).

5.2 Agriculture

In India, IIIT Allahabad developed an AI model **CVGG-16** that detects plant leaf diseases using smartphone cameras, helping farmers protect crops (Times of India, 2025).

5.3 Reducing Health Inequalities

AI is also being used to reduce healthcare disparities. The University of Pittsburgh's **CPACE project** applies AI tools to improve cancer diagnostics in underserved communities (Axios, 2025).

6. Challenges In Using AI

Despite its promise, AI in life sciences faces several challenges:

1. **Interpretability**: Many AI models act as "black boxes," making it hard to explain their decisions (Rudin, 2019).
2. **Scalability**: Training AI requires massive datasets and computing power.
3. **Validation**: AI tools need testing across diverse populations and clinical environments.
4. **Biosecurity Risks**: In 2024, experts warned that AI could potentially be misused to design harmful biological agents (Urbina et al., 2022).

7. Future Directions

The future of AI in life sciences includes:

- More transparent and interpretable AI models.
- Foundation models (like ChromFound) becoming standard tools.
- Integration of AI with laboratory automation and robotics.
- Stronger governance and ethical frameworks to ensure safe use.

8. Conclusion

Artificial Intelligence has emerged as a transformative force in the life sciences, offering unprecedented opportunities to analyze complex biological systems, accelerate drug discovery, personalize medicine, and deepen our understanding of health and disease. By integrating large-scale datasets—from genomics, transcriptomics, proteomics, and imaging—AI provides predictive models that can capture hidden patterns beyond human capability. Applications such as AI-powered diagnostics, precision oncology, protein structure prediction, and single-cell analysis (e.g., scVI and scANVI) highlight its potential to reshape both research and clinical practice.

Despite these advances, several challenges remain. Issues of **data quality, standardization, interpretability, and bias** must be addressed to ensure reliability and fairness in AI-driven discoveries. Ethical concerns, including patient privacy, accountability, and equitable access, also demand careful attention. Moreover, the integration of AI into everyday biomedical workflows requires interdisciplinary collaboration between computer scientists, biologists, clinicians, and policy-makers.

Looking ahead, the synergy between AI and life sciences is poised to **redefine biomedical research and healthcare delivery**. Future progress will depend not only on technological innovation but also on responsible governance, open data sharing, and transparent validation of AI models. If these conditions are met, AI will not merely serve as a tool for data analysis but as a **catalyst for a new era of precision, efficiency, and discovery in life sciences**, ultimately contributing to better human health and well-being.

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