AI in Biotechnology

(based on Potential Impacts of AI, by Alexandrina Gomes, **Beatriz Gonçalves, Bruno Inglês, Sara Silvério, Carlos A. Pinto et al.; https://www.mdpi.com/2076-3417/14/24/11801)**

This review will address how AI is being applied to societies' day-to-day problems and activities, as well as a more in-depth perspective of how AI is being applied and can be applied in the future within the biotechnology field, giving special attention to the fields of green, red, white, and blue biotechnology, and providing some opinions on what possibly can be achieved in the future using this technology.

Biotechnology refers to the use and manipulation of biological systems or living organisms to develop new technologies to improve our quality of life, with modern genetics and advanced computing playing key roles in its evolution . AI is mainly acting in the fields of biochemistry, genetics, and molecular biology, followed by agricultural and biological sciences and, finally, medicine.

The application of AI in the life science field can potentiate processes in a way that was never thought possible before. One of the ways that this is seen is in the development of drugs for medicinal purposes. Machine learning (ML) methods can transform drug discovery and development into cheaper, quicker, and more efficient processes by using large datasets of innumerous compounds and their respective biological activity in predictive software . In addition, the recent advancements in molecular sciences allowed a greater understanding of human biology, which facilitates the identification of defective molecular structures (drug targets) and consequently also facilitates the development of such drugs. Prior to these advancements, finding medicines for specific medical conditions was a random and inefficient process.

AI is crucial not only in the investigation process that occurs in laboratories and in data analysis, but also to assist in the extensive bibliographic research that must be conducted in every step of every project.

The biotechnological field is often divided into diverse colors, each corresponding to a specific area of study. The four main colors are green, red, white, and blue. The green sector covers the topics of plants and agricultural techniques, the red sector focuses on health, medicine, and therapeutics, the white sector focuses on the industrial branch, and the blue sector comprises everything that involves aquatic or marine systems.

Green Biotechnology (Agriculture)

Green biotechnology, as previously stated, focuses on techniques applied to all plant- and agricultural-related areas. The main current applications of AI in this area are mostly based on crop improvement through the creation of personalized algorithms dedicated to analyzing the physical and chemical state of crops, such as soil and weather information, which allows for rapid data processing and real-time responses for each individual need. Crop improvement is essential in facing the global challenges of food demand and security, which is each day more and more crucial.

One example of this is described in [26], where the authors describe the application of AI in soil health and quality by employing IoT (internet of things) sensors in a coffee plantation; this application analyses soil temperature, moisture, acidity, nutrient level,

CO_2 levels, and more, and transmits the data through a wireless connection. These data are gathered and then used for predicting soil conditions and crop hazards. In [27], the use of structured light imaging (SLI) is described as a technique to detect bruises on apples, which are invisible to the naked eye. The ability to detect invisible bruises on fruit in an agricultural situation can be very interesting for future prevention of problems causing unwanted bruises, which result in economic loss and food waste. AI is also being applied in pest control through an accurate, targeted application of fertilizers when and where they are needed. This represents a sustainable way to reduce the excess use of chemicals and to protect crops from contamination. AI technologies can also employ their image algorithms for monitoring crops' defects in shape, color, or size . Awais and colleagues (2024) described the development of an AI-controlled automated irrigation system with power generation which, with accurate weather forecasting and high-efficiency multi-layer solar panels, can become a more sustainable way of growing crops.

However, the dependence on reliable internet connectivity fails to be considered, especially given the context of agriculture and the location of the fields. Additionally, the possible rejection of AI technologies by farmers cannot be overlooked; unwillingness to trust and rely on AI is to be expected. Still, it is noted that improving farmers' digital literacy is a necessity to successfully employ AI in agriculture.

Red Biotechnology (Health)

In this biotechnology sector, AI is being used in a wide range of applications related to drug development, diseases prediction, gene editing, proteomics, developing predictive models, image recognition, predicting treatments and biomarkers, diagnosing, and designing specific treatments personalized according to individual patient needs.

In Saudi Arabia, AI technologies were being applied to help in COVID-19 vaccination plans; in the development and trial assays of BPM31510 (a drug capable of detecting solid tumors); in the in vitro fertilization field to assess implantation success and outcome prediction; and even trying to replace invasive procedures like colonoscopy by non-invasive fecal sampling analyses.

A crucial step in drug development is the understanding of the drug's bioactivity and its specific mechanisms. A study has proven the powerful tool that AI represents in this area, by being able to analyze immensely large datasets and identifying possible candidates for drugs with specific characteristics. AI can aid in every step of drug development, but ethical issues and other obstacles can arise, which means that there is still a lot of room for research. Another study showed the possibility of using a trained feedforward neural network (FNN), allowing the prediction of biomarkers of breast cancer diagnosis using plasma proteomic profiling, which has been proved to improve the specificity and efficiency of early cancer detection. The enhanced technique can be applied in fields such as cancer research, therapies for genetic disorders, and numerous others.

A theme that has been growing and attracting the attention of society is the relation between habits, traits, and diseases with the age of an individual. AI, ML, and DL algorithms are being used to efficiently identify age predictors of individuals. This can improve the comprehension of important biological processes and change the way current patient data are treated, while also opening a new market in biotechnology for extending the longevity of both humans and other living organisms.

In addition, an AI algorithm recently solved a problem that has been around for more than 50 years, i.e., the "protein folding problem". The AI group DeepMind, owned by Google, developed the program *AlphaFold* and, after years of intense research, one of the system's versions was able to predict the complex process in which proteins fold into 3D structures, based on the proteins' amino acid sequence. This discovery allows a deeper understanding of the basic elements of biological processes, facilitating the comprehension of disease mechanisms, medicine design, improved crops, and sustainable enzymes.

AI applications in the medical field are interesting, especially due to the possibility of obtaining more precise data and diagnosis (even with large and heavy data), and consequently improving patient health and reducing death by misdiagnosis, inadequate treatment, or inefficient drugs.

White Biotechnology (Industrial)

White biotechnology refers to the industrial area of biological applications, ranging from biofuels, fermentation, enzyme development, and other biomolecule production, to the food industry . The 4th industrial revolution is a new concept that has been discussed, characterized using new technologies in industries and creating "smart factories" focused on efficiency, low costs, sustainability, and higher production and ethics, all supported by AI via operation control, optimization, and high process automatization.

Enzyme development can be enhanced through AI, namely in designing complex reactions where enzymes participate, to study an easier way to develop new food products. Moreover, precision fermentation (the use of specific fungi/yeasts to obtain products of interest) can benefit from the understanding of the microbes' structure and from the editing tools that AI provides.

Creative industries are associated with the creation of new products, concepts, or methods, requiring innovation skills, creative thinking, experimental hypotheses, and other features that can be hard to achieve by humans. AI can aid in these tasks using its knowledge to create new patterns and goods.

Lastly, these technologies can also aid with food safety issues. By combining the use of AI sensors incorporated in foods and food processing steps, and assessing the massive amounts of data generated by the analysis of the physical and chemical proprieties of the materials (temperature, humidity, and others), it is possible to detect if there are any hazards for human health derived from the consumption of the food. Furthermore, AI can help avoid food waste by optimizing the production process, and detect food fraud, not only through sensors, but also holograms and photonic crystals, which are more accessible for consumers than other food fraud-detecting methods (spectroscopy and chromatography).

Blue Biotechnology (Aquatic)

Blue biotechnology, also known as marine or aquatic biotechnology, has been an emerging branch since the 1940s. This branch focuses on the creation and development of processes that transform aquatic living organisms, like algae, microalgae, bacteria, and fungi, as well as other resources, into a variety of products with a wide range of applications. The interest in marine life increased when researchers were looking for cellular metabolites like enzymes or proteins with specific characteristics that made them more suitable and effective in industrial processes.

Current biotechnological scopes of action include enhancing aquaculture through the manipulation of the nutritional intake of the living culture throughout its life stages, thus increasing the quality of the culture; controlling and providing disease resistance to pathogens; measuring environmental impact and reducing it; and designing and discovering new medicine and therapeutics based on marine organisms' metabolisms and metabolites .

Despite AI being relatively recent in this field and having few applications reported as of the time of this article, there are already some ideas and possible applications discussed in the literature. As proposed by [54,55], AI could effectively aid in increasing the viability and efficiency of aquacultural practices. AI could be used to control water quality, thus improving the culture's health, survivability, and productivity, while reducing the need for the usage of toxic chemicals, cutting costs, and contributing to a more sustainable practice. It is also proposed that AI can be used to directly analyze, and provide an alert for, possible diseases spreading through the culture, by analyzing the culture's behaviors that could indicate infections or stress, predicting and preventing outbreaks, and maintaining a safe and clean culture medium. AI could also be used as a predictive model for the size and gender of the species, allowing for enhanced control over the culture.

Advantages and Disadvantages of AI

AI brings several advantages to research in analyzing, storing, and understanding multidimensional data, both qualitative and quantitative. Additionally, it can improve the management of hard or dangerous tasks within a safer way, with less stress or difficulties and less space and time, allowing humans to be available for other complex tasks. Moreover, AI can handle large amounts of data and even discover new patterns that are harder for researchers to identify and understand. The wide range of applications and continuous improvements are vital to the inclusion of AI systems in people's everyday lives. AI can also be helpful to reduce waste and improve cost-efficiency. AI can be extremely helpful in sensing real-time conditions, detecting, controlling, and responding according to the needs of the study objects by gathering relevant information associated with them. These platforms are also trained to be secure when it comes to cyberattacks through the identification of weaknesses and risks.

However, like everything that is new, AI can be associated with some disadvantages that may lead to uncertainty and even fear of using this tool and, of course, ethical concerns. Errors or programming mismatches can drive wrong or biased commands. Additionally, human jobs could be affected, and the possibility of depending on a programmer is still not commonly accepted, mainly due to its potential for resulting in creativity loss, lack of the human touch, or, for the younger brains, a lazier attitude. AI also requires both a lot of funding and time for ML, as well as capable professionals, which are sometimes not immediately available. Furthermore, the overall lack of legislation regarding development, use, and accountability when errors occur is alarming. AI is also seen with fear when it comes to privacy, or the "black box problem" associated with DL complexity, because of people's lack of information. AI usage for the writing of scientific papers and articles can help enhance the publications; however, it can lead to discreditation of the research or the findings, or even allow the publication of misinformation that can harm research and investigation practices, and possibly lead to plagiarism. Another disadvantage of this technology is the enormous amount of energy required. By 2027, 1.5 million AI units will be running at full capacity, consuming over 85 terawatt-hours of electricity per year.