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Editorial

Innovative solutions: Of internet of things and biotechnology

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Abstract
The broad term, "biotechnology" dates to domestication of animals, cultivation of plants, and their modification through breeding programmes using artificial choice and conjugation. Attaining sustainability requires fast research and developments in every sector including the most diversified field of biotechnology. The Internet of Things (IoT), one of the coveted areas in technological revolution carries tremendous potential for the transformation of research, innovation and invention in every discipline. IoT provides a window for the efficient, reproducible, fast and precise research into biotechnological research. The potential role of IoT in advancing innovation, conferring economic up-scaling and invention in biotechnology was explored in this editorial.

Keywords: *Biotechnology, internet of things, innovation, renewable natural resources.*

Introduction
Biotechnology is the technology that uses biology to develop new products, methods and organisms intended to improve the society. Biotechnology, usually abbreviated as "Biotech", has been in existence since the domestication of plants and animals at the beginning of civilization and the discovery of fermentation. Internet of Things (IoT) simply means taking all the physical places and things in the world and connecting them to the internet. Technically, these would require that computing devices, mechanical and digital machines, objects, animals or people are provided with unique identifiers with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The concept of IoT therefore provides the ability to collect information and send it, receive information and act on it or the ability to do both. In this edition, one of the articles presents an IoT architecture for a fire detection system using small, low-cost cameras to collect surveillance data from large buildings. The data is then uploaded to the cloud, where a Machine Learning algorithm detects fires in digital images. The authors concluded that the proposed IoT fire detection system was effective because the response time was well within the permitted range for emergency response systems. The advancement in biotechnology necessitates the need for the integration of IoT to enhance the precision, reproducibility, productivity as well as incursion into new territories in biological research, invention and innovation.

The Evolution of Biotechnology
Biotechnology began with agricultural revolution, characterized by domestication of living organisms or modifying their genetic makeup through selective breeding to express or eliminate

certain genetic characteristics in their offspring, while fermentation was used as a tool mainly for food preservation. Fermentation has been described as the first use of biotechnology. However, biotechnology was limited to slow, agricultural methods such as selective breeding until the 19th century when biologist Gregor Mendel discovered the basic principles of heredity and genetics, while scientists Louis Pasteur and Joseph Lister discovered the microbial processes of fermentation.

Fermentation, in addition to its use in food processing has many other biotechnological applications: to produce drugs that can destroy or inhibit the growth of harmful bacteria and viruses (antibiotics and antiviral drugs). For example, it is during the process of fermentation that the fungi of the genus Penicillium produced one of the first antibiotics to be discovered, penicillin, which has saved many thousands of lives. Also, another benefit of microbial fermentation is ethanol, a biofuel, which is a renewable source of energy made using living or dead material, such as plant, which can serve as an alternative to gasoline.

Genetic engineering is the foundation of modern biotechnology practices and recent advances. It enabled the first direct manipulation of plant and animal genomes. The use and commercialization of modern biotechnology often fall into four main fields: agriculture, environment, industry and medicine.

Agriculture: Agricultural biotechnology genetically engineer plants and animals for efficiency in agriculture, increased nutritional value and reduction in food insecurity. These include selective breeding that produces healthier, bigger livestock and crops; infusion of food with nutrient supplementation to improve diets and for medical treatments. Others are drought-resistant crops, meat grown in the laboratory, biologically produced pesticides and herbicides which are not harmful to the environment and humans, etc. In this edition, author (s) explored the biocontrol potentials of Trichoderma species in the control of Fusarium wilt in five tomatoes (*Lycopersicon esculentum L.*) varieties cultivated under greenhouse conditions in Southwest Nigeria. They informed that tomato plants grown with Trichoderma sp. had better performance in terms of average fruit yield count and showed the least disease severity rating. They recommended further exploration of Trichoderma species as means of control for fungus-based diseases in tomato plants.

Environment: environmental biotechnology develops sustainable environmental practices and products that reduce pollution and waste. Some examples of environmental biotechnology are phytoremediation, which uses genetically engineered microorganisms to purify soils of heavy metals and other pollutants; bioremediation introduces microorganisms into waste sites to organically break down nonrecyclable waste, while plastic-eating bacteria breaks down waste plastics in soils and water. Additionally, GMO foods stay fresher for longer, which help to reduce food waste and cover-crops like corn are used as biofuels.

Industry: Industrial biotechnology uses microorganisms to produce industrial goods, such as fermentation and the use of enzymes and microbes to streamline chemical manufacturing and reduce operational costs and chemical emissions; biodegradable garments and textiles made from the proteins of living organisms, like the silk proteins of spiders.

Medicine: Biotechnology and biomedical research are the basis of the modern pharmaceutical industry. Some of the advances are stem cell research that helps replace or repair dead or defective cells; gene therapy for diseases such as leukaemia; 3D printing or growing of organs and bones in labs; mRNA vaccines, monoclonal antibody treatments and research for COVID-19.

Innovative Solutions at the Biotechnology-IoT Interface

Internet of Things has led to paradigmatic developments in performing mundane tasks and has been widely accepted as a promising paradigm that can transform society and industry with its ability to achieve the seamless integration of various devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities.

***IoT and Agricultural Biotechnology interface*:** Agricultural biotechnology embracing IoT transforms agricultural practices through smart and precision farming, thereby enhancing the productivity of crops in a controlled and accurate manner. Various high end IoT enabled products and services like variable rate irrigation optimizer (VRI), soil moisture probes make farmers to understand soil fertility, composition and enhance the efficiency of water utilization. More recently, the concept of smart green houses that comprises IoT based sensors that can intelligently measure, and control humidity, temperature, pressure and light levels saves time, cost, energy and labour-intensive process of farmers with no manual intervention and increased productivity. The advent of drones in both ground as well as aerial based systems revolutionized agriculture by real time monitoring of irrigation, soil variability, field analysis, planting, crop health and diseases assessment leading to IoT induced agriculture efficiency by generation of real-time data for the prediction of plant height and health, crop yield, nutritional composition of crop, canopy area mapping, etc.

IoT and Environmental Biotechnology Interface

Environment monitoring has attracted more and more attention due to the growing concern about climate change. Conventional environmental monitoring systems such as oceanographic and hydrographic research vessels are expensive with time-consuming and low-resolution data collection and analysis processes. Internet of Things has been playing an important role in this area with different sensors deployed to measure and monitor various physical and chemical parameters in real time using different IoT system architectures, sensing, control and communication technologies, including ocean sensing and monitoring; air and surface water quality monitoring; coral reef monitoring; aquaculture farm monitoring; wave and current monitoring.

IoT and Industry Interface

In pharmaceutical research and industry, the discovery of novel drugs and biologics are the promising avenue for commercialization. The implementation of smart and automated equipment and accessories provides precision and improvement in the quality of drugs and other products, while real time monitoring and high-through put screening of drugs with smart sensing leads to better adherence to regulatory requirements. Advancements in smart packaging labels such as 2D bar-coding, radio frequency identification tags confer the benefit of online tracking of products from manufacturing to distribution. This is also applicable to other industries.

IoT and Biomedicine interface

The intersection of Internet of Things (IoT) and biotechnology is reshaping the landscape of healthcare and biomedicine, ushering in an era of unprecedented advancements and efficiencies. Some of the advances are:

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Connected Devices in Diagnostics and Patient Monitoring: Smart sensors and wearable devices enable real-time monitoring of vital signs, providing physicians with a continuous stream of data for accurate and timely intervention, and facilitates remote patient monitoring.

Precision Medicine and Personalized Treatments: Enables the tailoring of treatments to specific genetic, environmental, and lifestyle factors consequent to collection and analyses of extensive datasets from individual patients.

Biological Material Supply Chain Optimization: IoT provides real-time tracking and monitoring of biological samples/materials, which ensures their integrity and the reliability of research outcomes and commercialization processes.

Data Security and Privacy: Robust cybersecurity safeguards sensitive research and patient information and research data, thus ensuring the integrity and confidentiality of research and healthcare data.

Conclusion

Green biotechnology, which applies to agriculture, is well known and involves processes such as the development of pest-resistant grains or the accelerated evolution of disease-resistant animals. Blue biotechnology on the other hand is positioned as one of the emerging sectors within the Blue Economy. Blue biotechnology develops solutions in various fields such as food production, energy, medicine, aquaculture, bioremediation, and the chemical industry. Blue biotechnology has great potential to contribute to sustainable development, as well as to address global challenges such as food security and climate change mitigation, among others. Future advances at the interface of biotechnology and IoT will commence from research, in established and emerging fields. In this era of "omics" with high evolutionary pace of novel microbial strains, phages and other biological breakthroughs, results from biotechnological research would need to be more precise, reproducible and scalable. IoT has enabled instruments and equipment embedded with intelligence and interconnected communication protocols like RF and Bluetooth which could be used for the collection of data, which can then be stored in cloud servers, making them available virtually for authentication and reproducibility. Sophisticated automated robotic laboratory workflow has been launched while artificial intelligence and automation in gene synthesis has also been deployed for finding and creating novel compounds and biological solutions. Immense potential therefore exists for the application of IoT in biotechnological research, innovation and development.

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