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Advancing applied pharmaceutical technology: A paradigm shift toward sustainable innovation and interdisciplinary convergence

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Applied pharmaceutical technology is an evolving field with an important intersection, where more responsibility has been put on it than ever in the history of the enterprise, and at the same time, there is the demand for sustainability and efficiency. With us firmly embracing the mid-2020s, the Journal of Applied Pharmaceutical Science (JAPS) has become an irreplaceable source of information that brings the research that transforms the basic scientific principles into practical pharmaceutical options. The editorial provides a very insightful analysis of the existing trends, future directions, and crucial policy changes in this field, especially the fact that they incorporate sustainable processes and technologies, modern biotechnologies, and a variety of interdisciplinary collaborations which are at the very core of what our research group at JIS University does.

Indeed, the enduring issues in drug discovery and development, namely the rising costs, delays, and failure rates are compelling a fundamental recheck of the conventional strategies. Artificial intelligence (AI) and machine learning have become revolutionary as well in this regard. These supercomputers are not observed as side tools, but they are being extensively embedded into all aspects of the pharmaceutical value chain, including early-stage drug target identification and lead optimization as well as optimizing clinical trial design [1,2]. An example would be AI-based drug repurposing which has the advantage of being a quicker and less expensive route to potential new treatments since it seeks to establish new uses of existing drugs [1]. The combination of big data, omics technologies, and AI has simultaneously arrived at an unprecedented level of knowledge of complex biological systems and opens the next chapter in more accurate, personalized medicine. The industry is moving more toward data-driven innovation as our research group actively pursues computational methods, such as bioinformatics analysis, to supplement experimental endeavors.

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At the same time, nano is still a pillar in the progress of targeted drug delivery. This was possible because of the ability to engineer the materials at the nanoscale enabling the creation of advanced delivery systems that beat biological barriers to enhancing bioavailability as well as lowering systemic toxicity of the delivery system. The recent tendencies point to the increased interest in stimuli-responsive nanoparticles and biocompatible nanocarriers [3,4]. Drug-resistant bacteria are highly complicated and require different therapeutic solutions. Our experience with graphene oxide-para amino benzoic acid nanosheets and alginic acid nanoparticles shows that these systems can be useful in the development of accurately and efficiently delivered therapeutic agents [5,6]. These are innovations that are important in increasing the therapeutic index of drugs and multiplying treatment opportunities for difficult-to-treat diseases.

One of the key trends defining the future of applied pharmaceutical technology is the massive tendency toward the sustainable pharmaceutical manufacturing. With the application of green chemistry principles and principles of the circular economy within the industry, low solvent utilization, the efficient use of energy, and balanced energy utilization are employed to limit the environmental impact of the industry [7]. In addition to the optimization of the processes, valorization of waste biomass to manufacture useful pharmaceutical intermediates and excipients is making huge traction. The necessity is directly met in our research at JIS University which is devoted to the study of algal biotechnology and microbial engineering as approaches to the valorization of waste biomass. We investigate the possibilities of the application of oleaginous microbes and algal biomass as replenishing feedstocks in the production of value-added biomolecules, enzymes, and their potential chemical derivatives during the manufacture of pharmaceutical intermediates or pharmaceutical products that are eco-friendly alternatives to the classical chemical syntheses [8–10]. This is synonymous with the larger drive toward a bio-based economy to pharmaceuticals.

The exploding biopharmaceutical industry is another big industry of growth and innovation. Therapeutic proteins, monoclonal antibodies, and cell therapies, encompassing gene therapies, are changing the therapeutic environment in the treatment of many diseases [11]. The intricacies of creating, producing, and licensing these complex therapies call to them the need of having a multi-disciplinary team, one which combines molecular biology, process engineering, and quality control to the letter. Moreover, mines of natural products, especially those of varied microbial and algal origin, portends to hold unending transport of fresh bioactive compounds with therapeutic possibilities. Our research in microbial engineering and algal biotechnology, through application of the microbial factory to the production of pharmaceuticals and food ingredients, goes right to the heart of this new territory [8–10].

Importantly, the emerging policy trends are progressing in parallel with the scientific and technological research in order to ensure safety of patients, promote innovation, and cover the global health disparities. Regulations, including bilateral agencies such as the European Medicines Agency and the World Health Organization (WHO), are periodically revising regulations to adapt to new treatment processes and medical devices integrated with AI [12]. The future EU AI Act (2025) is a recent example of the move to open regulatory frameworks around AI applications in healthcare, which would require more transparency and accountability of the AI models [12]. More so, a rise in the importance of environmental sustainability in the context of pharmaceutical regulations can be noted, as an approach like the European Green Deal is affecting production, packaging, and waste disposal processes [7,12]. Recent guidelines on the topic of the WHO are especially important as compared to those of the previous year (TRS 1044 - Annex 4, 2022), where they increasingly focus on a life-cycle approach to facilitate the safe and efficient transfer of pharmaceutical technologies, notably in low- and middle-income countries, contributing to universal access to medicines [13].

To sum up, the sphere of applied pharmaceutical technology is in the transformative era, due to breakthroughs in the fields of AI, nanotechnology, and biotechnology, along with sound adherence to the concept of sustainability. The level of interdisciplinary work with a wide spectrum of interdisciplinary knowledge (computational science, materials science, microbiology, and chemical engineering) is fundamental in the need to transform these scientific advancements into clinically useful, globally available pharmaceutical products. The context of this synergistic research is presented endlessly in JAPS. By promoting publication of high-level high impact papers, JAPS helps the development of healthcare on the global level. We would like to invite researchers to keep sending their ground-breaking work, especially the one that touches the intersection of green ideas and high-tech with unmet medical demands. There is optimism in the future of applied pharmaceutical technology and it is through concerted efforts that we as a collective can collectively propel a new dawn of safer, more effective, and even more accessible medicines to all.

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