



Digital Twin Technology in Pharmaceutical Formulation and Smart Manufacturing

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Digital Twin Technology in Pharmaceutical Formulation and Smart Manufacturing

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Preface

Artificial Intelligence, data analytics, Internet of Things (IoT), cloud computing, and intelligent automation have led to a digital revolution in the pharmaceutical industry. Digital Twin technology is one of the most promising innovations for changing the face of pharmaceutical science, as it is applicable to the research, formulation, manufacturing, quality assurance and patient healthcare processes. Digital twins are a virtual representation that is dynamic, and that can be monitored throughout the pharmaceutical life cycle for real-time optimisation, predictivity modelling and data-driven decisions. *Digital Twin Technology in Pharmaceutical Formulation and Smart Manufacturing* is a collection of edited articles that aimed to provide insights into the principles, applications, opportunities, and challenging aspects of Digital Twin technology in the modern pharmaceutical sciences for researchers, academicians, pharmaceutical professionals, regulatory scientists, and students. These chapters offer a multiple-disciplinary overview that spans from the pharmaceutical sciences to computational models, artificial intelligence and machine learning, Industry 4.0, and other smart manufacturing technologies.

The book starts with an overview of the conceptual basis of Digital Twin technology and its development in pharmaceutical sciences. It then considers its use in preformulation studies, molecular design, formulation development, process modelling, Process Analytical Technology, Quality by Design, predictive (drug) performance, regulatory compliance, data integrity, cybersecurity and intelligent manufacturing ecosystems. The contributors also report about new areas of application for personalized medicine, clinical research, pharmacovigilance, sustainable manufacture and automatic pharmaceutical production. A key merit of this book is the linkage of theoretical considerations and practical applications. The contributors have pointed out the capabilities of Digital Twins in the areas of accelerating the product development process, pushing manufacturing towards higher efficiency, curbing experiments costs, increasing product quality, fortifying regulatory compliance and verifying the continuous process. Furthermore, the text recognizes the limitations of current practice, such as data interoperability, model validation, cyber-security, ethics, and changing regulatory policies, and offers a balanced and forward-looking view.

In the context of Pharma 4.0, Digital Twin technology has the potential to be a vital part of intelligent manufacturing and precision health care. The combination of virtual simulation, real-time analytics, AI and connected systems creates untapped and unparalleled opportunities for innovation, operational excellence and improved patient

outcomes while leading the way for sustainable pharmaceutical development. Many thanks to all chapter authors for their sound expertise and contribution. They have synthesized this in their work to make this Volume an authoritative reference on one of the most rapidly evolving areas of pharmaceutical technology. Thanks also to the reviewers and the publishing staff for their feedback and input in the book development process.

We believe this book will prove to be a valuable reference for those interested in and engaging in the use of Digital Twin technologies in the field of pharmaceutical formulation and smart manufacturing in both research and applications. We hope that topics discussed in these chapters will stimulate more research and cross-fertilization between the various other disciplines, and, in addition, help to develop new and more effective systems for drug manufacture and delivery that will better serve patient needs.

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