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Significance and Future Perspective of Biomedical Science in Manufacture of Pharmaceutical Drugs

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Abstract: Recent research in pharma advances to embrace the cross-functional efforts of biological, medical, physical and engineering sciences together in designing new delivery systems for the diagnosis, prevention and treatment of many of life-threatening diseases. Biomedical science is at the forefront of numerous innovative trends that are shaping the future of medicine and the healthcare system. It plays a vital role in the pharmaceutical manufacturing sector of drug discovery and development of novel products. Biomedical science provides the foundation for: innovations in nano-medicine which enable targeted drug delivery with desired release profile; increased use of biologics and bio-similars; driving innovations in production processes of more efficient and scalable cell culture systems or cell-based therapies; step forward in stem cell research; advancing in the field of regenerative medicine etc. This article emphasizes the role and implications of biomedical science in disease diagnosis and management, drug development and therapy, preventive medicine, regenerative medicine, medical devices and technologies, cancer research and therapy, neuroscience, genomics and molecular biology, targeted drug delivery systems, biologics and biosimilars, advanced drug screening techniques, personalized medicine, artificial intelligence in drug discovery, gene therapies, digital health integration, bioprinting and tissue engineering, nanotechnology in medicine, stem cell technology and point-of-care-diagnostics. It was concluded that tremendous growth and changes in pharmaceutical manufacturing research and treatment of diseases may occur due to the amalgamation of knowledge from these different scientific domains. In coming days, scientific and systematic study needs to be explored to overcome various challenges encountered while merging these areas of research.

Keywords: **biomedical, biosimilar, bioprinting, bioengineering, biosensors, personalized medicine**

1. INTRODUCTION

Biomedical science is a field that combines biology, chemistry and medicine to study and improve the health of humans and animals. Drug design and discovery is an innovation process that translates the outcomes of fundamental biomedical research into therapeutics that are ultimately made available to people with medical disorders.[1] With the development of modern medical sciences based on anatomy, physiology, microbiology and immunology, drug discovery is no longer a merely accidental process depending solely on experience. The rise of the modern chemical and pharmaceutical industry has enabled the use of not only natural sources but also chemically synthesized substances to fight against various types of human diseases. Driven by the discovery of the double-helix structure of DNA and the development of molecular biology, the understanding of diseases and drug targets has deepened, extending to the genetic and molecular levels. Moreover, owing to the development of protein structural biology, direct interactions between small drug molecules and their target macromolecules can be captured. Technological advances in biomedical research led to the discovery of the targeted drug for cancer and other life-threatening diseases. The discovery of natural product lead compounds and knowing the mechanisms of action to be the frontier of fundamental research and a promising path to the discovery of new drug targets and cellular signaling pathways. Even though the emergence of chemically synthesized drugs, biotech based products remain the major resource for drug innovation which focuses on drug target identification and validation; phenotypic screening and target de-convolution; biochemical analyses of drug targets and their pathways; new methods or relevant applications in molecular drug design and computer-aided drug discovery; design, synthesis, and biological evaluation of novel biologically active compounds (including diagnostics or chemical probes); structural or molecular biological studies elucidating molecular recognition processes; fragment-based drug discovery; pharmaceutical/red biotechnology; isolation, structural characterization, biosynthesis, bioengineering and pharmacological evaluation of natural products; distribution, pharmacokinetics and metabolic transformations of drugs or biologically active compounds in drug development; drug delivery and formulation (design and characterization of dosage forms, release mechanisms and in vivo testing); preclinical development studies; translational animal models; mechanisms of action and signalling pathways; toxicology; gene therapy, cell therapy and immunotherapy; personalized medicine and pharmacogenomics; clinical drug evaluation; patient safety and sustained use of medicines; etc.

The scope of basic biomedical research is broad and ranges from the study of single atoms and molecules to the complex functions and behaviors of the whole organism. It is nonetheless an important component of clinical success. In particular, it provides a detailed understanding of disease processes that undergird the development of new diagnostic procedures, therapeutic interventions, and preventative strategies that can be tested in clinical studies. In turn, the encounters of astute clinicians with patients can stimulate clinical investigations that may suggest novel mechanisms of disease that can be further examined in basic studies that may involve model organisms. Observations that drive new understandings of human diseases and the development of new strategies for their prevention, diagnosis, and treatment, that flow bi-directionally from patient to laboratory and back, often passing through various stages of experimentation and validation in lower and higher animal species. There can be no doubt that the frequency and intensity of interactions between basic and clinical scientists will continue to increase. However, the basic and clinical workforces are the most part distinct and linked by a third genus of biomedical scientists dubbed "translational" researchers, who have been trained to be knowledgeable in both the basic and clinical biomedical sciences, as well as proficient in patient care.[2]

The feebleness of the biomedical model is that it does not consider the impact that factors other than physical, such as environmental and psychosocial which play on health. In many cases, the treatment of a patient can be hindered if focused singularly on the biomedical model. Biomedical science faces many challenges. Shortage of funding and research resources is one of the significant challenges as it is expensive and in developing countries, grants are often non-existent or under-utilized. Securing funding, in particular, can be a challenging task, as competition for grants is scarce and resources are often limited. Biomedical research faces unique ethical challenges, including issues of confidentiality, the need for equity and inclusion, and the ethical management of sensitive data. The culmination of the research journey often lies in the dissemination of findings. Integrating biomedical research into clinical care is increasingly complex and demanding, with numerous barriers to performing practical aspects of investigation. Data management can be difficult to organize, store, and retrieve. Biomedical partnerships and collaboration can be complex, with challenges such as power imbalances, trust deficits, and local administrative issues. Biomedical science is a vast technical field and more complex, it can be difficult to explain in a reader-friendly way. This research has undergone a great revolution, resulting in new knowledge at the tissue, cellular and genomic levels, which has favoured more precise and personalized medicine. This revolution has also meant that multi-sectorial and international cooperation and collaboration between the public and private spheres are key in the face of new challenges. There is also a shortage of skilled and experienced researchers in this field. Yet, it is through systematic planning and preparation, that researchers can make breakthroughs advancing our understanding of health and its determinants. Large-scale projects that generate research tools or databases can face accessibility concerns. It can be difficult to define the genetic component of common diseases, such as heart attacks, strokes, and diabetes. Addressing these challenges requires a multifaceted approach, including increased funding, better support and mentorship, streamlined regulatory processes, and a cultural shift towards valuing collaborative and interdisciplinary research.

Biomedical research has been revolutionized in the past 20 years by major advances in technology and a sufficiently large and diverse workforce trained are essential to apply scientific discoveries to the improvement of human health. That workforce must be able to conduct research in a wide variety of settings, including academic institutions, government laboratories, and a broad range of companies including pharmaceutics, biotechnology, bioengineering, and related others. This review gives a comprehensive study and complete analysis of the important trends in the field of biomedical science concerning pharmaceutical manufacturing and the treatment of diseases. Biomedical science resides at the intersection of science and healthcare, offering profound insights into human health and disease. As an emerging field, it shapes the future of healthcare by opening doors for ground-breaking research and creative therapies.

2. DISEASE DIAGNOSIS AND MANAGEMENT[3]

The diagnosis is usually performed through one of these methods i.e., examining the physical condition of the patient, exploring the patient's history, or from diagnostic tests which are analyzed by various healthcare professionals. Biomedical diagnostics refers to the use of biosensor devices that provide information associated with a specific health condition or disease. Medical biosensors can diagnose diseases and health conditions, such as diabetes, cardiovascular issues, infectious diseases and cancer. The market for biomedical diagnostics is expected to grow steadily, reaching $43 billion by 2029, due to a growing and aging global population increasing health expenditure and more prevalent lifestyle ailments such as obesity, cancer and cardiovascular diseases. Millions of people in emerging markets such as China and India are entering the middle class and pushing up the demand for a high standard of healthcare. Traditionally, biomedical diagnosis is mainly performed by sending collected samples like blood, urine, or genetic samples to an off-site analytical laboratory. This approach has been fundamentally changed by point-of-care biosensor devices, which allow biomedical diagnosis at the time and place of patient care. Trillions of dollars have been poured into the innovation of advanced biosensor devices that are small, sensitive, and have a fast sample-to-answer response. Below are a few of important categories of diagnostic aids.

2.1 Lab-on-a-chip (LOC): A large portion of point-of-care biosensors are based on microfluidic techniques to simplify the steps of testing, automate the process and enable the miniaturization of biomedical devices. This miniaturized device integrates one or several laboratory functions on a single integrated circuit (commonly called a "chip") of only millimeters to a few square centimeters to achieve automation and high-throughput screening. LOCs can perform a variety of laboratory tasks, which include sample preparation, analysis, detection, DNA sequencing, biochemical detection, chemical synthesis, clinical diagnostics and biomarker validation. Some challenges with LOCs include the reliability of routine droplet processing in microfluidic biochips. Researchers are working on strategies to improve the reliability of LOCs, such as improved material selection, optimized fabrication processes, and rigorous quality control measures. LOCs are safer for chemical, radioactive, or biological studies due to smaller fluid volumes and stored energies. LOCs are useful in situations where resources, sample availability, or time are limited, such as in developing countries or field applications. Other advantages of LOCs include faster analysis, compactness, lower fabrication costs and a safer platform. Examples of applications include measurements of blood gases, blood glucose, and cholesterol or counting the number of HIV cells.

2.2 Lateral flow assays: Lateral flow assays (LFA) use test lines embedded in a paper strip that bind to a target molecule if it's present in the sample. LFAs are often used for diagnostic and environmental purposes and are the basis for many at-home rapid tests. It provides a quick, user-friendly, and cost-effective platform to detect specific biomolecules, including mRNAs. LFAs have several challenges, including their qualitative nature, poor reproducibility for "weak antibodies", low specificity due to too high a sensitivity, poor stability of antibodies used, high batch-to-batch variation, interfacing with nanomaterials in complex biological environments which can lead to undesirable side effects, low resolution, unable to control the flow rate, requirement of a large volume of reagents; improper reagents distribution before and during a test run, affecting sample's capillary flow time by membrane materials used in LFAs which can alter an assay's sensitivity and specificity; image processing on wearable devices like smartphone-based readouts cause reflection, different lighting conditions, and blurred images. LFAs are used for a variety of applications which include, home pregnancy tests, identification of diseases like Ebola and SARS-CoV-2, monitoring food safety by detecting toxins and other chemicals and detection of hepatitis C virus and toxins.

2.3 Electrochemical test strips: Electrochemical test strips use electrodes to measure the electrical response of a reaction to determine the concentration of a substance in blood. Beyond the traditional glucose testing strips, for non-blood diabetic management, such as continuous glucose monitoring, these are used. It also includes monitoring of lactic acid and cholesterol. Therefore, developing portable, low-cost nanoelectrochemical sensors might soon become a major research axis.

2.4 Molecular Diagnostics: Molecular diagnostics analyzes DNA, RNA, and proteins in a tissue or fluid sample to identify diseases or the risk of developing them. It can also be used to monitor the effectiveness of treatment and look for disease recurrence. Molecular diagnostics uses molecular biology to analyze biological markers in the genome and proteome. It involves detecting and measuring cellular alterations, genetic sequences, and amino acids. It is used in a variety of fields, including infectious disease, genetics, pharmacogenomics, and oncology. For example, molecular diagnostic solutions were created during the COVID-19 pandemic to quickly and accurately detect the SARS-CoV-2 virus.[4]

2.5 DNA sequencing: DNA sequencing is a laboratory technique that determines the order of the four bases that make up a DNA molecule including adenine, thymine, cytosine and guanine. DNA sequencing is used to determine which DNA stretches contain genes, identify the type of cancer a patient has, understand illnesses, help doctors make informed treatment decisions, and explore new areas of research. Sequencing human genomes on these platforms, however, presents numerous production and bioinformatics challenges. Production issues like sample contamination, library chimeras and variable run quality have become increasingly problematic in the transition from the technology development lab to production floor. DNA sequencing technology has advanced in many ways, including automation to reduce errors and increase efficiency, development of software platforms to identify variants, quantify and assemble large amounts of sequencing data; next-generation sequencing technologies that sequence parallelly by running many reactions at the same time to offer speed, scalability, and ultra-high throughput; nanopore sequencing method which involves threading DNA strands through tiny pores in a membrane to read the bases one at a time, sequencing is now less expensive, handle more samples at a time in machines, increased read depth allows for cloned fragment and paired-end sequencing using double-stranded DNA sequencing technologies, DNA fragment isolation and purification using magnetic beads enables higher quality and purer starting material, portable genome sequencing for doing diagnostic tests at patient bedsides by the clinicians.

3. DRUG DEVELOPMENT AND THERAPY[5]

Biomedical research used in many aspects of drug development and therapy, including drug design and discovery to create therapeutics that treat medical disorders; biomedical engineering, where engineering techniques like genetic engineering, tissue engineering, and fluids engineering are used to test combinations of drugs; pharmaceutical biotechnology**,** the biological substances from living organisms are used to create drug molecules; human disease models, bioengineered models of human diseases are used to bridge the gap between animal models and human physiology; biomedical therapy, to treat psychological disorders and physiological symptoms. Some examples of biomedical therapies include psychopharmacotherapy, electroconvulsive therapy, and psychosurgery.

4. PREVENTIVE MEDICINE[6]

Preventive medicine is defined by the American Board of Preventive Medicine (ABPM) as the specialty of medical practice that focuses on the health of individuals, communities, and defined populations. Its goal is to protect, promote, and maintain health and well-being and to prevent disease, disability, and premature death. Preventive medicine specialists have core competencies in biostatistics, epidemiology, environmental and occupational medicine, social and behavioral factors in health and disease, planning and evaluation of health services, management of health care organizations, research into causes of disease and injury in population groups, and the practice of prevention in clinical medicine. It also focuses on the prevention of drug abuse and excessive alcohol use, a tobacco-free environment, healthy eating, avoiding injuries by violence-free living, mental and emotional health, and reproductive and sexual health. It applies primary, secondary, and tertiary prevention measures within clinical medicine. In the primary level, the patient is at risk for a disease but is not yet affected. This identifies behavioral, environmental, genetic, and other factors that increase the chance of contracting the disease. Risk factors such as smoking can be changed, though genetic factors cannot. The prepathogenesis period requires good health promotion to achieve primary disease prevention (health education, immunization, correction of poor habits). In the secondary level, risk factors combine to cause a disease. It is usually unmanifested, clinically undetectable, becoming detectable once specific pathologic changes occur. A suggestive factor that may suggest disease development is blood in the stool, a warning sign of colorectal cancer. During pathogenesis, secondary prevention may be achieved by early diagnosis and prompt treatment. At tertiary level, disease signs and symptoms appear. The clinical horizon is the point at which the condition can be scientifically detected. Most preventive health care focuses on this level. There must be disability limitation and rehabilitation, including maximizing of remaining functional capacity. This level is more expensive, in terms of health care.

5. REGENERATIVE MEDICINE[7]

Regenerative medicine may be defined as the process of replacing or "regenerating" human cells, tissues or organs to restore or establish normal function. This field holds the promise of regenerating damaged tissues and organs in the body by repairing or replacing portions of or whole damaged tissues (i.e., bone, cartilage, blood vessels, bladder, skin, etc.) or by stimulating the body's repair mechanisms to heal tissues or organs. Regenerative medicine also may enable scientists to grow tissues and organs in the laboratory and safely implant them when the body is unable to heal itself. Often, the tissues involved require certain mechanical and structural properties for proper functioning. The term has also been applied to efforts to perform specific biochemical functions using cells within an artificially created support system (e.g., artificial pancreas or liver). Current estimates indicate that approximately one in three Americans could potentially benefit from regenerative medicine. Examples include cell therapies by injecting stem cells or progenitor cells, immunomodulation therapy by regenerating biologically active molecules administered alone or as secretions using infused cells, and tissue engineering by transplantation of laboratory-grown organs and tissues. The study of regenerative medicine has the potential to help scientists and clinicians to devise early-intervention treatments for traumatic injury or degenerative diseases, by regrowth or replacement of cells or tissues. Originally regenerative medicine was an outgrowth from the field of tissue engineering and now expanded to encompass the use of stem cells for modeling disease as well as autologous transplant and therapeutic delivery of functional molecules, the production of tissues and organs in a dish, the role of immune function in tissue repair, and the burgeoning area of biomedical engineering. Regenerative medicine is highly cross-disciplinary and serves as a bridge between basic science and clinical medicine. The spectacular progress in the field of stem cell research has laid the foundation for cell-based therapies for diseases that cannot be cured by conventional medicines. The indefinite self-renewal and potential to differentiate into other types of cells represent stem cells as frontiers of regenerative medicine. The trans-differentiating potential of stem cells varies with the source and according to that regenerative applications also change. Advancements in gene editing and tissue engineering technology have endorsed the ex vivo remodeling of stem cells grown into 3D organoids and tissue structures for personalized applications.

6. MEDICAL DEVICES AND TECHNOLOGIES[8,9]

Medical technology is a multi-stage process through which a new biological or chemical agent, prototype medical device, or clinical procedure is technically modified and clinically evaluated until it is considered ready for general use. Biomedical and healthcare devices are paramount to monitor, evaluate, and record physiological signals. These devices provide a better quality of life to millions of patients across the world. Various types have been developed to perform different functions and powering these devices has remained a challenge. Biomedical electronic devices that can self-harvest, store and power are highly demanded. Recent advancements in solar cell technology that have given rise to hybrid and organic solar cells with key features, such as light weight, flexibility, biocompatibility and size reduction, among others, have made them attractive in biomedical electronic device applications. Solar cells are used in powering various types of biomedical devices areas which include implants, electronic skin, radio-integrated monitoring, dental brushes and diagnostic equipment. These devices can incorporate chemicals to reduce microbial colonization in an attempt to decrease infection rates. Biomedical devices have been significantly developed as a valuable biomedical tool. People can now monitor daily health using state-of-the-art biomedical systems such as skin-patchable and implantable devices. More importantly, biomedical systems are in an evolutionary stage, advanced by the IoT (Internet of Things) and ICT (Information and Communication Technology), where they can communicate with external systems and databases for real-time tracking and detection, diagnosis, and treatment. Biofuel cells can be the ultimate solution to a power source for wearable and implantable biomedical systems; however, these cells are still in their infant stage in terms of performance and system optimization. Therefore, energy storage devices such as super-capacitors and lithium-ion batteries, which invariably deliver sufficient and constant power to biomedical systems, include pacemakers, implantable radio transmitters, gastric stimulators, smart gesture gloves, fitness and motion trackers, and wearable biosensors. Biomedical devices integrated with these energy storage devices are directly attached to or implanted into the body as skin-patchable or in-vivo implantable devices, respectably. Thus, all their materials and components must tolerate severe variations in human motion and biological environments such as stress, pressure, and temperature. Biomedical energy storage devices have a unique interface between the material/device and human skin/tissue, which differs from the conventional interfaces applied to mobile, electrical vehicles, and renewable energy fields. According to regulating authorities such as the US FDA, biomedical devices should be classed into different criteria according to their complexity and required control level, to assure safety and effectiveness. The choice of material, based on a combination of its physical, chemical, mechanical, and biological properties, is associated with the function it performs and the period of contact with the human body. To evaluate the feasibility of skin-patchable energy storage devices in biomedical applications, the issues necessary to consider for the design of the materials and devices includes adhesion, performance degradation and sensitization. The adhesion energy must be larger than the total energies of substrate bending and skin elasticity. They would be electrochemically superior and stable during a long lifetime under the skin with constant body environmental changes, and highly sensitive stimulates selected body organs according to external changes such as pressure and strain. Therefore, flexible body-patchable energy storage materials should achieve good adhesiveness, mechanical durability, and sensitive response towards body movement before they can be applied to biomedical systems such as smart hair, medical/cosmetic patches, healthcare screens, and glove/fingernail and fitness/motion trackers. The demands for implantable medical devices depend on their functionality and location in the human body, tissue, or organ in an in-vivo environment. They should be biocompatible to comply with the test for cytotoxicity carcinogenicity, genotoxicity, reproductive and developmental toxicity. The device should be safe and reliable. The medical device should be designed as miniature and lightweight as possible to reduce the stress on the surrounding tissue, muscles, and organs and to minimize the burden on the user. The durability of energy storage devices is considered to be a key parameter for both skin-patchable and implantable applications. Therefore, the device is necessary to satisfy specific requirements such as miniaturization, bio-integration, biocompatibility, biodegradability, and functionality. If they complies all requirements, they can be applied to biomedical systems such as brain neuro-stimulators, cochlear implants, cardiac defibrillators, pacemakers, pain management devices, gastric stimulators, insulin pumps, foot drop implants, etc. In the biomedical field, the demand for patchable and implantable energy storage devices is on the rise. However, there are no clear standards to date, and essential evaluation criteria must be addressed for each type of biomedical device.

7. CANCER RESEARCH AND THERAPY[10]

To date, scientists are struggling to understand the complete mechanism of carcinogenesis. In the future, the real-time detection of cancer may help scientists to identify some of the complicated biological mechanisms. Certain special features of cancer cells enable researchers to deliver the drug or to develop the right drug therapy. These cell properties include over-expression or over-activity in the uptake of certain nutrients e.g. folic acid and increased permeability. Product approach like drug conjugates and complexes serves as a good platform to solve issues like solubility, toxicity, poor penetration and stability related to cancer drugs. Besides this, several drug delivery platforms are under development by researchers in academia as well as in industry to deliver therapeutic molecules and new chemical entities to the targeted site in the body. Amongst them, nanotechnology both at molecular and supramolecular levels is a leading platform and can help to image, detect and treat cancer. Surface modification of nanoparticles by coating or anchoring their surface with special markers, materials, peptides, proteins, antibodies or antigens add extra features and thereby can enhance the effectiveness. These treatments can be treated by nano technique individually or in combination with some assisting techniques like a magnetic field, photo or light field, and sonic rays. New biological therapies that are advancing in this direction include antisense therapy, cell therapy, gene therapy, radiation therapy and SiRNA interfaces. In the oncological diagnostic and treatment system, identifying the primary site is fundamental for standardized treatment. Yet, 3–5% of cancers remain with undetermined primary sites after pathological diagnosis, classified as CUP. CUP's incidence ranges from 6 to 16 per 100,000, accounting for 2.3% to 7.8% of all malignant tumors, and it ranks fourth in mortality. The discovery of the primary site poses a significant challenge due to a lack of effective detection methods. As a result, 20–50% of patients do not have an identifiable primary site, and most CUP primary lesions found during autopsies are less than 1 cm, undetectable by current technologies. Hence, summarizing and discussing the research progress in early detection, precise diagnosis, and targeted treatment strategies for CUP are of paramount importance.

Clinical imaging tests for CUP typically include X-ray, CT, MRI, and PET/CT techniques. These tests can aid in a more accurate diagnosis of the tumour by determining its location, size, shape, and association with surrounding tissues. The primary site of a tumor be detected early and diagnosed accurately. Therefore, identifying the primary site and accurately understanding the tumor's origin and tissue type are vital for guiding appropriate treatment strategies. The difficulty in the diagnosis of CUP is a result of the following factors: primary tumours may be too small, slow-growing, and undetectable by current imaging or other diagnostic techniques; metastasized tumour cells might have altered morphologies, thus not resembling the original primary site; primary lesions could be eliminated by the body's immune system (no longer existing primary sites); and primary tumours might have been inadvertently removed or destroyed during surgery or treatment. Studies have shown that in highly differentiated cancers, oncogenes in metastatic cells can be used to trace the tissue of origin. Therefore, immunohistochemistry (IHC) plays a critical role in the assessment of metastatic sites. However, due to the high heterogeneity of CUP tumours, conventional pathological diagnostic techniques have limitations, such as insufficient tumour sampling, specimen fixation affecting tumor antigenicity, observer subjectivity, and numerous clinical interfering factors, which do not entirely meet clinical needs. To overcome these challenges, researchers have explored new technologies, such as F-FDG PET/CT, liquid biopsy, molecular diagnostics, in vivo self-assembling probes, and AI-based identification for multimodal imaging and spectroscopic analysis of CUP, providing evidence-based support for diagnosis at multiple levels and scales.

With advances in imaging, histopathology, and molecular diagnostic technologies, an integrated and complementary approach of various testing methods is an essential part of driving the continued advancement of the clinical diagnosis and treatment of cancer. This will aid in more accurately identifying the primary site for many patients, thereby achieving precise diagnosis and effective treatment of CUP. Recent research progress has begun to unravel the mystery of CUP, yet the enigma of cancers with unknown primary sites persists. It remains premature to guide the optimal treatment of CUP based solely on partial molecular profiling results. With the increasing application of multi-omics studies and bio-nanotargeting technology in the field of cancer, future developments will focus on more precise tracing methods for the primary lesion in CUP to better guide clinical treatment. Additionally, during research processes, there is a need for convincing methods or technology validation using animal and artificial models. In this regard, patient-derived xenografts (PDXs) involve the transplantation of tissue from patients into animals to create tumour models. Since these models directly originate from patients, they preserve histopathological characteristics and cellular heterogeneity, offering significant value in exploring and validating diagnostic and therapeutic strategies and studying rare cancer types. Moreover, organoids, derived from primary tissues or stem cells and cultivated ex vivo into self-renewing 3D models exhibiting organ functions, maintain stable phenotypes and genetic characteristics. They realistically simulate various aspects of tumours in vivo, providing distinct advantages in drug screening and applications with CRISPR technology, and they are poised for significant future applications.

Artificial intelligence technology is one of the fastest-growing fields in this era, with limitless future applications and influence. However, current AI-assisted cancer origin prediction based on whole-slide images still requires standardization and improvements in the diagnostic process. This method necessitates further training of this histology-based AI model with a larger number of cases and involvement in clinical trials to ascertain whether it can enhance diagnostic capabilities and patient prognosis. Additionally, the AI model needs to be expanded to include a wider range of other types of clinical imaging data, such as pathological and radiological images, to provide more comprehensive predictions using multiple data modalities. This will offer the AI model a holistic view of the tumour, enabling it not only to predict the type of tumor and patient prognosis but also potentially to forecast the best treatment options.

8. NEUROSCIENCE[11]

Neuroscience is the scientific field that focuses on the study of the nervous system. It is a field of study that draws from a vast range of disciplines, such as anatomy, physiology, biochemistry, psychology, and even artificial intelligence. Neuroscience aims to better understand how the complex network of neurons works together to allow us to think, learn, remember, and respond to our environment. Neuroscience has led to the development of treatments and interventions for neurological disorders, such as Alzheimer's disease, Parkinson's disease, and depression. It has also informed our understanding of how information is processed and utilized in the brain, allowing us to better understand how we learn and remember, as well as the development of more effective educational techniques. Ultimately, the understanding of neuroscience has had a positive impact on our ability to

improve the health and well-being of both individuals and populations. Advances in neuroscience and biomedical engineering deeply affect the clinical practice of physical medicine & rehabilitation. New research findings and engineering tools are continuously made available that have the potential to dramatically enhance the ability of clinicians to design effective rehabilitation interventions.

9. GENOMICS AND MOLECULAR BIOLOGY[12]

Molecular Biology and Genetics seek to understand how the molecules that makeup cells determine the behavior of living things. Biologists use molecular and genetic tools to study the function of those molecules in the complex milieu of the living cell. It is necessary to understand the fundamental processes of transcription and translation, mechanisms of global gene control including signal transduction pathways, the function of the visual and olfactory systems, and the nature of genetic diversity in natural populations and how that affects their evolution, among others. The systems under study cover the range of model organisms (bacteria, yeast, slime molds, worms, fruit flies, zebrafish, and mice) though the results of these studies relate directly or indirectly to human health. The Cell Biology, Genetics, and Molecular Medicine (CGM) discipline provides a gateway to all basic, medical, and translational research by emphasizing the importance of cell, molecular, and systems biology approaches to study the foundations of life, health, and human disease.

10. TARGETED DRUG DELIVERY SYSTEMS[13,14]

Drug delivery to the body can be divided into two broad groups either local or systemic. In the case of systemic delivery, drugs are sent into systemic circulation in a therapeutic concentration range, which besides reaching the diseased site reaches the majority of other sites of the body. This exposure of the drug to the other sites of the body causes various side effects and maintenance of therapeutic concentration requires a large dose of the drug. For the treatment of chronic diseases maintaining of steady-state drug concentration for a longer period, is more difficult and multiple dosing usually leads to the drug concentration falling off the therapeutic range many times. Because of these problems associated with the conventional systemic delivery of the drugs, there is a need for the development of a targeted drug delivery system - a system that can deliver the drug selectively to the diseased site in a specified steady concentration for the prescribed time. They are widely used to improve the safety and therapeutic efficacy of encapsulated drugs due to their unique physicochemical and biological properties. By combining therapeutic drugs with nanoparticles using rational targeting pathways, nano-targeted delivery systems were created to overcome the main drawbacks of conventional drug treatment, including insufficient stability and solubility, lack of transmembrane transport, short circulation time, and undesirable toxic effects. It is necessary to understand the developments in different targeting design strategies and therapeutic approaches employing various nanomaterial-based systems. Combining therapeutic drugs with nanoparticles and designing suitable targeting pathways is a promising targeted drug delivery method that can deliver many molecules to specific locations in the body. To achieve high targeting efficacy, the DDS must be retained in the physiological system for an appropriate time to target specific cells and tissues to release the delivery drug, avoiding its destruction by the immune system. Nanoparticles can improve the stability and solubility of encapsulated drugs, facilitate transmembrane transport, and prolong cycle times, thereby improving safety and effectiveness. Nanoparticles can enter the bloodstream through blood vessels and then act at specific sites within the blood vessels to treat intravascular diseases, which are called intravascular drug delivery. Nanoparticles can also cross the endothelium of blood vessels or reach target tissues through local administration such as oral, inhalation, subcutaneous administration, *etc.*, which is called extravascular drug delivery. However, the precise delivery of therapeutic drugs to the target area remains an important issue that needs further investigation to enhance the treatment efficiency of various diseases.

11. PERSONALIZED MEDICINE[15-17]

Personalized medicine (PM) is a medical treatment that tailors prevention and treatment strategies for an individual patient. It is the field of medicine in which decisions concerning disease prevention, diagnosis, and treatment are tailored to individual patients based on information derived from genetic and genomic data. Personalized medicine centers on the concept that information about a patient's genes and genome allow physicians to make more informed and effective decisions about a patient's care. This approach is based on understanding the differences between patients with the same disease and represents a change from the "one size fits all" concept. According to this concept, appropriate therapies should be selected for specific groups of patients. PM makes it possible to predict whether a particular therapy will be effective for a particular patient. PM will still have to overcome many challenges and barriers before it can be successfully implemented in healthcare systems. However, it is essential to remember that PM is not a medical revolution but an evolution. The goal and the expectation in future include: finding an accompanying tool and approaches for the implementation of PM; the scientists, innovators, healthcare providers, and others be able to provide the most suitable medicine, at the right dose, for the right person, at the right time, at a reasonable cost for the benefit of society and its citizens; finding the incentives and create appropriate financial models to implement PM in daily clinical practice.

12. ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY[18]

Artificial Intelligence (AI) has revolutionized many aspects of the pharmaceuticals and recently started to gearup its application in various sectors of the pharmaceutical industry as a front-runner beneficiary. AI assists pharma industries to improve the overall life cycle of products and it can be implemented in pharma ranging from drug discovery to product management. AI is used in diverse areas of the pharmaceutical sectors viz., drug discovery and development, drug repurposing, polypharmacology, chemical synthesis, prediction of drug properties such as toxicity, bioactivity, and physicochemical characteristics, improving pharmaceutical productivity, clinical trials, etc., thus reducing the human workload as well as achieving targets in a short period. It is necessary to understand the ongoing as well as future challenges related to AI including data quality, generalizability, computational demands, and ethical considerations, tools and techniques to be used, their respective solutions in pharmaceutical industries for improving patient compliance. The emergence of Artificial Intelligence (AI) in drug discovery marks a pivotal shift in pharmaceutical research, blending sophisticated computational techniques with conventional scientific exploration to break

through enduring obstacles. Traditionally drug development process has demanded significant time and resources, requiring an average of 12 years and a cost of US$2.6 billion to advance a single molecule from conception to FDA approval. Despite these efforts, the process is marked by high attrition rates, significant adverse effects of modern drugs, and persistent challenges in addressing chronic diseases such as diabetes and cancers. AI significantly enhances the identification process of viable lead compounds, markedly accelerating the drug development timeline. This advancement is achieved through AI's ability to analyze a wide array of molecular configurations and predict their potential binding affinities, streamlining the pathway from concept to clinic.

The essence of drug design lies in the discovery of small molecules that fulfill a set of critical criteria. These include pharmacological efficacy, a favorable safety profile, suitable chemical and biological properties, and the innovation necessary to secure intellectual property rights for commercial viability. While computational tools have revolutionized drug design, transforming the approach to discovery, traditional methods encounter several challenges, such as extensive input time, high computational costs, and variable reliability. AI stands out as a solution capable of surmounting these challenges, enhancing the utility and effectiveness of computational techniques in drug development. A key application of drug design involves the study of protein structures, as many diseases are linked to protein dysfunction. Structural drug design aims to identify small molecules that can selectively interact with protein targets. Traditionally, predicting the three-dimensional (3D) structure of proteins has been both costly and time-consuming, with limited accuracy in de novo predictions of 3D structures.

The advent of AI, particularly deep learning and feature extraction tools, has revolutionized this aspect of drug design. These technologies enable the precise prediction of secondary protein structures and the mapping of protein contacts, thereby improving our understanding of the relationship between structure and sequence. The ultimate goal is to harness deep learning to predict 3D protein structures with enhanced accuracy, facilitating the exploration of protein-protein interactions (PPI) and advancing the field of structural drug design. This integration of AI into drug design represents a significant leap forward, promising to improve the speed, cost efficiency, and success rates of drug development initiatives.

13. GENE THERAPIES[19]

Genes contain DNA, the code that controls much of the body's form and function. It controls everything from hair color and height to breathing, walking and digesting food. Genes that don't work properly can cause disease. Sometimes these genes are called mutations. Gene therapy aims to fix a faulty gene or replace it with a healthy gene to try to cure disease or make the body better able to fight disease. It holds promise as a treatment for a wide range of diseases, such as cancer, cystic fibrosis, heart disease, diabetes, haemophilia and AIDS. The U.S. Food and Drug Administration (FDA) has approved gene therapy products for several conditions, but for most people, gene therapy is available only as part of a clinical trial.

Clinical trials help healthcare professionals learn how gene therapy affects the body. Gene therapy is done for: Fixing genes that don't work properly - Faulty genes that cause disease could be turned off so that they no longer promote disease or healthy genes that help prevent disease could be turned on so that they could stop the disease; Replace genes that don't work properly - Some cells become diseased because certain genes don't work properly or no longer work at all. Replacing these genes with healthy genes may help treat certain diseases. For example, a gene called p53 usually prevents tumor growth. Several types of cancer have been linked to problems with the p53 gene. If healthcare professionals could replace the faulty p53 gene, the healthy gene might cause the cancer cells to die; Make the immune system aware of diseased cells - In some cases, our immune system doesn't attack diseased cells because it doesn't see them as intruders. Healthcare professionals could use gene therapy to train the immune system to see these cells as a threat.

14. DIGITAL HEALTH INTEGRATION[20-22]

Digital health integrations refer to the use of digital technology and connected devices to improve health outcomes and healthcare delivery. This includes telemedicine, electronic health records, wearable devices, mobile health applications, and other forms of digital health technology. To this end, several research and developmental activities in various fields are gaining momentum. For instance, in the medical devices sector, several smart biomedical materials and medical devices that are digitally enabled are rapidly being developed and introduced into clinical settings. In the pharma and allied sectors, digital health-focused technologies are widely being used through various stages of drug development, viz. computer-aided drug design, computational modeling for predictive toxicology, and big data analytics for clinical trial management. Digital health is a rapidly growing field that offers exciting opportunities for innovation and improvement in healthcare delivery. The goal of digital health is to make healthcare more efficient, accessible, and effective, by leveraging the power of digital technology to collect, analyze, store and share health data. The growth of the digital health market can be attributed to several factors, including the increasing adoption of smartphones and other digital devices, the growing demand for remote monitoring and telemedicine services, and the increasing focus on the development of digital health solutions to address the challenges posed by the pandemic diseases like covid-19.

15. BIO-PRTINTING AND TISSUE ENGINEERING[23,24]

3D bio-printing or additive manufacturing is an emerging innovative technology revolutionizing the field of biomedical applications by combining engineering, pharmaceutical manufacturing, art, education, and medicine. This process involved incorporating the cells with biocompatible materials to design the required tissue or organ model in situ for various in vivo applications. Conventional 3D printing is involved in constructing the model without incorporating any living components, thereby limiting its use in several recent biological applications. However, this uses additional biological complexities, including material choice, cell types, and their growth and differentiation factors. Biomedical applications such as cancer therapy, tissue engineering, bone regeneration, and wound healing involving 3D printing have gained much attention in recent years. 3D printing defines the layer-by-layer deposition of bio-inks (tissue spheroids, microcarriers, cell pellets, etc.) in an exceptionally designed fashion as prescribed by a software-supported system to create the desired 3D structure. Earlier, this technique was used only from the mold to develop the desired 3D structures from the biological materials. However, the designs became more complex upon

developing the technology from resin-based to solvent-free aqueous system. The introduction of direct printing of biomaterials with or without the incorporation of live cells could further be used for transplantation. With rapid technological advancement in cell biology and material science, 3D bioprinting was better modernized, and tissues were incorporated into the complex models making the researcher close to eradicating the problem. These tissue engineering models have been used to create medical devices in prosthodontics. 3D printing is one of the viable and most efficient approaches to the problems faced by 2D printing structures. Flexible design, rapid prototyping, print-on-demand, and strong and lightweight parts are the benefits of 3D printing over 2D printing. To print a complex structure, one needs a proper way or approach to overcome the specific issues and design the system accordingly. 3D bioprinting has been used to construct 2D tissues for solid organs. Skin, hollow tubes (blood vessels), hollow nontubular organs (bladder), and other solid organs such as kidneys can be constructed using 3D bioprinting. Hollow organs are more complex to construct as compared with solid ones. Thus, they take an unusually long time to develop. Scientists have developed different methods to produce living components, structures, and organs with similar biological and mechanical properties. Three main central approaches are biomimicry, autonomous self-assembly and mini tissue building block.

Tissue engineering represents a radically multidisciplinary approach and impinges on a variety of fundamental and applied biomedical technologies such as developmental biology, genomic and post-genomic technologies, biomaterials, biomedical engineering, biophysics and biomechanics, and transplantation science for clinical and non-clinical applications. It refers to the application of principles and methods of engineering and life sciences toward the fundamental understanding of structure-function relationships in normal and pathological mammalian tissues and the development of biological substitutes to restore, maintain, or improve tissue function. The objective of tissue engineering is to allow the body's own cells, over time, to eventually replace the implanted scaffold or tissue engineered construct. Tissue engineering approaches, formed through the understanding of natural biological tissues, are generally based on the triad—appropriate cells, matrix/scaffold to host them live, and signaling molecules to enhance the tissue growing process. A functional tissue can be developed in place of the damaged tissue through the judicious use of the components of this triad. For a specific application, the most appropriate form of cells, scaffolds, and mediators has to be identified and implemented. The design basis of tissue engineering depends on the level of understanding of the interactions between signalling molecules of the extracellular matrix (ECM) and cells enclosed in it, and of the gene expression needed to induce differentiation and tissue-specific growth. The native ECM is a hierarchically organized dynamic structure which provides mechanical support for embedded cells, as well as essential environment for their functioning. ECM is instrumental in promoting and regulating cellular functions such as adhesion, migration, proliferation, differentiation, and morphogenesis. Therefore the prime requirement in tissue engineering is to develop an analogue or substitute to the local extracellular matrix. It relies on the concept of using cells, biomaterials, and tissue-inducing factors either alone or in different combinations to accomplish tissue regeneration in-vivo or in-vitro for transplantation. For example, they may involve isolating cells from a patient or donor, culturing them in-vitro under appropriate conditions, and re-implanting them into the defective site of the patient to recover their normal functions. This may involve certain types of materials as scaffolds or matrices that act as guides to the tissue form. Growth factors and other molecules may be provided to stimulate cellular function. Important factors influencing the course of regeneration are the vascular and mechanical environments. To provide further stimuli to regulate cell function, associated advances in gene technologies, induction of mechanical forces or custom-made bioreactors and bioprocess engineering systems may be applied.

16. NANOTECHNOLOGY IN MEDICINE[25]

The ability to investigate substances at the molecular level has boosted the search for materials with outstanding properties for use in medicine. The application of these novel materials has generated a new research field of nanobiotechnology, which plays a central role in disease diagnosis, drug design and delivery, and implants. Nano-carrier includes metallic and metal oxide nanoparticles, carbon nanotubes, liposomes, and nanopatterned flat surfaces. The chemical and physical properties of the surface of these materials allow their use in diagnosis, biosensing and bioimaging devices, drug delivery systems, and bone substitute implants. The toxicology of these particles is studied in the light of a new field referred to as nanotoxicology that reveals the surface effects emerging from nanostructured materials. The design of nanostructures by controlling their surface properties is presented as a strategy to achieve improved responses aimed at a specific application in diagnosis, biosensing and bioimaging devices, drug delivery systems, and bone-substituting implants.

17. STEM CELL TECHNOLOGY[26]

Stem cells are the unspecialized cell population with unique self-renewal ability and act as the precursor of all the body cells. Broadly, stem cells are of two types: one is embryonic stem cells and the other is adult or somatic stem cells. Embryonic stem cells are the cells of the zygote of the blastocyst which give rise to all kinds of body cells including embryonic cells, and they can reconstruct a complete organism. The adult stem cells have limited differentiation ability in comparison with embryonic stem cells and they proliferate into some specific kind of cells. This unique ability of the stem cell makes it a compelling biomedical and therapeutic tool. Stem cells primarily serve as regenerative medicine for particular tissue regeneration or whole organ regeneration in any physical injury or disease condition (like diabetes, cancer, periodontal disorder, etc.), tissue grafting and plastic surgery, etc. It is also used in various preclinical and clinical investigations, biomedical engineering and as a potential diagnostic tool (such as the development of biomarkers) for non-invasive diagnosis of severe disorders. Stem cells are being used in a wide variety of ways ranging from developing artificial organs for research and transplantation to even mitochondrial therapy. Many factors are currently holding back stem cell research, causing its slow development and therefore, better and more efficient therapies need to be developed. These factors are: problems in culturing most stem cells, conventional 2D culturing techniques being expensive and inefficient for culturing stem cells, difficulty in mimicking the stem cell niche, loss of capacity to differentiate during culturing, lack of standardized 3D culturing techniques, lack of proper scale up techniques, etc.; pluripotent stem cells (PSCs) may result in the formation of teratoma (benign tumors, containing tissues of all germ layers) when injected into the body.; cultures studying placental stem cells all result in a mixture of different types of cells. It is challenging to get specialized cells in high purity in a sustainable way. Furthermore, the introduction of stem cells into the body can result in an immune response.

Various developments in stem cell therapy include the below:[27]

17.1.1 HSC transplantation: Healthy HSCs (hematopoietic stem cells) can be transplanted into patients suffering from various types of bone marrow or blood disorders such as leukemia, lymphoma, and tumors to replace the dysfunctional bone marrow cells. The transfer can be autologous (cells originating from the patient), allogeneic (cells originating from a different person), or syngeneic (cells originating from identical twins). Bone marrow transplants have a long history and have become a standard medical procedure..

17.1.2 HSC therapy (HSCT): HSCT has been used to treat multiple sclerosis in clinical trials. Multiple sclerosis is an autoimmune disease targeting the central nervous system. The traditional approach for the treatment of multiple sclerosis is disease-modifying therapy (DMT). DMT targets the immune system by modulating it, alternating the immune cell trafficking, or reducing the immune cell population. However, it requires long-term administration and can have serious side effects. The clinical trials of HSCT have produced better results than DMT.

17.1.3 Placental stem cell therapy: Placental stem cells have shown promising results and potential in healing and curing diseases in various parts of the body such as alzheimer's, liver diseases, pancreatic diseases, myocardial infarction, muscle dystrophy, lung fibrosis, and large lytic lesions in bones. They also have applications in tissue engineering.

17.1.4 Autologous limbal stem cells (holoclar) transplantation: Autologous limbal cell culture contains stem cells (holoclones) that can be used to treat patients with loss of corneal epithelium. Burns to the eye may lead to loss of vision by destroying the limbus or causing limbal stem cell deficiency. Holoclar has been formally approved in Europe for moderate to severe limbal stem cell deficiency in adults.

17.1.5 Development toward artificial organ engineering: When stem cells are cultured in a 3D environment, in permissive growth conditions without any external input, they multiply and differentiate into structures like their origin. These structures mimic organs, including providing the niche for stem cells, and are called "organoids." Organoids show a level of organization that is not replicable with current technology, but they show heterogeneity in size, shape, cell composition, etc., from culture to culture. These organoids are used for various studies.

17.1.6 Hollow organ engineering: Stem cells show promising results in the engineering of hollow organs such as trachea and vagina. There is a case report showing the successful use of autologous stem cells for the successful production of trachea. Stem cells can be used to engineer new trachea for patients suffering due to mustard gas. The use of an appropriate scaffold along with mesenchymal stem cells (MSCs) can form the basis for developing artificial vaginas for treating many diseases which are ignored or have non-effective treatments.

17.1.7 Anti-aging effects: The aging process is characterized by molecular mechanisms, including DNA damage, telomere shortening, loss of proteostasis, mitochondrial dysfunction, and stem cell exhaustion. Adipose-derived stem cells promote mitophagy and increase mitochondrial production while also reducing reactive oxygen species, eventually changing the cell metabolism to resemble youthful cells. The pathways related to the metabolism of nucleotides and those associated with mitochondria are enriched as well.

17.1.8 Minimizing mitochondrial injury: Mitochondrial dysfunction plays an important role in the pathogenesis of many seemingly unrelated diseases such as neurodegenerative disorders, cardiac diseases, sepsis, cancer, diabetes, and fluoroquinolone-associated disability. MSCs accelerate mitochondrial recovery, promote mitophagy, and induce the transfer of healthy mitochondria in cells suffering from mitochondrial damage or dysfunction.

17.1.9 Treatment of diabetes: Multiple types of stem cells have been used to treat diabetes in clinical trials. Diabetes mellitus can be caused by lifestyle choices and genetic inheritance (type 2 diabetes), autoimmune causes (type 1 diabetes), or even hormonal changes due to pregnancy (gestational diabetes). Typical treatment of diabetes includes injection of insulin, but it poses an issue due to high insulin costs and the temporary nature of the treatment. Stem cells can solve this problem by directly healing the pancreatic cells. In addition, diabetes-related injuries such as non-healing wounds are being treated using stem cells.

17.1.10 Disease modeling and study of differentiation: Since their development, induced pluripotent stem cells (iPSCs) have been used by scientists in a variety of ways for studying the pathogenesis of diseases, for inventing novel ways of iPSC formation, for studying the inheritance of genetic diseases, for studying neurodegenerative diseases, etc.

17.1.11 Cell-free therapy: Cell-derived membrane-bound vesicles and extracellular vesicles (EVs) from stem cells such as exosomes have been shown to have effects such as neuro-protection, neuro-regeneration, neural development, and improvement in neural function. The use of EVs reduces the risks and limitations of cell-based therapy, being non-invasive, crossing blood-brain barrier, and being non-tumorous.

17.1.12 Wound healing: Stem cells promote cell proliferation and cell differentiation at the wound site, help in the control of immune response, and contain antibacterial properties due to the secretion of antimicrobial factors. The use of autologous stem cells removes the possibility of immune rejection.

17.1.13 Treatment of burn wounds: Stem cells show better potential and results in treating burn wounds than currently available methods. Using stem cells by direct injection, tissue-engineered grafts or exosome treatment shows promising results in burn wound healing.

17.1.14 Significance in research - Stem cells are being used to study diseases such as congenital heart disease, and neurodevelopmental defects and for the study of the effects of the environment on cell and tissue development.

The future perspective of stem cells includes the below:[28]

17.2.1 Stem cells in gene editing - By combining stem cell technology with gene editing methods like CRISPR-Cas9, new opportunities for treating hereditary disorders and fixing genetic flaws are made possible. Gene-edited stem cells may be used to treat genetic diseases and lessen the chance of damaging mutations being passed on to future generations.

17.2.2 Stem cells for autoimmune illnesses - The immune deficiencies suffered due to AIDS can be treated using stem cells. They control the immune system and encourage tissue regeneration, holding potential for treating autoimmune illnesses. Future studies will concentrate on creating secure and efficient stem cell treatments for diseases such as type 1 diabetes, rheumatoid arthritis, and multiple sclerosis.

17.2.3 Regenerative medicine - In the field of regenerative medicine, damaged or diseased tissues and organs can be repaired or replaced with healthy cells derived from stem cells. This could revolutionize the treatment of conditions such as heart disease, parkinson's, spinal cord injuries, and more.
17.2.4 Personalized medicine - With the advent of iPSCs, it is now possible to derive stem cells from a patient's cells, creating an unlimited source of personalized cells for therapeutic use. IPSCs can be genetically matched to the patient, significantly reducing the risk of immune rejection, and enabling tailored treatments for various medical conditions.
17.2.5 Tissue engineering - Organoids can be used for drug testing, disease modeling, and personalized medicine, paving the way for more precise and efficient treatments.
17.2.6 Artificial organs and body parts - In the not-so-distant future, we might witness the creation of fully functional artificial organs and body parts using stem cells. This could potentially alleviate the organ shortage for transplants and provide customized solutions for patients in need.

18. POINT-OF-CARE DIAGNOSTICS[29]

Biomedical diagnostics refers to the use of biosensor devices that provide information associated with a specific health condition or disease. It includes blood glucose testing, blood gas and electrolytes analysis, rapid coagulation testing, rapid cardiac markers diagnostics, drugs of abuse screening, urine strips testing, pregnancy testing, fecal occult blood analysis, food pathogens screening, haemoglobin diagnostics, infectious disease testing, etc. The market for biomedical diagnostics is expected to grow steadily, reaching $43 billion by 2029, due to a growing and aging global population, increasing health expenditure and more prevalent lifestyle ailments such as obesity, cancer and cardiovascular diseases. Millions of people in emerging markets such as China and India are entering the middle class and pushing up the demand for a high standard of healthcare. Traditionally, biomedical diagnosis is mainly performed by sending collected samples like blood, urine, or genetic samples to an off-site analytical laboratory. This approach has been fundamentally changed by point-of-care biosensor devices, which allow biomedical diagnosis at the time and place of patient care. Trillions of dollars have been poured into the innovation of advanced biosensor devices that are small, sensitive, and have a fast sample-to-answer response. POCT tests can be performed in many locations, including a patient's home, a doctor's office, a hospital, or even an ambulance. The results of POCT tests are typically available quickly so that they can be used to guide treatment. These tests can be performed by a variety of people, including doctors, nurses, emergency first responders, and other healthcare practitioners. In some cases, patients may perform the test themselves, which is known as a "self-test" or "home test". The advantages of POCT include quick results, portability and simplicity, however, these tests can sometimes produce inaccurate results, which can reduce their demand compared to traditional laboratory testing. Some examples of POCT testing devices include cornell nutriphone which analyses a person's nutritional status by measuring levels of iron, vitamin A, vitamin D, and vitamin B12 in blood samples and cellphone-based POC technologies which can detect cells, biomolecules, nanoparticles, and microorganisms.

19. CONCLUSION

Biomedical research helps to understand the molecular and cellular processes that occur in the body and is imperative in pharmaceutical manufacturing which can lead to the creation of new treatments and medications for managing diseases and health conditions. Without this, it would be merely impossible to understand, prevent and cure diseases. The pharmaceutical sector relies heavily on biomedical scientists for drug development and testing. Biomedical researchers are involved in designing and conducting clinical trials, ensuring the safety and efficacy of new medications. The future of biomedical science looks promising with trends such as personalized medicine, 3D printing, biosimilars, virtual data sharing platforms for **e**lectronic health records, new imaging technologies to allow earlier disease detection, wearable medical devices for measuring health parameters, over-the-counter test kits for helping to check for a wide array of infections, etc. Pharmaceutical industries take a vital part in interdisciplinary research and advanced technologies like CRISPR gene editing, high-throughput sequencing, artificial intelligence, etc. In the future, an increase in multi-faceted research collaboration by drug manufacturers with other fields like engineering and computer science, and also between the public and private sectors to address global health challenges.

REFERENCES

[1] Ian NW, Donald FW. 2013. Drug design and discovery: translational biomedical science varies among countries. Clin Transl Sci., 6(5): 409-413.
[2] Gillespie S. 2022. Scope of Biomedical Science and Research Development, Insights in Biomedicine. Open access Short Communication, 07(11): 107.
[3] Biomedical diagnostics at point-of-care 2019-2029. Technologies, Applications, Forecasts - IDTechEx. Cambridge, Research and Consultancy, UK.
[4] Induni NW, Anurag L, Suhas T, Francis AN, David R. 2023. Emerging Applications of Biomedical Science in Pandemic Prevention and Control: A Review. Curious, 15(8): 10 pa.
[5] Hua Li, Weib W and Xuc H. 2022. Drug discovery is an eternal challenge for the biomedical sciences. Acta Materia Medica, 1(1): 1-3.
[6] Jahangir M, Morvarid M, Oyindamola A, Katia F. 2023. Preventive Medicine, Health Care Today in the United States. Academic Press.
[7] Ahmed E. Altyar A, El-Sayed A, Abdeen A, et.al. 2023. Future regenerative medicine developments and their therapeutic applications. Biomedicine & Pharmacotherapy,158.114131: 1-18.
[8] Boyle J, Maeder A, Bell J, John S and Scott R. 2005. Medical device research. Expert Rev. Med. Devices, 2(1): 41–45.
[9] Kasoju N, Remya NS, Sasi R, Sujesh S, et.al. 2023. Digital health: Trends, opportunities and challenges in medical devices. Pharma and bio-technology, CSI Transactions on ICT 11(1): 11-30

[10] Liu X, Jiang H and Wang X, 2024. Advances in cancer research: Current and future diagnostic and therapeutic strategies. MDPI Biosensors, 14(2):100.
[11] Application of Biomedical Engineering in Neuroscience. 2019. Sudip Paul: 1stEdition. Springer Singapore.
[12] Amolkumar US, Kishore UT, Kanika. 2015. Chapter - Genomics: An Integrative Approach for Molecular Biology. Biotechnology-Progress and Prospects, Studium Press, 234-270.
[13] Mahajan HS, Patil SB, Gattani SG, Kuchekar BS. 2007. Targeted drug delivery systems. Pharma Times, 39(2): 19-21
[14] Cheng X, Xie Q and SunY. 2023. Advances in nanomaterial-based targeted drug delivery systems.. Frontier in Bioengineering and Biotechnology. DOI 10.3389/fbioe.2023.1177151: 1-27.
[15] Stefanicka-Wojtas D, Kurpas D. 2023. Personalised medicine - Implementation to the healthcare system in Europe (Focus Group Discussions). Journal of Personalized Medicine, 13(3):380.
[16] Kara Rogers. Nov 2024. Personalised medicine, Encyclopedia Brittannica.
[17] Vicente AM, Ballensiefen W and Jönsson J. 2020. How personalised medicine will transform healthcare by 2030: Journal of translational medicine, 18(1): 180.
[18] Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. 2021. Artificial intelligence in drug discovery and development. Drug Discov Today, 26(1): 80-93.
[19] Scott C. Litin M.D., Gene Therapy: Mayo clinic Family Health Book, 5th Edition, Mayo Clinic Press.
[20] Anas A. Alhur. 2023. Integrating digital health into medical curricula: A review of current practices and future directions. International Journal of Biosciences, 23(6); 34-43.
[21] Shah B, Allen JLY, Chaudhury H, Shaughnessy JO, Tyrrell CSB. 2022. The role of digital health in the future of integrated care. Clinics in Integrated Care, Vol 15: 100131
[22] Global strategy on digital health. 2020-2025. World Health Organization 2021. 60 pages
[23] Tripathi S, Mandal SS, Bauri S, Maiti P. 2022. 3D bioprinting and its innovative approach for biomedical applications, MedComm Wiley, 1-38.
[24] Olson JL, Atala A, Yoo JJ, Chonnam. 2011. Tissue Engineering: Current Strategies and Future Directions. Medical Journal, 47(1): 1–13.
[25] Ramos A, Tovani CB. 2017. Biomedical applications of nanotechnology. Biophysical Reviews, 9(2): 79-89.
[26] Agrawal M, Alexander A, Khan J, et.al. 2019. Recent Biomedical Applications on Stem Cell Therapy: A Brief Overview; Current Stem Cell Research and Therapy, 14(2): 127-136.
[27] Ranjeet SM, 2016. Stem cells applications in regenerative medicine and disease therapeutics. Int J Cell Biol.,1-24**.**
[28] Gupta DR, Singh S. 2024. Stem cells: Current applications and future prospects. Indian Journal of Medical Sciences, 76(1): 1-6
[29] Heidt B, Siqueira WF, Eersels K. 2020. Point of Care Diagnostics in Resource-Limited Settings: A Review of the Present and Future of PoC in Its Most Needed Environment. Biosensors, 10(10):133. doi: 10.3390/bios10100133