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A Few Words about Biomedical Engineering

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ABSTRACT

Biomedical engineering is one of the fastest spreading fields of engineering science. The innovations that have been produced are intended to improve health and quality of life - from the development of artificial organs, the improvement of imaging technologies that enable doctors to see more accurately than ever before, to technologies for monitoring patients at a distance. The technologies used combine engineering knowledge with applied knowledge from the fields of biology, chemistry and physics.

Keywords: *Biomedicine, Biomaterials, 3D, 4D, Nanotechnology.*

INTRODUCTION

Medical technology is one of the most visible aspects of the modern world; it is impossible to avoid and uniquely compelling [1]. People from all walks of life are eager to hear about new machines, new medicines, and new devices that will uncover hidden disease, treat previously untreatable ailments, and mend weary or broken organs. Evidence for this high interest is everywhere. We know that modern medicine is built on steady progress in science, but it is just as heavily dependent on innovations in engineering. It is engineers who transfer scientific knowledge into useful products, devices, and methods; therefore, progress in biomedical engineering is arguably more central to our experience of modern medicine than are advances in science. Some of the most fascinating stories of the 20th century involved the development of new medical technologies. Whole-organ transplantation, such as the first heart transplant in 1967, could not occur until there were machines to sustain life during the operation, tools for the surgeons to operate with and repair the wounds they created, and methods for preserving organs during transport. Thousands of transplants are performed annually in the United States today, but the need for organs far exceeds the supply. Biomedical engineers have been working for many decades to create an artificial heart, and there is no doubt that this work will continue until it is successful.

Clinical testing of the Salkpolio vaccine, in which millions of doses were administered to children, could not happen without the engineering methods to cheaply produce the vaccine in large quantity. The Human Genome Project would have not been possible without automated machines for deoxyribonucleic acid (DNA) sequencing.

Medical technology has also invaded our homes in surprising and influential ways. Every home has a thermometer, specially designed to permit the recording of body temperature. But we can now also test for pregnancy at home, so that one of the most life-changing medical discoveries can be done in privacy. Blood glucose tests, which are essential for proper treatment of diabetes, have advanced rapidly and now are commonly done at home. Your home can be easily equipped to be a screening center for high blood pressure, high cholesterol, glucose monitoring, and ovulation prediction.

BIOFABRICATION

Biofabrication is a multidisciplinary (and may be inter disciplinary) research field combining principles, protocols, and practice from engineering, biology, and material sciences through the use of manufacturing processes to build models and create biomimetics, bio prototypes, and bioproducts at the cutting edge of bioengineering innovation [2]. Within the last decade, biofabrication emerged as a new paradigm and potentially dominant technological platform for the twenty-first century manufacturing, particularly for those considering new industries and modes of production as the driving forces of the so-called Fourth Industrial Revolution. More than an isolated scientific approach, this term encompasses multiple techniques and methods that produce or employ biological assets and innovative materials to generate proof-of-concepts that are beyond current knowledge and thus labeled as science fiction or visionary concepts by nonspecialists.

BIOMATERIALS

Numerous materials abound on earth with a unique identity and application [3]. Among biomaterials are a class of entities can able to interact with bio environment and tissues for various requisites. Biomaterials are evolving exponentially from the last 50 years, through the combined aspects of medicine, biology, chemistry, and materials science. Majorly, the engineered material participated in disease diagnosis or therapy or both, and sometimes it acts as therapeutic as well. In this journey, the material must exhibit essential physicochemical, mechanical, and biological properties in order to augment or replace or support an organ or a tissue or a part of the body, to make the diseased/unhealthy part functional. To fulfill the function, the candidate must be biostable, biocompatible, and bio-tolerable as the immune system may treat the substance as a foreign material. The definition of biomaterials was framed in different ways, but most prominently "Biomaterials are a class of materials- be it natural or synthetic, alive or lifeless, and usually made of multiple components that interact with the biological systems. They are often used in medical applications to augment or replace a natural function."

Biomaterials are used for several applications, such as joint replacements, bone plates, bone cement, artificial ligaments and tendons, dental implants for tooth fixation, blood vessel prostheses, heart valves, artificial tissue, contact lenses, and breast implants. In the future, biomaterials are expected to enhance the regeneration of natural tissues, thereby promoting the restoration of structural, functional, metabolic, and biochemical behavior as well as biomechanical performance.

TISSUE ENGINEERING

Biomaterials play a significant role in tissue engineering [4]. Biomaterials prove an integral component of tissue regeneration and reconstruction. From the obvious application of artificial valve design to the less apparent role of injection needle design in bone marrow transplantation, biomaterial development is a necessary step in the advancement of tissue engineering. Devices must provide mechanical support, prevent undesirable tissue interactions, and potentially allow for timely biodegradation. Biomaterial devices can be broken down into two types, each existing on a scale as small as a few hundred microns. Immunoprotective devices contain semi permeable membranes that prevent specific host immune system elements from entering the device. Open devices, in contrast, are designed for systems to be fully integrated with the host and have large pores (greater than 10 mm), allowing for free transport of cells and molecules.

Tissue engineering is a biomedical engineering discipline integrating biology with engineering to create tissues or cellular products outside the body (ex vivo) or to use the gained knowledge to better manage the repair of tissues within the body (in vivo) [5]. This discipline requires understanding of diverse biological fields, including cell and molecular biology, physiology and systems integration, stem cell proliferation and differentiation, extracellular matrix chemistry and compounds, and endocrinology. It also requires knowledge of many engineering fields, including biochemical and mechanical engineering, polymer sciences, bioreactor design and application, mass transfer analysis of gas and liquid metabolites, and biomaterials. Translation of tissue engineering constructs to clinical applications will involve yet other scientific disciplines so novel engineered tissues will be easily accepted and used by clinicians. The combination of these sciences has spawned the field of regenerative medicine, which is closely aligned with tissue engineering but has a focus on strategies that use the body's natural regeneration mechanisms to repair damaged tissues. Two of the main goals of these fields are cell therapies for the repair of damaged tissues, involving injection or engraftment of cells or cellular suspensions, sometimes in combination with scaffolding material, or establishing tissue ex vivo for use as grafts or extracorporeal organs to assist or supplement ailing in vivo organs. Clinical trials with cell therapies or extra corporeally created tissues have begun to be undertaken in the area of skin, cartilage, bone, heart, neural, and liver tissues, and the first tissue-engineered products have become available in the last decade. In addition, tissue engineering strategies are being employed to develop improved in vitro diagnostic and screening techniques, as well as creating improved tissue models to study disease. Both scientific and economic issues will define the success of these and future therapeutic modalities.

3D

In recent years, advances in additive manufacturing, also known as three-dimensional (3D) printing, have attracted great attention as a “new industrial revolution” [6]. The 3D printing field as a whole is projected to make an impact in nearly every industry because of both the flexibility of the technology and the continual decrease in the costs. The medical industry is not immune from this disruption as 3D printing will advance the field as a whole in new directions. At the moment, 3D printing has found a niche application a sacritical tool in surgical preplanning. In this application, a digital model of a region of interest can be generated through CT or MRI scans that can be used as a basis for a physical model fabricated through 3D printing. Other applications include surgical guides and fabrication of some implants. These implants are primarily structural in native, serving more of a structural or a space-filling role to facilitate the growth of a new tissue rather as a tissue engineering implant. Often, the materials that make up these implants are synthetic, such as titanium or thermoplastics. Although 3D printing shows the potential in the fabrication of patient-specific implants, these traditional 3D printing systems are not compatible with biological materials that would be utilized to fabricate truly regenerative and cellularized implants. The convergence of 3D printing and tissue engineering can be thought as a new field known as 3D bio printing. 3D bio printing will enable the manufacturing of biological constructs that can not only serve as regenerative implants in the clinics but also as models of organ systems for applications such as drug screening or a mechanism to study cell behaviour in three dimensions for research and cell expansion rather than the currently utilized 2Dcell culture techniques.

Biological tissues are composed of three components, the cells, the surrounding extracellular matrix (ECM), and the intra cellularfluid, that provide a favorable environment suitable for cell proliferation and maintenance of phenotype. There capitulation of the characteristics of the native ECM must be considered when developing biomaterials. However, the arrangement of these biomaterials within a construct to recapitulate the native tissue architecture is critical for the functionality of the resulting construct. Bio printing can be utilized to precisely position these biomaterials and therefore cells within the construct. These printable biomaterials can be considered a specialized subclass known as bio inks.

4D

The recent advances in 4D printing, which adds the fourth dimension “time” to the 3D printed complex structures [7], open anew avenue to 3D printing of biological and medical structures and devices with dynamic behaviors. The 4D printing is realized by creatively integrating engineered active materials into high-resolution 3D printing technologies, which enable the precise deposition of the active materials at micron scales. Under environmental stimuli, e.g. temperature, water, and light, the properties of the active materials change, which subsequently result in the shape changes of the 3D printed structures overtime.

Despite great progress in the field of 4D printing, its further development for biomedical applications requires the development of novel stimuli-responsive 3D printable biomaterials, advanced 3D printing technologies capable of ancient and rapid deposition of multiple active materials, and computational design tools in corporating realistic material models to predict the 3D printed object behavior under environmental stimuli.

Laser

The use of laser can achieve a high temperature beyond the melting points for polymeric, metallic, and ceramic bonding [8]. Lasers can weld polymers such as nylon or polystyrene; metals including steel, titanium, and alloy mixtures; and composites. Lasers intering works with single-component powders where the laser melts only the outer surface of the particles (surface melting), fusing the solid non-melted cores to each other and to the previously assembled layer. This process does not usually require support structures. It also works with two-component powders, typically either coated powder or a powder mixture. The physical process can be full melting, partial melting, or liquid-phase sintering. Depending on the material, up to >80% density can be achieved with material properties comparable to those from conventional manufacturing methods. These usually suggest 26% porosity. In many cases, large numbers of parts can be packed within the powder bed, allowing for very high productivity. Laser sintering of components allows for good dimensional precision, low cost, high production speed, and material diversification. Compared with machining and other conventional manufacturing processes, it is possible to get fully functional prototypes, molds, or models in just a few days based on 3D CAD data, helping to significantly reduce time to market. Laser sintering supports a wide range of production with a complex geometry of products. By avoiding the time and cost associated with tooling, the use of laser-targeted products can lead some industries to gain higher competitiveness. To date, laser sintering has already become a key technology in electronic manufacturing, making fast, flexible, and cost-effective production possible directly from CAD files. In particular, selective laser sintering can manufacture products with small quantities of high-quality parts. Therefore, custom biomedical devices are ideal applications.

Making prosthetics using highly flexible processes such as rapid prototyping is ideal. Laser sintering can be applied in the manufacturing of biomedical implants. The 3Ddigital CAD file was then downloaded to a selective laser sintering machine, and the product was fused from titanium powder layer by layer.

NANOTECHNOLOGY

Nanotechnology allows for the production of efficient markers and extremely precise diagnostic tools and imaging devices, which allows for early diagnoses, all of which can improve treatments and quality of life for patients and decrease overall morbidity and mortality rates [9]. These devices are also in line with regenerative medicine in that they help improve our understanding of interactions in the human body which allows for the development of new therapies. Understanding the pathophysiological basis of diseases and how nanomaterials interact with cells and tissues in the body are essential other design, development, and application of nanomaterials in medicine. There is currently a gap in knowledge surrounding nanomaterial interactions in the human body, including, toxicity, pharmacokinetics, and pharmaco dynamics, which limits the technologies used and developed today. However, nano materials have the potential to improve personalized medicine as well as the targeting of therapeutics,dose-response,and bioavailability, among many other aspects of medicine. They show promise in the development of the multifunctional and next generation of biomedical devices that will further improve healthcare. Moreover, the broad range of nanomedicine to include genetics, molecular biology, cellular biology, chemistry, biochemistry, material science, proteomics, and bioengineering means that advances in this field will have broad applications in field of science and greatly improve patient care. Overall, nanomaterials hold great promise for medical applications, and many avenues for nanomaterial application have yet to be explored.

RESEARCH ETHICS

Research ethics as the generic concept governs the standards of conduct for scientific researchers [10]. Research ethics was first and foremost developed as a concept in medical research; it has been extended to other fields such as social sciences, information technology, engineering, and so forth. Research ethics be mainly discussed in basic principles such as minimizing the risk of harm, obtaining informed consent, protecting anonymity and confidentiality, avoiding deceptive practices, and providing the right to withdraw. Research ethics, also, is distinguished from publication ethics. Whereas research ethics focuses on standards protecting the right of human participants or animals involved in research, publication ethics focuses on standards ensuring public trust in scientific findings, high-quality scientific publications, and people who receive credit for their ideas. In other words, publication ethics are standards to guarantee the research integrity (scientific integrity, or academic integrity). Accordingly, scientific integrity ensures values and practices such as objectivity, clarity, reproducibility, maintenance of academic standards, honesty and rigor in academic publishing, and utility. The violation of scientific integrity is defined as scientific misconduct. Scientific misconduct includes disvalues and malpractices in professional scientific research or academic area such as fabrication, bias, plagiarism, falsification, censorship, inadequate procedural, outside interference, and information security. All participants in academic research area, for example, authors, editors, reviewers of journals, research institutions, and even uninvolved scientific colleagues, are responsible for research and publication ethics.

CONCLUSION

Biomedical technology encompasses a wide range of disciplines and applications, all of which have one thing in common: a beneficial impact on health and quality of life. Biomedical engineering tries to spread and expand knowledge about the structure and operation of complex biological systems in different environments with an engineering approach and methods. Biomedical engineering is constantly developing new technologies, devices and procedures to monitor, maintain and improve health and quality of life and is one of the fastest growing areas that will have a major impact on our future lives.

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