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BIOMEDICAL ENGINEERING – PART OF MEDICINE

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Abstract: Biomedical engineers represent significant multidisciplinary and interdisciplinary interconnection of technical, humanities and natural sciences. By integrating and applying technical, physical science disciplines to the fields of biology and medicine, they enable comprehensive systemic levels of tissues and organisms as a whole to be influenced. The ability of targeted, regulated proliferation, differentiation, tissues / organ / organism reparation enables not only to improve the quality of healthcare but also to improve the quality of life of the injured individual. The goal of biological engineers is to better understand, replace or fix a target system to ultimately improve the quality of healthcare [1]. In this brief, transparent article, we focus on the various areas of biomedical engineering research in the world.

1 Introduction

Biomedical engineering is the fastest growing career and this trend is expected to continue over the next decade. Biomedical engineers educate and prepare next-generation leaders to advance bioscience and biotechnology via quantitative, integrative, and design oriented analysis & synthesis of molecular and cellular biological mechanisms at the intersection of engineering, the life sciences and healthcare. These are several diagnostic, analytical, monitoring, imaging, therapeutic devices, such as medical devices, have been developed by biomedical engineers. For example: cardiological stents, defibrillators, ECG, monotorous equipment HOLTER, mobile cardiology ambulatory telemetry (MCOT), EEG, RTG, CT, MRI, fMRI, PET, cochlear implant, anesthesia monitoring technology, pacemakers, rehabilitation systems, prosthetics, laser surgery, sophisticated da Vinci surgical robot [1].

An increasing gap between organ donation and organ transplantation has inspired scientists to find out alternative approaches and substitutes to make the organs functional. The US National Institutes of Health has defined regenerative medicine as “the process of creating living, functional tissues to repair or replace tissue or organ function lost due to age, disease, damage, or congenital defects” [2]. Tissue engineering provides a generic structure for the emerging field of regenerative medicine that has significant potential for orthopedic applications [3-12]. Advances in molecular, cellular, and tissue biology have led to significant discoveries in biomedical engineering in the areas of nanotechnology, tissue, cell and chemical engineering, stem cell, neural cell research, and so on. They lead to the development of "micro level", neural, prosthetic, telemedicine, etc., resulting in nerve prostheses, bionic vision, intelligent nanoterapies, replacement tissues / organs, parts of systems [1].

Advanced computer models provide the means to accurately interpret diagnostic values in new ways, moving us towards a more personal therapy. In addition to simply providing technical aids, bioengineers enable advanced information, sensors and wireless monitoring technologies to facilitate the interpretation of patient health data and prompt decision-making by physicians on the therapeutic approach.

2 TERM - tissue engineering and regenerative medicine

Regenerative medicine is a relatively new, evolving area in which many medical, biological and physical sciences are used primarily to address the lack of biological organs and tissues available for transplantation or therapy, secondary to organ or tissue pathology. The branches of regenerative medicine are tissue engineering, diagnostic platforms, cell and therapeutic therapies, supportive technologies [8, 9].

Tissue engineering is a field of regenerative medicine in which *ex-vivo* replacement tissues, organs, and other body parts are developed, e.g. skin, ears, and the like. *Tissue engineering* evolved from the field of biomaterials development and refers to the practice of combining scaffolds, cells, and biologically active molecules into functional tissues. The goal of tissue engineering is to assemble functional constructs that restore, maintain, or improve damaged tissues or whole organs.

The subject of cell therapy research is now increasingly in the therapy of applied pluripotent stem cells for their repair properties in the treatment of pathological conditions. Cellular collection kits and new techniques for their delivery have been developed, which are used as tools of regenerative technologies in the clinical environment (Figure 1). For example: A tissue-engineered graft can be seeded with pluripotent cells and then be maintained in culture media while having mechanical stimulus applied to the graft in order to aid in differentiation and maturation of the tissue-engineered construct. [3, 7-10, 13].

Figure 1 A commercially available bioreactor is depicted in this image (DynaGen bioreactor system, Tissue Growth Technologies, Minnetonka, MN, USA) [14].

Regenerative medicine has evolved tremendously in recent years and appears to be a promising approach in restoring function and regeneration of diseased tissues and organs. Since cell function occurs at the nanometer scale, nanotechnology can influence and even alter cellular behaviour, which ultimately enhances the functioning of tissue or organ. The traditional approaches of nanotechnology in regenerative medicine can be related to: 1) nanoparticles; 2) scaffolds with nanofibers; 3) scaffolds with nanotopographic modifications; 4) drug/gene delivery; and 5) extracellular matrix (ECM) patterning. The newer and rational approaches include a combination of these traditional methods [2]. Supportive technologies appear to be an essential aspect of regenerative medicine. Other of example of regenerative medicine technology is harvesting, isolation, *in vitro* cultivation, proliferation of the pluripotent stem cell of a patient, and subsequent inoculation on scaffolds (Figure 2). The scaffolds are then seeded with cells that have been growing in Petri dishes. These cells can be harvested from either a stem cell line or a donor ideally the recipient of the transplant. The cell-scaffold construct is then bathed in a medium that encourages the cells to grow and multiply. As the cells multiply, they begin to acquire the shape of the scaffold, which eventually breaks down and is absorbed by the tissue. Scaffolds allow three-dimensional orientation, and potentially help in the organization and differentiation of stem cells. In order to promote stem cell differentiation and remodelling into mature end-organ tissue, various growth factors and mechanical stimuli are applied. As a result of the tissue engineering process, a new tissue is prepared for surgery, suitable for transplantation, reconstruction, substitution that is theoretically optimized to accelerate the healing and regeneration process (Figure 2) [14].

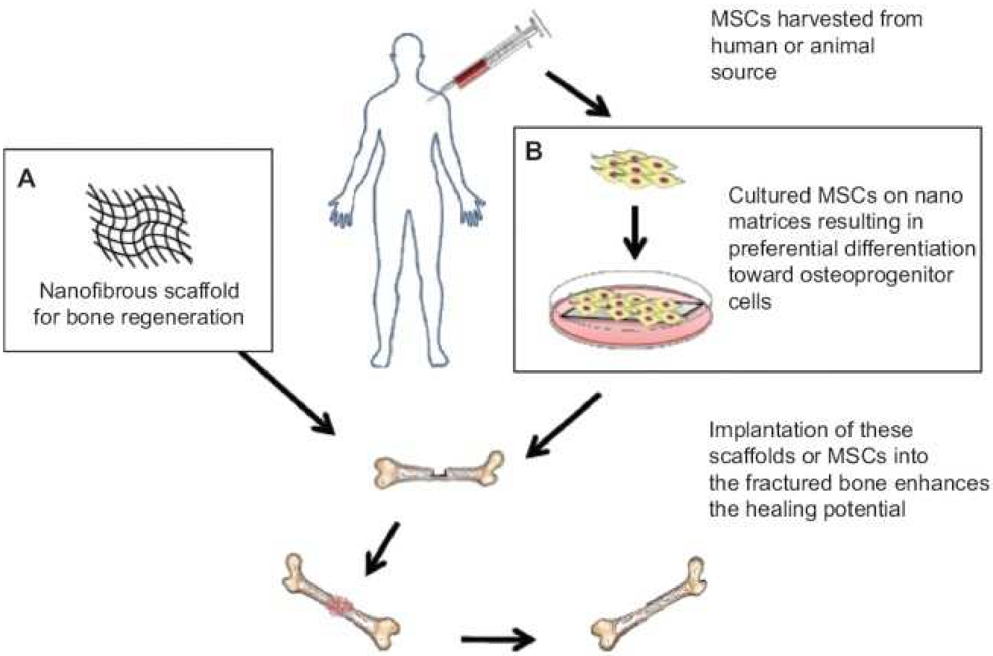

Figure 2: Schematic representation of bone regeneration using nanotechnology. Improved bone healing using (A) nanofibrous scaffold and (B) culturing mesenchymal stem cells on nano matrices [2].

The stem cell field is also advancing rapidly, opening new avenues for this type of therapy. Therapeutic cloning and cellular programming may one day provide a potentially limitless source of cells for tissue engineering applications. While stem cells are still in the research phase, some therapies arising from tissue engineering endeavours have already entered the clinical setting successfully, indicating the promise regenerative medicine holds for the future [14].

The terms “tissue engineering” and “regenerative medicine” have become largely interchangeable, as the field hopes to focus on cures instead of treatments for complex, often chronic, diseases. This field continues to evolve. In addition to medical applications, non-therapeutic applications include using tissues as biosensors to detect biological or chemical threat agents, and tissue chips that can be used to test the toxicity of an experimental medication [15]. The UK government highlighted regenerative medicine as one of the key eight great technologies in their industrial strategy worthy of significant investment. The long-term aim of successful biomanufacture to repair composite defects depends on interdisciplinary collaboration between cell biologists, material scientists, engineers, and associated medical specialties; however currently, there is a current lack of coordination in the field as a whole [16]. Application of regenerative medicine technology may offer novel therapies for patients with injuries, end-stage organ failure, or other clinical problems. Currently patients suffering from diseased and injured organs can be treated with transplanted organs. Scientists in field of regenerative medicine and tissue engineering are now applying the principles of cell transplantation, material science, and bioengineering to construct biological substitutes that will restore and maintain normal function in diseased and injured tissues [17].

Department of Sports Medicine and Department of Orthopedic Surgery, Faculty of Medicine, Wake Forest University, Medical Center Boulevard, Winston-Salem, North Carolina 27157, USA created tissues of urethra, vagina, bladder neck and bladder in association with tissue engineering. They are currently developing vessels, heart valves, animal muscles, ear, fingers, kidneys, nerve, skin, skeletal muscles and trachea [4,6-10,18,19]. The use of new bioprinting technology or microorganisms enabled them to produce microscopic liver structure, tissue structure of the bladder and urethra, testes, cardiac muscle, and kidney structure [6,20-23]. It is hoped that, with ongoing collaboration, these technologies could be applied to patients at the Department of Sports Medicine and Arthroscopic Surgery [3].

3 Biomechanics

Biomechanics and bioengineering are related to engineering, including the application of principles, laws and methods of mechanics to develop and improve medical diagnostics, biomedical devices and biomechanical models [24]. The term biomechanics is used to describe the application of mechanics to biological systems [25,26]. Biomechanics in studying how motor systems create movement and strength often use traditional techniques that are insufficient to clarify the mechanics of living systems. Mechanisms of biological systems are usually much more complex than mechanical systems and require more recent and advanced analytical techniques. As in other areas of bioengineering, biomechanics are applied not only at the macro level, but also where the joints are connected, but can also be studied at the molecular level. In fact, the mechanism of biological systems at the macro level is affected by what occurs at the level of muscles, tissues and molecules.

Biomechanics provides conceptual and mathematical tools that are necessary for understanding how living things move and how kinesiology professionals might improve movement or make movement safer. The application of biomechanics to human movement can be classified into two main areas: the improvement of performance and the reduction or treatment of injury. Another application of biomechanics is in the medical areas of orthotics and prosthetics, in relation to preventing injury, but many prosthetics are being designed to improve the performance e.f. of disablet athletes etc. Biotribology is a field of biomechanics that deals with friction, wear and lubrication, especially for human joints. For example, questions such as implantation of the knee due to the influence of time, such wear is influenced by the lubrication effects of the synovial fluid and the like.

4 Biorobotics

Biorobotics is a term that loosely covers the fields of cybernetics, bionics and even genetic engineering as a collective study.

With an undestanding of biomechanics, engineers can develop biologically inspired robots with improved and enhanced capabilities over traditional robots, which are how shall we say robotic! Biologically inspired robots have greater mobility and flexibility than traditional robots and often possess sensory abilities. Biorobotic technologies are often utilized to provide assistance to accomodate a deficiency either as fully functioning robots or highly advanced prosthetic, the latter represents one area in which neural engineering and biorobotics intersect as both disciplines are required in order to first signal and then generate movement.Such devices may also be used to measure the state of disease, track progress or offer interactive training experiences than can speed recovery from an injury or stroke. Biorobotics encompasses a diverse array of disciplines with a myriad of application. Researcers in Italy are developing artificial sensing skin that can detect pressure as contact is made with an object [27]. Tactile sensors are important not only for self-standing robots and limb prostheses but as a means of restoring the sense. Stanford engineers create artificial skin that can send pressure sensation to brain cell (Figure 3). Stanford engineers have created a plastic skin-like material that can detect pressure and deliver a Morse code-like signal directly to a living brain cell. The work takes a big step toward adding a sense of touch to prosthetic limbs [28].

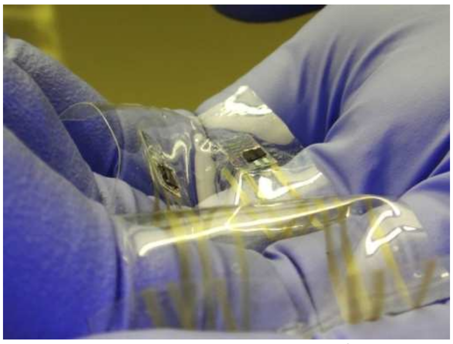

Figure 3 Stretchable skin with flexible artificial mechanoreceptors (Credit: Bao Research Group/Stanford University [29]

The team of engineers and scientists from Caltech and ETH in Zurich have developed artificial skin that can detect temperature changes [30].

Italian scientists are also exploring the potencial for early diagnosis of autism by monitoring sensory-motor development through mechatronic-sensorized toys, such as rattles with force and contact sensors [31]. This one application of biorobotics requires contribution from biomedical engineers studying tissue engineering, neural engineering, biomimetics.

Endoscopic robots at the tip of probe can, for example remove a polyp during colonoscopy. And mechatronic handheld tools allow surgeons to manipulate their hands at the macro level while affecting similar responses from mechanical device opening at the micro level. One day, this could even lead to „ cellular surgery“[1].

5 Bioinformatics and Computational Biology

Computational biology and also bioinformatics draw upon many of the same disciplines to derive distinct, but related information about biological processes. Bioengineers working in computational biology might explore how blood flows through the body or how air flows through the lungs. This „plumbing“ can be mathematically modeled to help determine the health of an individual patient. Computational biology explains how biological processes work at the macro level. By using computer models, various hypotheses are tested to understand how tissues, organs and whole ecosystems function. By better understanding how specific biological pathways work, bioengineers are working to design a better retinal stimulator to restore vision [1].

Within the larger field of computational biology, bioinformatics also known as „computational molecular biology“ focuses on the exploration of biological processes at the molecular level.Sophisticated algorithms are developed to study genes (genomics), gene expression (transcriptomics), proteins (proteomics), lipids (lipidomics), metabolites (metabolomics), and other cell-bound molecules [1,32-35]. Dynamic molecular and cellular processes are revealed by mapping, visualizing and recognizing patterns in sequences and expression of DNA and proteins, analyzing protein structures, modeling molecular pathways [1, 36-39].

The Physiome project represents an international effort to better understanding of physiology using a computational framework that crosses multiple spatial and temporal scales [1].

The increasing need to manage and interpret the large volume of data and information gleaned from these activities has increased research efforts in the areas of databases, computational techniques and tools, and complex human-computer interfaces that allow users to archive and retrieve data. But bioinformatics and computational biology are not to be confused with health informatics, which focuses on the mining of patient data for clinical applications [1].

Conclusions

The use of tissue engineering as well as regenerative medicine technology is an exciting paradigm for solving the problems of orthopedic medicine and prosthetics. Although biological and tissue engineering solutions are currently limited, the future has great potential for the further development of existing technologies that can ultimately improve surgical results, accelerate recovery and reduce postoperative rehabilitation constraints.

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