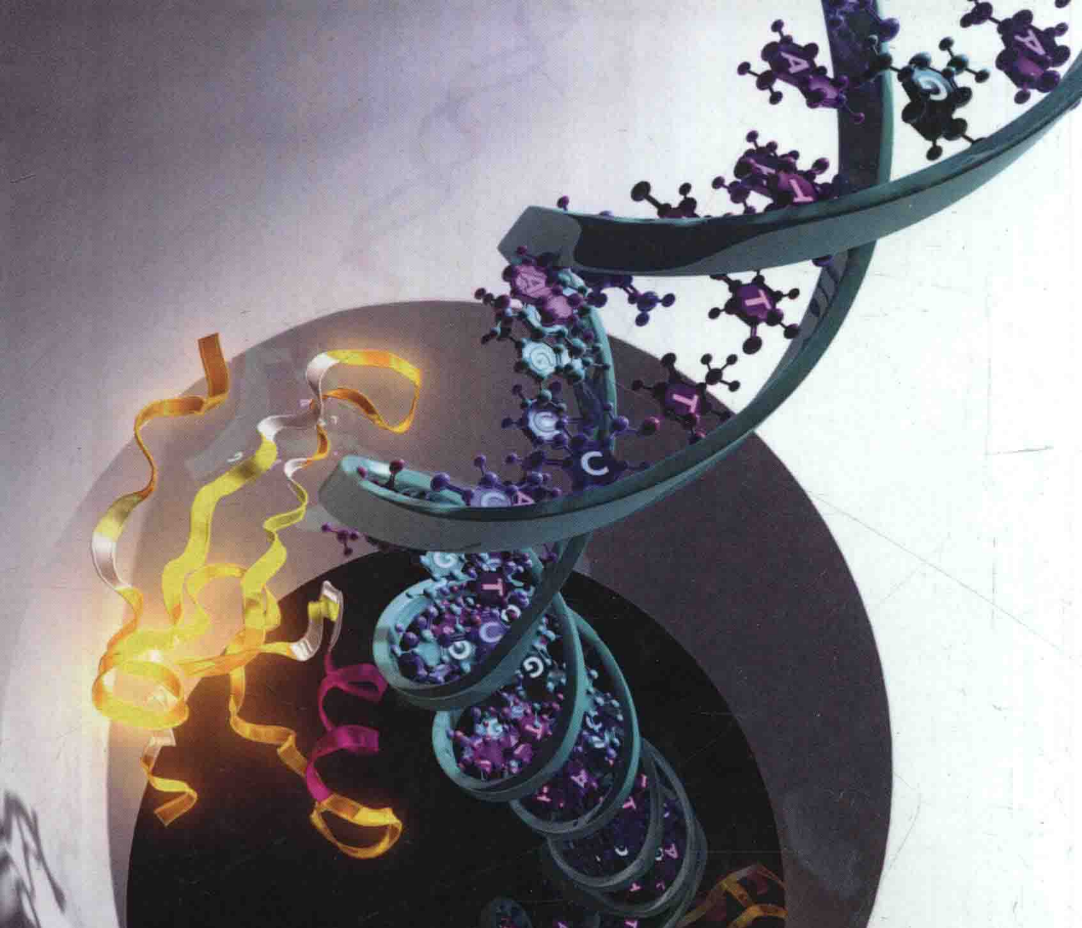

# Advances in Bioengineering

Stephen Rego, Ph.D.

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*Editor:*

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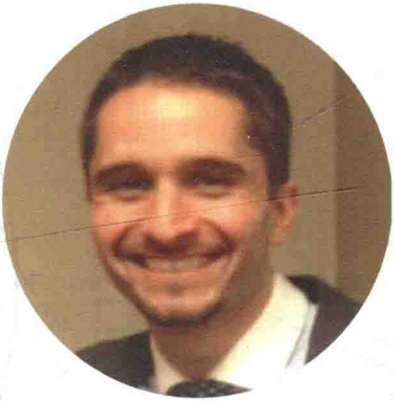

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Stephen obtained his PhD from the University of North Carolina at Charlotte in 2013 where his graduate research focused on cancer immunology and the tumor microenvironment. He received postdoctoral training in regenerative and translational medicine, specifically gastrointestinal tissue engineering, at the Wake Forest Institute of Regenerative Medicine. Currently, Stephen is an instructor for anatomy and physiology and biology at Forsyth Technical Community College.

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# Preface

Bioengineering is an exciting field that is rapidly advancing and has enormous potential to benefit humanity in numerous ways. Bioengineering is a subfield of regenerative medicine that aims to utilize regeneration to improve human health. Approaches to bioengineering may include building organs in vitro using cells and scaffolds or modifying the genetic material of an organism to achieve a desired phenotype. Currently, there is a huge push to advance some of the technologies being developed through bioengineering into clinical or environmental use. However, there are a number of barriers that scientist must overcome in order for this goal to be realized. This subject is discussed in detail in the first section of this book. The remaining content of this book focuses on the advances of specific ideas and technologies in the field of bioengineering. With regards to biomedical research the specific advances discussed in this book include the use of decellularized matrices, mesenchymal stem cells, biological scaffolds, drug delivery, prostheses, bone regeneration, cardiac regeneration, neural regeneration and vascular grafts and implantation techniques. Advances in the use of bioengineering to produce biofuels are also discussed.

**Editor**

**Stephen Rego, Ph.D.**

# INTRODUCTION

The principle engineering applications involving the fields of biology and medicine are known as bioengineering. The field addresses various challenges that exist within the biological scientific community and also encompasses all aspects of biomedical engineering and biotechnology. Basically, anything that involves technology and engineering as well as living systems is considered bioengineering. A number of different methodologies have been developed and implemented in an effort to achieve the best results in biological engineering. Each of these methods can be applied to medical equipment, diagnostic devices, bio-materials and other medical and biological needs. The varieties of methodologies have supported the development of different types of job fields for bioengineers.

In the general field of life sciences, bioengineering is relevant with a number of disciplines. Molecular biology uses bioengineering to aid in the study of molecules in the sciences of chemistry and genetics. Biochemistry and cytology utilize the principles to assist with studies of a living organism's chemical processes including the cellular components and structure. The applications are also implemented in the study of microorganisms known as microbiology. The medical field uses bioengineering to identify drug interaction in the field of pharmacology. The biomedical science of immunology utilizes it to help analyze the immune system and disorders with physiology. Neuroscience also makes use of the processes in the study of the brain.

The concept of the science was coined by a British broadcaster named Heinze Wolff in 1954. Since that time, a number of advancements in the field have occurred and become commonplace in the world of human health care. Genetic engineering has made considerable progress in the understanding of the hereditary origins of many diseases. Also, the concept of artificial organs and limbs stems heavily from bioengineering.

An example of this is the artificial heart and prosthetic limbs, which are directly identified as being part of the field. Other applications for the field of science include the development of genetically modified foods. The simple adjustment of vegetation to produce more efficient and substantial yields has revolutionized the food industry. Other civil engineering construction also implement the engineering principles to assist with windbreaks, water runoff protection, surface soil protection and other ecological enhancements.

According to the National Institute of Health, bioengineering is one of the fastest-growing fields of science and medicine. The Federal Bureau of Labor Statistics estimates that bioengineering and biomedical engineering jobs with increase by approximately 7,600 each year until 2015. This is nearly a 32 percent increase each year. Various industries such as manufacturing, pharmaceuticals, health care and government are all estimated to have a larger need for people knowledgeable about this field.

## *Difference between Biotechnology and Bioengineering*

The application of technology on living as well as nonliving organisms is known as Biotechnology. The developing, designing and transforming the technology that involves in biotechnology are called as Bioengineering. We can take a case in point. With the help of biotechnology we can create cells that will make hormones that will relive us of our stress, whilst Bioengineering will develop a system, that will manufacture those hormones much faster and in mass scale as to market that hormone as a product.

## Key differentiators between Biotechnology and Bioengineering

Biotechnology and Bioengineering have their important roles in today's society. The key differentiators' between these two branches are given below:

- Whilst Biotechnology can be defined as the use of biological systems in the development of drugs or pertinent products, bioengineering is the use of the principles of engineering as well as its techniques to problems that arise in biology and medicine. We can take the design and manufacture of artificial limbs as well as organs as an example.

- Also Biotechnology is the application of aspects of living organisms in the arenas of medicine, agriculture, technology and business, Biological engineering is the use of the methods as well as concepts of science and mathematics to resolve problems that arise in life sciences.

One other major difference between the two is that, while biotechnology is mainly concerned with the genetic mutation as well as genetic machination of gene cells, Bioengineering encompasses two chief ideas - (i) the use of engineering sciences to examine and study how animals as well as plants function (ii) the use of engineering technologies as to create and design new devices.

## Biotechnology vs Biomedical Engineering

Biotechnology and biomedical engineering are highly interdisciplinary subjects influenced by various other fields. As they share certain fundamentals of biology, sometimes, these two terms are used interchangeably. However, their scopes and applications differ considerably. Biotechnology covers a broader scope depending more on natural sciences, while biomedical engineering focuses mainly on medicine and engineering principles.

## Biotechnology

Biotechnology is defined as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." It is a broad and complex discipline mainly encompassing pure biological sciences such as genetics, microbiology, molecular and cell biology, biochemistry etc. and the fields outside biology, such as engineering and information technology. Although, the term 'biotechnology' is modern, it has been practiced since the dawn of civilization. The most common examples being making bread, beer, wine and cheese through fermentation and selective breeding of useful animal and plant species. Modern biotechnology uses new techniques that provide much more understanding and control over, living processes. Today, it has varied applications, predominantly in the areas of health care, agriculture, environment and industrial processes. Some common applications of biotechnology are production of disease resistant and nutritionally enhanced crops, gene therapy, genetic screening and enzymes that act as industrial catalysts. Biotechnology is also applied in the areas of pollution control, waste management, mining, energy production, forestry and aquaculture. However, biotechnology is not entirely free of risks. Huge controversies have arisen over the production of genetically modified organisms due to the alteration of their natural compositions which could damage the balance of nature, eventually leading to unknown consequences.

## Biomedical Engineering

Biomedical engineering is defined as the application of engineering principles and design concepts to medicine and biology. It is involved in developing innovative biologies, materials, processes, implants, devices and informatics approaches for the prevention, diagnosis, and treatment of diseases, for patient rehabilitation, and for improving health. Biomedical engineering is a relatively new engineering discipline. It is an interdisciplinary subject, influenced by many other engineering and medical fields including biomedical electronics, biomaterials, bioinstrumentation, clinical engineering, cellular, tissue and genetic engineering. Some major biomedical engineering applications include the development of biocompatible prostheses, diagnostic and therapeutic medical devices ranging from clinical equipment to common imaging equipment such as MRIs and EEGs. Its biotechnology related applications include regenerative tissue growth and production of biopharmaceuticals. Examples of commonly used biomedical engineering products are prosthetic eye used in ophthalmology, breast implants and pacemakers.

## Difference between Biotechnology and Biomedical Engineering

The scopes and applications of biotechnology and biomedical engineering overlap to some extent, but posses their own characteristics. Both are interdisciplinary areas influenced by various other fields. Biotechnology is more dependent on natural sciences, while biomedical engineering uses concepts and principles of physical science to solve problems. Further, biomedical engineering is more focused on medicine and healthcare applications while biotechnology addresses almost all forms of life sciences, hence covering a broader scope. The fundamental concepts of biotechnology have been practiced for centuries, but biomedical engineering has only recently emerged as its own discipline. Unlike the direct manipulation of biological materials in biotechnology, biomedical engineering emphasizes more on higher systems approaches when utilizing living things.

## *Biofuel Cell*

A biofuel cell is a device that uses biological materials to generate electricity in a direct way through redox reactions. This contrasts with conventional use of biofuels to generate electricity from the heat provided by combustion of the material. The principle behind biofuel cell technology is to mimic various natural processes that are used to produce energy within living organisms. In some cases, bacteria may play a role in these fuel cells. As of 2011, biofuel cells show potential as an alternative energy source and in various medical and bioengineering applications.

Living organisms obtain energy from the oxidation of carbohydrates, which are generated by photosynthesis in plants and ingested as food by animals. Enzymes facilitate the reactions, in which carbohydrates are converted into carbon dioxide and water by the removal of electrons, which are then stored in adenosine triphosphate (ATP) molecules. In a biofuel cell, electrons produced by the oxidation of organic molecules — usually carbohydrates, as in living organisms — are used to generate an electrical current. The idea of using these biological processes to generate electricity has been around since the 1960s, but early attempts to construct a practical, working biofuel cell encountered difficulties.

A biofuel cell will typically consist of a container divided into two sections by a permeable barrier. In one section, the oxidation of a carbohydrate — for example,